Progressive Rehabilitation and Closure Plan

Dugald River Mine

MMG Limited

Environmental authority applicant: MMG Dugald River Pty Ltd | September 2021



Prepared for: Department of Environment and Science
Prepared by: SGM Environmental Pty Limited
Tenure number: EPML00731213
Document ID: 19005-001
Version: V2-1
Date of submission: 26 February 2021
Date of resubmission: 30 September 2021

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3.0 Rehabilitation planning part

3.1 Mine planning

The Dugald River deposit was discovered in 1881 and has a long history of exploration and small-scale prospecting and mining. Zinifex Australia Limited (Zinifex) took control of the deposit in 2004 and in addition to further exploration works, started environmental studies. An application to prepare a voluntary environmental impact statement (EIS) was granted by the Queensland Government and the terms of reference were handed down in August 2008. Zinifex subsequently underwent a merger with Oxiana Limited and became OZ Minerals Australia Limited. MMG Dugald River Pty Ltd (MMG) purchased the deposit in June 2009 with the EIS submitted in November 2010.

The development of the Dugald River Mine (the Mine) was approved in 2012 with construction commencing in early 2013. The first shipment of approximately (~) 10.5 tonnes (t) of zinc (Zn) concentrate occurred in December 2017.

3.1.1 Location details

The Mine is located ~ 65 kilometres (km) north-west of Cloncurry and 85 km north-east of Mount Isa (Figure 1). This region of north-west Queensland is characterised by mineral exploration, mining and pastoral activities. Access to the Mine is via the Burke Development Road ~ 59 km north-west of Cloncurry.

3.1.2 Mine description

3.1.2.1 Mining tenements

The Mine resides on 40 mining leases (MLs) and one mineral development licence (MDL). The land tenure covering the Mine boundary is given in Table 1.

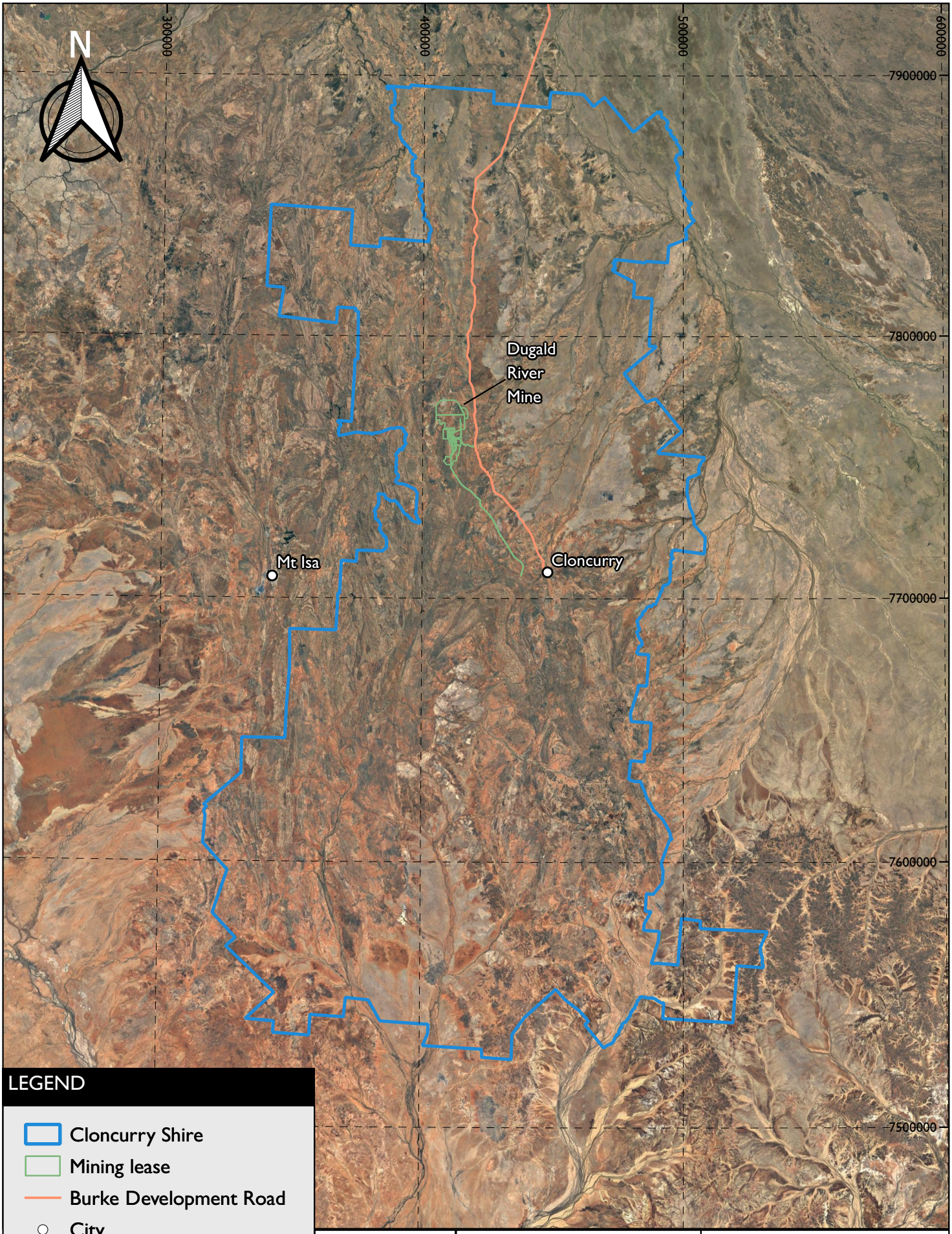
Table 1 Land tenure

Tenure type	Number	Name	Area (hectares (ha))
ML	2467	Dugald 1	16.2
ML	2468	Dugald 2	16.2
ML	2469	Dugald 3	16.2
ML	2470	Dugald 4	16.2
ML	2471	Dugald 5	16.2
ML	2477	Dugald 6	32.5
ML	2478	Dugald 7	129.5
ML	2479	Dugald 8	32.4
ML	2480	Dugald 9	32.4
ML	2481	Dugald 10	129.5
ML	2482	Dugald 11	32.4

Tenure type	Number	Name	Area (hectares (ha))
ML	2496	Dugald River No 6	129.5
ML	2497	Dugald River No 7	8.1
ML	2498	Dugald River 8	29.1
ML	2499	Dugald River 9	28.1
ML	2500	Dugald River 10	28.3
ML	2501	Dugald River 11	30.4
ML	2502	Dugald River 12	31.6
ML	2556	Clandestine 7	127.7
ML	2557	Clandestine 8	129.1
ML	2558	Clandestine 13	128.5
ML	2559	Clandestine 14	98.7
ML	2596	Dugald River 51	19.0
ML	2599	Dugald River 57	44.8
ML	2601	Dugald River 61	28.5
ML	2638	Knapdale	122.5
ML	2684	Dugald River 12	1.0
ML	2685	Dugald No 13	2.5
ML	7496	Dugald	24.7
ML	90047	Knapdale No 2	8.4
ML	90049	Dugald South No 7	0.3
ML	90050	Dugald South No 8	0.2
ML	90051	Scanlan No 6	9.6
ML	90211	Dugald TSF	642.7
ML	90212	Dugald TXS1	100.5
ML	90213	Dugald TXS2	31.7
ML	90218	Dugald WPipe	43.5
ML	90220	Dugald PLine	507.9
ML	90230	DAccess	120.8
ML	90237	Dugald TXS3	20.5
MDL	79	-	227.5

Tenure type	Number	Name	Area (hectares (ha))
Total			**3,195.4**

This PRC plan incorporates the 3,195.4 ha of land that is shown in Figure 2.



LEGEND

- Cloncurry Shire
- Mining lease
- Burke Development Road
- City

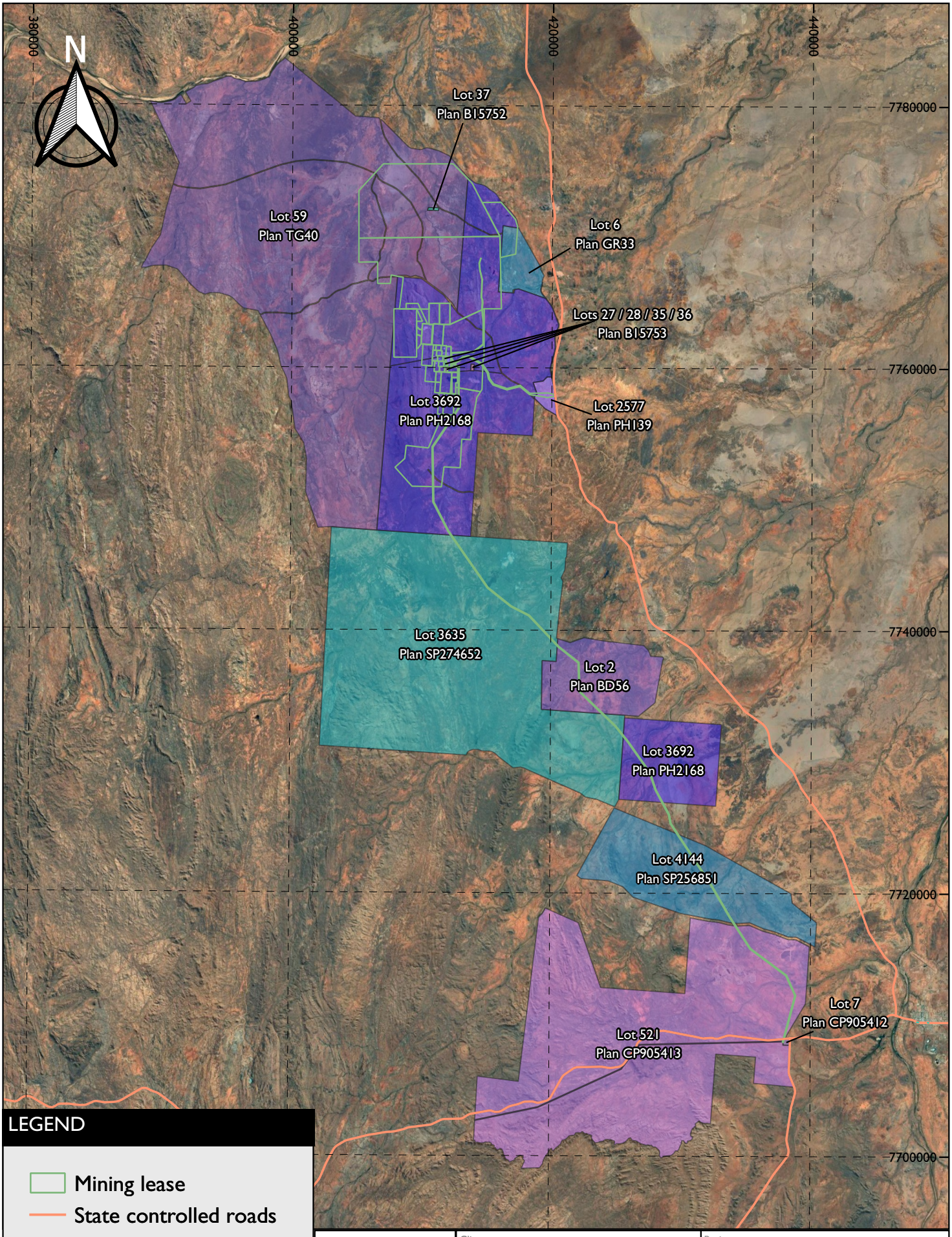
Scale 1 : 2 000 000

0 25 50 75 km

SGMenvironmental

Client	MMG Limited
Project	Progressive Rehabilitation and Closure Plan
Design: SGM Environmental 18.01.2021 Scale: 1 :2,000,000 CRS: GDA94 / MGA zone 54	
Title	Mine Location
FIGURE	1

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LEGEND

- Mining lease
- State controlled roads

Scale 1 : 400 000

0 5 10 15 km

Client: MMG Limited		Project: Progressive Rehabilitation and Closure Plan	
Design: SGM Environmental 18.01.2021 Scale: 1 : 400,000 CRS: GDA94 / MGA zone 54		Title: Tenure Boundaries	FIGURE: 2

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3.1.2.2 Environmentally relevant activities

Activities that will, or have the potential to, release harmful contaminants into the environment are defined as environmentally relevant activities (ERAs) under the *Environmental Protection Act 1994* (EP Act). All ERAs must be listed and described in the site-specific ERA assessment report for inclusion in the environment authority (EA) and are allocated an aggregate environmental score (AES) that represents their level of environmental risk.

The ERAs listed on the Mine EA EPML00731213 are given in Table 2.

Table 2 Mine ERAs

ERA number	Description of activity	Aggregate environmental score
8-(1)	Chemical storage >50 t class 1 or 2	51
8-(3)	Chemical storage >500 cubic metres (m^3) class C1 or C2	85
8-(4)	Chemical storage >200 t solids or gases	31
15	Fuel burning >500 kilograms per hour (kg/h)	35
16-(2c)	Extractive >1,000,000 t	57
16-(3c)	Screening >1,000,000 tonnes per year (t/y)	47
31-(2b)	Mineral processing >100,000 t/y resource	280
33	Crushing, milling, grinding or screening >5,000 t/y	-
56	Regulated waste storage	-
63-(1b)(i)	Sewage treatment >100 to 1500EP — infiltration trench (IT) or irrigation scheme (IR)	27
63-(1b)(ii)	Sewage treatment >100 to 1500EP — no IT or IR	53
Schedule 3 (16)	Mining gold (Au) ore, site specific	216
Schedule 3 (17)	Mining copper (Cu) ore, site specific	217
Schedule 3 (18)	Mining lead (Pb), silver (Ag) or Zn ore, site specific	185

3.1.2.3 Primary mine features / infrastructure

The Mine includes the following primary mine features (the features) (Figure 3):

- underground workings including:
  - two mine portal entrances;
  - two underground mine declines (North and South mines); and
  - associated networks (ie. ventilation, power, water and drainage);
- one non-acid forming (NAF) waste rock dump (WRD);
- two potentially acid forming (PAF) WRDs (stage 1 and stage 2);
- one tailings storage facility (TSF);
- two TSF borrow pits (A and B);

- two borrow pits (C1 and C2);
- two topsoil stockpiles (A and B)
- the accommodation village;
- the communications tower;
- one run-of-mine (ROM) pad;
- the mine infrastructure area (MIA) including:
  - administration building;
  - gatehouse and security;
  - core storage yard;
  - change house;
  - laydown and hardstand areas;
  - heavy vehicle workshop;
  - fuel station and storage;
  - sewage treatment plant and water treatment plant;
  - paste plant;
  - concentrate storage;
  - shared warehouse yard and construction laydown area;
  - 220 kilovolt (kV) switchyard;
  - main plant substation; and
  - crushed ore stockpile;
- the access road, haul roads and internal light and heavy vehicle roads (roads);
- water storage, supply and distribution including:
  - sediment dam A, C, D, F and G;
  - raw water dam;
  - underground mine water collection dam;
  - ROM area runoff dam;
  - process plan runoff dam and containment dam;
  - heavy vehicle (HV) workshop runoff pond;
  - NAF pad runoff dam;
  - stage 1 PAF pad runoff dam;
  - stage 2 PAF pad runoff dam;
  - sewage treatment plant (STP) dam stage 1;
  - STP dam stage 2;
  - water distribution pipelines; and
  - surface water drainage structures;
- exploration.

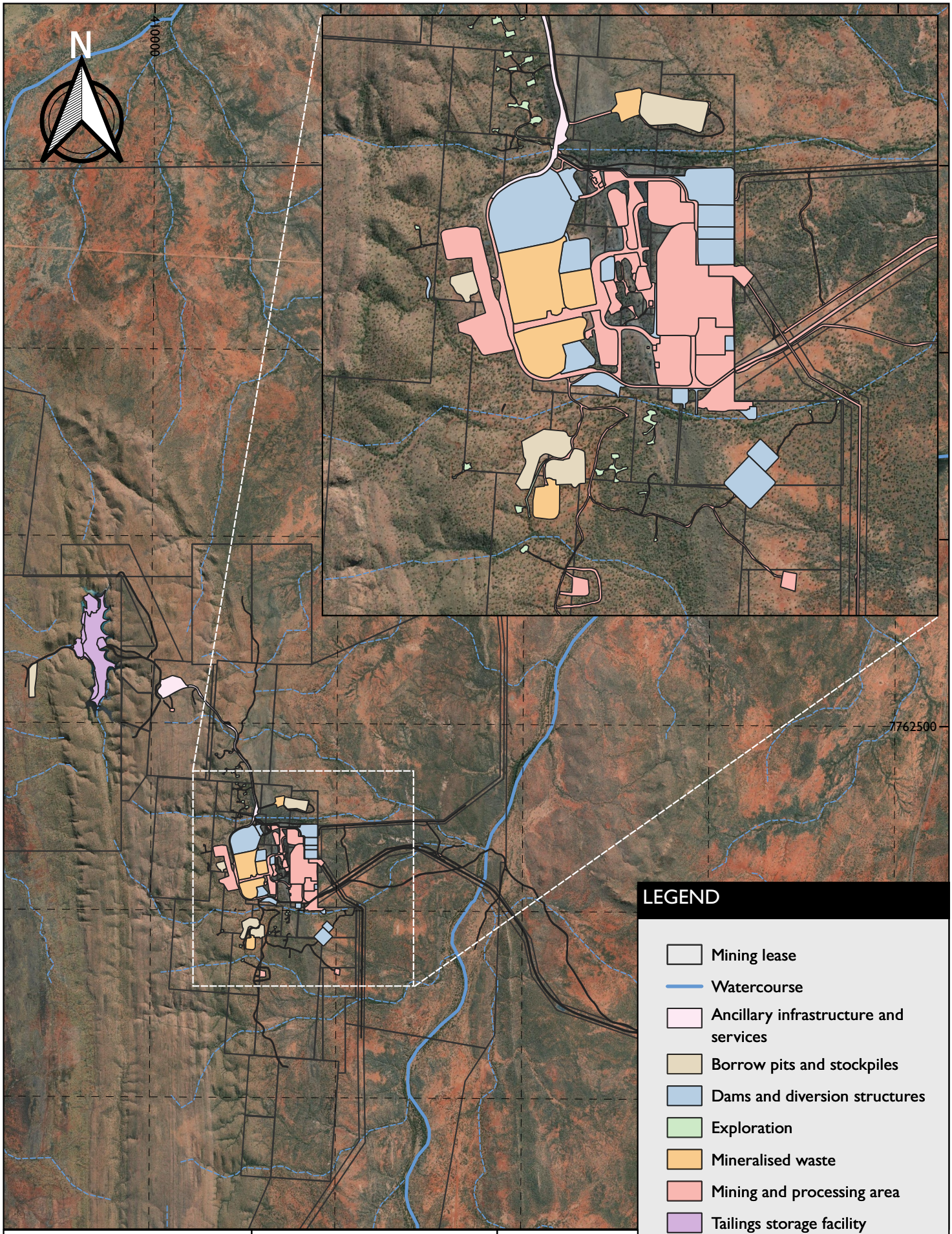
3.1.2.4 Type of mining operation

Resource estimates for the Mine (defined in December 2019) total 59.3 million tonnes (Mt) of Zn / Pb / Ag ore. The Mine will use conventional underground mining techniques and is expected to process up to 2.1 Mt of ore annually. The Mine is currently planned to have a 17-year life-of-mine (LOM). Concentrate is transported by rail from Cloncurry to the Port of Townsville for export. The Mine employs around 500 employees and contractors that are fly-in, fly-out or local residents.

3.1.2.5 Proposed duration of operation

The LOM plan is outlined below:

- late 2015 — start of underground mining;
- early 2018 — completion of processing plant construction and start of commissioning;
- 2037 — end of production date; and
- 2067 — lease relinquishment.



LEGEND

- Mining lease
- Watercourse
- Ancillary infrastructure and services
- Borrow pits and stockpiles
- Dams and diversion structures
- Exploration
- Mineralised waste
- Mining and processing area
- Tailings storage facility

Scale 1 : 70 000

0 1 2 km

Project: Progressive Rehabilitation and Closure Plan		Client: MMG Limited	
Figure: 3	Title: Primary Features	Design: SGM Environmental Pty Ltd 09.09.2021 Scale: 1 : 70,000 CRS: GDA94 / MGA zone 54	SGMenvironmental

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The availability and progressive rehabilitation of land throughout the LOM is outlined in PRC plan schedule (the Schedule) (Appendix A).

3.1.3 Baseline information

3.1.3.1 Site topography

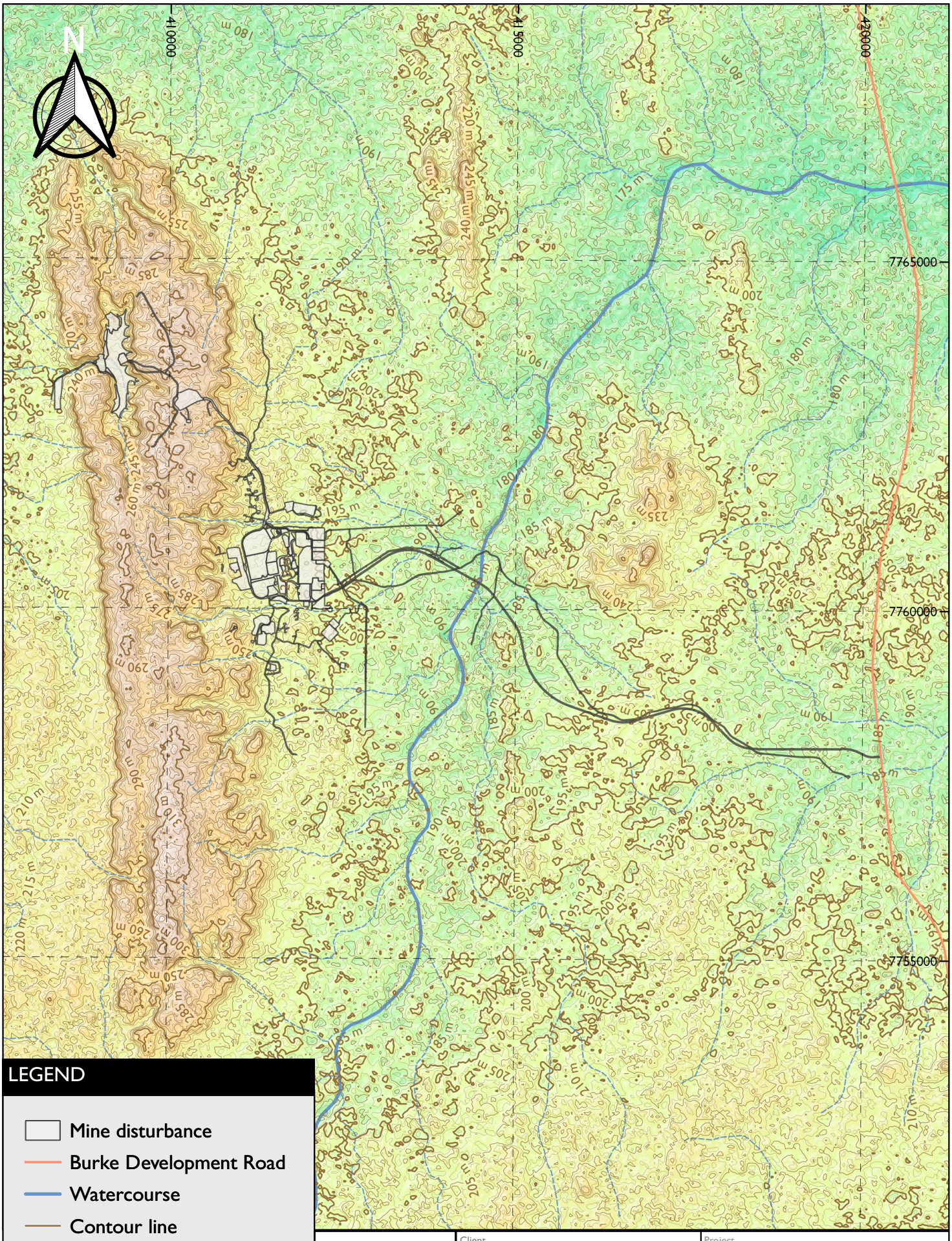
a Local

The topography of the Mine site is undulating with a dominant ridgeline, the Knapdale Range (the Range), running through the central portion of the area in a north to south direction (Figure 4). The Range is ~ 14 km long and 3 km wide and rises to approximately 300 metres (m) above sea level and 100 m above the region. The Range forms the drainage divide between the Dugald River and Cabbage Tree Creek within the Mine site.

Immediately to the east of the Range, the topography is gently sloping and grades into the floodplain of the Dugald River. This flatter terrain contains the operational area of the Mine, process plant and WRDs. The TSF Is located in a steep sided valley on the western side of the Range and the accommodation village facility is located on a plateau of the Range.

b Regional

The landforms surrounding the Mine include rugged hills and mountain ranges separated by undulating valleys, with Mount Rose Bee to the north-east, the Waggaboonyah and Leander Ranges directly west and the Mount Godkin Range to the south. These generally rise to a maximum height of 400-500 m above sea level.



LEGEND

- Mine disturbance
- Burke Development Road
- Watercourse
- Contour line

Scale 1 : 75 000

0 1 2 3 km

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Client: MMG Limited	Project: Progressive Rehabilitation and Closure Plan
Design: SGM Environmental 24.02.2021 Scale: 1 :75,000 CRS: GDA94 / MGA zone 54	Title: Mine Topography FIGURE: 4

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3.1.3.2 Climate

The climate of the Mine and region is referred to as a local steppe climate. The region is classified as hot semi-arid climate (BSh) according to the Köppen-Geiger climate classification. These climates tend to have hot, sometimes extremely hot, summers and warm to cool winters, with some to minimal precipitation. High variability in rainfall, temperature and evaporation are common in north-west Queensland.

Local rainfall, evaporation and temperature data has been sourced from surrounding Bureau of Meteorology weather stations:

- Cloncurry Aero (station 029009) — operated from 1939 to 1975. This station was ~ 59 km south-east of the Mine.
- Cloncurry Airport (station 029141) — operational from 1978. This station is ~ 59 km south-east of the Mine.
- Mount Isa Aero (station 029127) — operational from 1966. This station is ~ 84 km south-west of the Mine.

The data is discussed below in Sections 3.1.3.2a-3.1.3.2d.

a Rain

January and February exhibit the highest mean monthly rainfall, averaging above 100 millimetres (mm). The driest months of the year are July and August, averaging under 5 mm of rainfall. The region experiences a distinctive wet season (between November and April), with very little rain falling in the remaining months of the year. The average annual rainfall for the region is 482 mm. Average monthly rainfall data for both of the Cloncurry weather stations are given in Table 3.

b Evaporation

The average annual potential evaporation at the Mine is estimated to be 3,066 mm, which is about 6.4 times higher than annual rainfall. The evaporation rate varies seasonally, with the highest evaporation rates occurring in the months between October and March. As evaporation data was not available for the Cloncurry weather stations, average monthly potential evaporation rates for the Mount Isa Aero weather station are given in Table 4.

c Temperatures

The mean annual maximum temperature is 32.7 degrees Celsius (˚C) with the hottest months being November through to January (over 37.0 ˚C). The mean annual minimum temperature is 18.6 ˚C, with the coolest months being June through to August (below 12.0 ˚C). Average monthly minimum and maximum temperatures for both Cloncurry weather stations are given in Table 5.

Table 3 Average monthly and annual rainfall

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean rainfall (mm) — Cloncurry Aero	107.8	124.3	78.6	20.3	18.3	7.8	6.0	4.8	6.6	13.8	24.2	57.8	470.6
Mean rainfall (mm) — Cloncurry Airport	161.6	108.4	79.0	16.6	7.0	7.5	3.5	3.2	6.0	16.4	32.7	72.4	492.7

Table 4 Average monthly and annual evaporation

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean evaporation (mm) — Mt Isa Aero	297.6	249.2	275.9	249.0	198.4	159.0	170.5	213.9	267.0	325.5	330.0	325.5	3,066.0

Table 5 Average monthly and annual temperature

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean maximum temperature (˚C) — Cloncurry Aero	37.4	35.7	34.7	32.3	28.1	25.5	25.2	27.7	31.4	35.3	37.6	38.1	32.4
Mean minimum temperature (˚C) — Cloncurry Aero	24.6	24.0	22.5	19.1	14.8	11.3	10.3	11.7	15.6	19.9	22.6	24.1	18.4
Mean maximum temperature (˚C) — Cloncurry Airport	36.9	36.4	35.8	33.7	29.4	26.2	26.4	28.8	33.1	36.5	38.0	38.8	33.3
Mean minimum temperature (˚C) — Cloncurry Airport	25.0	24.3	22.9	20.1	15.7	11.7	10.8	12.1	16.4	20.5	23.3	25.0	19.0

d Long-term projections

Rain

The *State of the Climate Report 2018* (CSIRO & BoM 2018) says that Australian rainfall is highly variable, which makes it difficult to identify significant trends over time. Northern Australian average annual rainfall has increased since national records began in 1900, largely due to increases in rainfall from October to April annually.

Temperature

The *State of the Climate Report 2018* (CSIRO & BoM 2018) says Australia's weather and climate are changing in response to a warming global climate system. Australia has warmed by around 1 °C since 1910, with most warming since 1950. Eight of Australia's top ten warmest years have occurred since 2005. The warming trend occurs against a background of year-to year climate variability, mostly associated with El Niño and La Niña in the tropical Pacific Ocean.

Sea surface temperatures in the Australian region have given a similar trend, warming by nearly 1 °C since 1910, with eight of the top ten warmest years occurring since 2005.

Bushfire

The *State of the Climate Report 2018* (CSIRO & BoM 2018) says Australia's shift to a warmer climate is accompanied by more extreme heat events on daily, multi-day and seasonal timescales. Australia-wide, increases in average temperature have been more notable across autumn, winter and spring, with the smallest trends in summer. The annual 90th percentile of daily McArthur Forest Fire Danger Index (FFDI) (ie. the most extreme 10 percent (%) of fire weather days), has increased in recent decades across much of eastern Australia.

The *Bushfire Hazard Provision in the Queensland State Planning Policy* (2019) identifies bushfire prone regions in Queensland and accounts for regional variability in bushfire weather severity. The mapping allows accurate identification of areas at risk from bushfire and allows greater confidence in design and mitigation strategies, proportional to the mapped risk level.

3.1.3.3 Geological setting

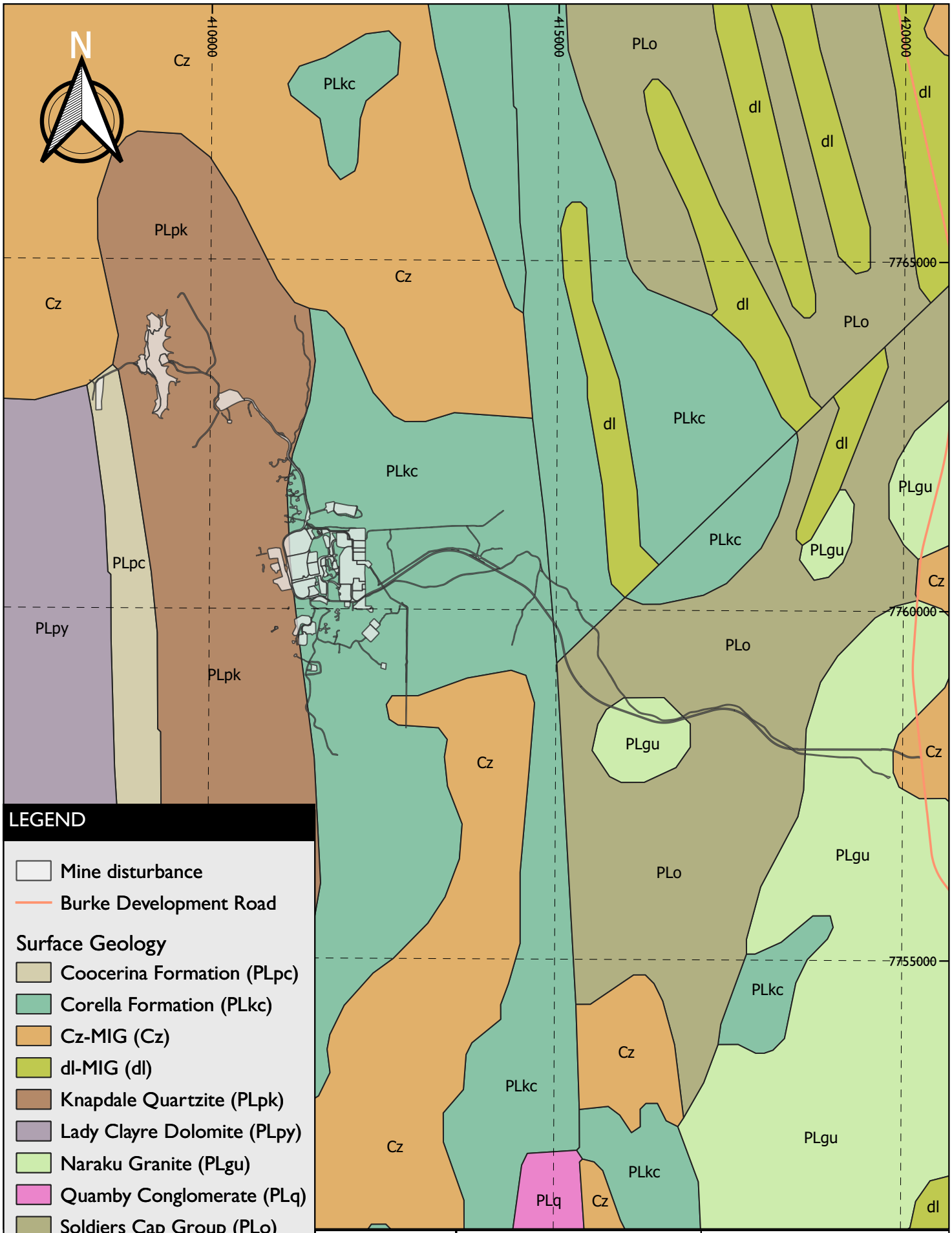
The geology of the Dugald River area is complicated by multiple deformation events and extensive faulting which resulted in considerable truncation of the rock units (Figure 5). The rocks consist of dolomite, quartzite, granofels, amphibolite, siltstone and shale. Tertiary and Quaternary sediments of the Dugald River are described as sand, gravel, silt and clay.

The Mine is in the transition zone between the two major physiographic divisions, the Mount Isa highlands and the vast Carpentaria plains. The deposit is located within a 3-4 km wide north to south trending high strain domain named the Mt Roseby Corridor. The Mount Roseby Corridor is bordered to the west by the Knapdale Quartzite and to the east by the Mt Rosebee Fault. The Knapdale Quartzite forms a prominent range of hills within the local area. The Mount Roseby corridor is comprised of the Mount Roseby Schist Formation that includes the local Hanging Wall Calc-silicates, Dugald River Slate (DRS) and the Footwall Limestone.

3.1.3.4 Stratigraphy

The stratigraphy within the Mine dips steeply to the west and comprises four main units:

- Knapdale Quartzite — pink, massive recrystallised dolomite, locally micaceous. The Knapdale Quartzite unit underlies all of the TSF;
- Mount Roseby Schist — calcareous silicate metasediments;
- Dugald River Slate — black calcareous slates and black graphite slate, hosts the Dugald River orebody which outcrops at the eastern edge of the unit; and
- Lady Clayre Formation — dark brown to black dolomite and dolomitic siltstone with minor quartz sandstone, siltstone and micaceous sandstone.



SGM environmental

Client: MMG Limited		Project: Progressive Rehabilitation and Closure Plan	
Design: SGM Environmental 24.02.2021 Scale: 1 : 75,000 CRS: GDA94 / MGA zone 54		Title: Geological Setting	FIGURE: 5

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3.1.3.5 Site hydrology and fluvial networks

a Catchment overview

Three major waterways drain through the Mine. The waterways are all ephemeral drainage systems which typically flow only during, and for brief periods following the wet season (November-April). Isolated pools along river and creek beds can persist through the dry season.

Dugald River catchment

The southern and eastern sections of the Mine are in the Dugald River catchment. Silvermine Creek and its tributaries drain the eastern section of the Mine before joining Dugald River, which runs in a north-easterly direction. Dugald River is a tributary of Cloncurry River, which in turn is a tributary of Flinders River. Flinders River flows into the Gulf of Carpentaria about 450 km northeast of the Mine.

Cabbage Tree Creek catchment

The western and northern sections of the Mine are in the Cabbage Tree Creek catchment. Cabbage Tree Creek runs in a northerly direction to the west of the Mine before joining up with Pinnacle Creek. Pinnacle Creek is a tributary of Leichhardt River, which flows into the Gulf of Carpentaria about 400 km north-west of the Mine.

Cattle Creek catchment

A significant portion of the Mine access road from Burke Developmental Road is located within the Cattle Creek catchment. Cattle Creek runs in a north-easterly direction further east of the Mine and drains into Corella River, a tributary of Cloncurry River which in turn is a tributary of Flinders River. Flinders River flows into the Gulf of Carpentaria about 450 km north-east of the Mine.

b Hydrologic modelling

The MLs cover 3,370 hectares (ha) of this, 1,642 ha is within the Dugald River catchment and the remaining 1,730 ha is within the Cabbage Tree Creek catchment. Of the total ML, only about 250 ha (7.4%) is disturbed by mining:

- mining operations and infrastructure disturb about 125 ha (9.5%) within the Silvermine Creek catchment. This represents about 0.2 % of the Dugald River catchment;
- the TSF occupies 90 ha (0.3 %) of the Cabbage Tree Creek catchment;
- the accommodation camp disturbs approximately 20 ha. The land disturbed by the camp represents less than 5% of the Blackard Creek catchment, 0.5% of the Silvermine Creek catchment and less than 0.01% of the Cabbage Tree Creek catchment; and
- land disturbed by the water pipeline and the access roads are not significant.

The influence of mining on peak flows, within the local and regional catchments are minimal.

c Water quality

An assessment of baseline water quality was done during the EIS process and informed EA monitoring parameters. Data from eight rising stage samplers (RSS) were used to provide baseline water quality for the Mine. The analysed water quality data was compared to the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ 2018) (the ANZECC guidelines). Specifically, the guidelines for Aquatic Ecosystems (95% protection level) and Livestock Drinking Water were used.

The approach used in assessing surface water quality compares dissolved metals and other toxicants to the ANZECC guidelines for Aquatic Ecosystems 95% protection level, total metals to the ANZECC guidelines for Livestock Drinking Water and physicochemical parameters to the relevant ANZECC guidelines for Aquatic Ecosystems or Livestock Drinking Water. Surface water quality data for Dugald River and Cabbage Tree Creek is given in Table 6.

Table 6 Surface water chemistry results

			Dugald River	Cabbage Tree Creek
Analyte	**Units**	**ANZECC guidelines**	**Median (range)**	**Median (range)**
Physicochemical				
pH	pH units	6.0-7.5	7.3 (6.4-8.4)	7.1 (4.6-8.1)
Electrical conductivity (EC)	Microsiemens per centimetre (µS/cm)	20-250	97 (34-822)	68 (11-561)
Alkalinity as CaCO3	Milligrams per litre (mg/L)	-	36 (8-147)	35 (1-1,010)
Chloride	mg/L	-	3 (1-144)	1 (1-95)
Dissolved Calcium (Ca)	mg/L	1,000	9 (1-124)	8 (1-120)
Dissolved Magnesium (Mg)	mg/L	2,000	2 (1-67)	1 (0.6-18)
Dissolved Potassium (K)	mg/L	-	4 (1-312)	3 (1-47)
Dissolved Sodium (Na)	mg/L	-	3 (1-84)	1 (0.5-13)
Dissolved Sulfate	mg/L	1,000	2 (<1-359)	<1 (<1-57)
Fluoride	mg/L	2.0	<0.1 (<0.1-1.1)	<0.1 (<0.1-1.0)
Nitrate	mg/L	0.16	0.11 (0.01-2.89)	0.08 (0.01-15.80)
Nitrite	mg/L	9.12	<0.01 (<0.01-0.04)	<0.01 (<0.01-149.00)
Nitrate + Nitrite	mg/L	-	0.07 (<0.01-2.06)	0.09 (<0.01-142.00)
Suspended Solids (SS)	mg/L	-	160 (<1-11,300)	500 (<1-43,600)
Total Dissolved Solids (TDS)	mg/L	4,000	90 (22-487)	51 (12-330)
Total Nitrogen (N)	mg/L	0.15	3.80 (0.20-12.00)	0.80 (0.10-20.00)

			Dugald River	Cabbage Tree Creek
Analyte	**Units**	**ANZECC guidelines**	**Median (range)**	**Median (range)**
Total Phosphorus (P)	mg/L	0.01	0.60 (0.08-1.89)	0.38 (0.03-3.66)
Turbidity	Nephelometric turbidity unit (NTU)	2-5	185 (45-1,600)	
Dissolved metals and metalloids				
Aluminium (Al)	mg/L	0.055	0.15 (0.01-1.56)	0.18 (0.02-0.62)
Antimony (Sb)	mg/L	0.009	<0.001	<0.001
Arsenic (As)	mg/L	0.024	<0.001	<0.001 (<0.001-0.004)
Barium (Ba)	mg/L	-	0.023 (0.006-0.417)	0.017 (0.003-0.463)
Beryllium (Be)	mg/L	-	<0.001	<0.001
Boron (B)	mg/L	0.37	0.05 (0.02-0.10)	0.1 (<0.01-0.11)
Cadmium (Cd)	mg/L	0.0002	<0.0001 (<0.0001-0.005)	<0.0001 (<0.0001-0.001)
Chromium (Cr)	mg/L	0.001	<0.001 (<0.001-0.010)	<0.001 (<0.001-0.034)
Cobalt (Co)	mg/L	0.0014	<0.001 (<0.001-0.003)	<0.001 (<0.001-0.26)
Cu	mg/L	0.0014	0.01 (<0.001-0.345)	0.009 (<0.001-0.650)
Iron (Fe)	mg/L	-	0.14 (<0.01-9.10)	0.16 (0.05-139)
Pb	mg/L	0.0034	<0.001 (<0.001-0.170)	<0.001 (<0.001-0.216)
Manganese (Mn)	mg/L	1.900	0.01 (<0.001-3.180)	0.003 (<0.001-3.960)
Mercury (Hg)	mg/L	0.00006	<0.0001	<0.0001
Molybdenum (Mo)	mg/L	0.034	<0.001 (<0.001-0.003)	<0.001

			Dugald River	Cabbage Tree Creek
Analyte	**Units**	**ANZECC guidelines**	**Median (range)**	**Median (range)**
Nickel (Ni)	mg/L	0.011	<0.001 (<0.001-0.026)	<0.001 (<0.001-0.029)
Selenium (Se)	mg/L	0.011	<0.01	<0.01
Ag	mg/L	0.00005	<0.001 (<0.001-0.010)	<0.001
Tin (Sn)	mg/L	-	316.000 (<0.001-11,300.000)	<0.001 (<0.001-0.003)
Vanadium (V)	mg/L	0.006	0.010 (0.009-0.029)	0.010 (0.001-0.054)
Zn	mg/L	0.008	0.012 (<0.001-3.250)	0.028 (0.003-2.130)
Total metals and metalloids				
Al	mg/L	5.00	0.61 (0.01-630.00)	0.71 (0.12-18.50)
Sb	mg/L	-	<0.001	<0.001
As	mg/L	0.500	0.002 (<0.001-0.011)	<0.001 (<0.001-0.039)
Ba	mg/L	-	0.031 (0.009-0.179)	0.046 (<0.001-11.1)
Be	mg/L	-	<0.001 (<0.001-0.002)	<0.001 (<0.001-0.081)
B	mg/L	-	<0.05	<0.05 (<0.05-0.1)
Cd	mg/L	0.0100	0.0001 (0.0001-0.0005)	0.0001 (0.0001-0.0032)
Cr	mg/L	1.000	0.001 (0.001-0.072)	0.011 (0.001-1.43)
Co	mg/L	-	0.001 (0.001-0.045)	0.008 (0.001-1.07)
Cu	mg/L	1.000	0.007 (0.001-0.272)	0.07 (0.002-13.4)
Fe	mg/L	-	1.09 (0.05-82.9)	10.3 (0.05-1,040)

			Dugald River	Cabbage Tree Creek
Analyte	**Units**	**ANZECC guidelines**	**Median (range)**	**Median (range)**
Pb	mg/L	0.100	0.001 (0.001-0.123)	0.018 (0.001-0.362)
Mn	mg/L	-	0.074 (0.001-0.979)	0.307 (0.002-52.3)
Hg	mg/L	0.0020	0.0001 (0.0001-0.0001)	0.0001 (0.0001-0.0001)
Mo	mg/L	0.15	0.001 (0.001-0.002)	0.001 (0.001-0.002)
Ni	mg/L	1.000	0.001 (0.001-0.040)	0.010 (0.001-1.340)
Se	mg/L	0.02	<0.01	<0.01
Ag	mg/L	-	0.001 (0.001-54.700)	0.001 (0.001-33.400)
V	mg/L	-	0.010 (<0.001-0.010)	0.010 (0.010-0.010)
Zn	mg/L	20.000	0.034 (<0.005-1.640)	0.202 (<0.005-1.600)

1. Green = ANZECC guidelines exceedance

3.1.3.6 Groundwater levels and properties

a Hydro stratigraphic units

Hydro stratigraphic units (HSUs) are zones within a hydrogeological system that have similar hydrogeological properties. At the broadest level, HSUs are categorised as aquifers (stores groundwater) and aquitards (barriers to groundwater). The HSUs within 5 km of the Mine are given in Table 7.

Table 7 Mine HSUs

HSU	Description	Aquifer / aquitard
Corella Formation	Aquifer occurs in the fractured calc-silicate rock at the geological boundary near the Dugald River Slate.	Prime aquifer (confined)
Dugald River Slate	Black calcareous silicate metasediments.	Aquitard
Lady Clayre Dolomite	Dark brown to black dolomite and dolomitic siltstone with minor quartz, sandstone, siltstone and micaceous sandstone.	Aquitard

b Hydrogeological properties

The prime aquifer occurs within fractured calc-silicate rocks in the Corella Formation at the geological boundary between the Corella Formation and the Dugald River Slate above the mineralised zone. Groundwater occurs in fractures, joints, solution channels and along bedding planes (secondary porosity) to a depth of ~ 70 metres below ground level (m bgl). The prime aquifer is confined. Very minor supplies of groundwater occur in the Dugald River Slate; however, the groundwater is saline and highly mineralised.

Groundwater recharge and discharge

The only mechanism for recharge to the prime aquifer is infiltration and deep percolation of rainfall. Natural groundwater discharge does not occur within the immediate vicinity of the Mine. There is no groundwater and surface water interaction as a result.

Two watercourses (Silvermine Creek and its tributary 'A') have developed along zones of structural weakness along the east to west faulting that dominates the area. The aquifer beneath those creeks is a zone of higher permeability and the aquifer beneath the interfluve is a zone of lower permeability. Recharge is likely to be greater along the creeks and less on the interfluve.

Groundwater bores

Six groundwater monitoring bores were installed at the Mine in 2008 to complement the historical groundwater monitoring. Two historical bores, Froggy Bore (GWBF) and Saturday Bore (SB1), are in strategic positions and have been included in the environmental groundwater monitoring program.

Several groundwater bores described in the EA are no longer used for compliance testing:

- MB10 and MB11 were installed to monitor groundwater levels near the Mine workings but were intercepted in 2012. Consequently, MB10 and MB11 are considered inactive and awaiting decommissioning; and
- MB9S was installed to monitor the shallow Knapdale Quartzite near the TSF. Water is only observed in the bore during and after the wet season, indicating that water levels are related to rainfall and / or surface water flows and not associated with groundwater or TSF seepage.

Groundwater bore details are given in Table 8.

Table 8 Groundwater bore properties

Bore number	Screened formation	Easting	Northing	Elevation head (m Australian Height Datum (AHD))	EA classification	Purpose
MB1	Mount Roseby Schist	411301	7761214	205.506	Background	Level and quality
MB3	Mount Roseby Schist	411391	7760127	209.757	Background	Level and quality
SB1	Mount Roseby Schist	414226	7760870	182.375	Background	Level and quality
MB5	Mount Roseby Schist	408537	7763364	202.474	Background / compliance	Level and quality
MB6	Mount Roseby Schist	408287	7763224	200.617	Background / compliance	Level and quality
MB9D	Knapdale Quartzite	408723	7763433	204.299	Background / compliance	Level and quality
MB2	Mount Roseby Schist	412191	7761189	196.890	Compliance	Level and quality
MB4	Mount Roseby Schist	412749	7760041	195.525	Compliance	Level and quality
GWBFAB	Dugald River Slate	411395	7761383	209.842	Interpretation	Level
MB1AB	Mount Roseby Schist	411199	7761205	208.278	Interpretation	Level
MB2AB	Mount Roseby Schist	412187	7761185	197.460	Interpretation	Level
MB3AB	Mount Roseby Schist	411421	7760107	209.130	Interpretation	Level
MB4AB	Mount Roseby Schist	412744	7760042	196.020	Interpretation	Level

Bore number	Screened formation	Easting	Northing	Elevation head (m Australian Height Datum (AHD))	EA classification	Purpose
SHALL6AB	Mount Roseby Schist	410983	7760929	217.028	Interpretation	Level

Notes: Coordinate reference system GDA 94 / MGA Zone 54

Levels and flow

Groundwater in the prime aquifer at the Mine generally flows to the east and north-east, consistent with the topographic fall towards Dugald River. The gradient of the potentiometric surface is 0.009, which is typical of a low bulk permeability aquifer sequence. In December 2009, pump out tests were conducted on the monitoring bores to assess the transmissivity and permeability of the aquifer. The results are given in Table 9.

Table 9 Calculated aquifer transmissivity and permeability values

Bore number	Aquifer transmissivity (squared metres per day (m^2/day))	Aquifer permeability (metres per day (m/day))
MB1	5.88×10^{-4}	7.53×10^{-6}
MB2	3.18×10^{1}	4.08×10^{-1}
MB3	2.29×10^{1}	2.60×10^{-1}
MB4	4.06×10^{0}	7.52×10^{-2}
MB5	7.19×10^{0}	9.21×10^{-2}
MB6	1.73×10^{-1}	2.23×10^{-3}

c Chemistry

Groundwater samples have been compared to the ANZECC guideline for Livestock Drinking Water, Irrigation and 95% protection levels. Samples have been collected from the compliance monitoring bores at the Mine at quarterly intervals. The analyses of these samples show that the groundwater quality varies very little. The results from the *Dugald River Mine Biennial Groundwater Review* (Appendix B) are the most recent and are given in Table 10.

Table 10 Groundwater chemistry results

		ANZECC			Bore number[1]							
Analyte	**Units**	**95% protection**	**Irrigation**	**Stock**	**MB1**	**MB2[2]**	**MB3**	**MB4**	**MB5**	**MB6**	**MB9D**	**SB1[2]**
Physicochemical												
pH	pH unit	6.5-8.5	-	6.5-8.5	7.31	7.53	7.25	7.14	7.09	7.16	7.18	7.43
EC	µS/cm	130	-	2,985	1,030	1,030	4,100	1,290	1,160	806	1,130	1,760
Total Alkalinity (CaCO3)	mg/L	-	-	-	532	323	446	523	428	420	423	510
TDS	mg/L	-	-	4,000	639	631	3,400	766	668	454	662	1,070
TSS	mg/L	-	-	-	<5	<5	<5	<5	<5	12	784	<5
Turbidity	NTU	-	-	-	0.5	-	<0.1	0.2	1.0	3.1	664.0	-
Fluoride	mg/L	-	2.0	2.0	1.6	1.2	2.4	1.4	0.4	1.0	0.5	0.9
Sulfate	mg/L	-	-	1,000	23	147	698	103	103	6	52	175
Chloride	mg/L	-	-	-	40	54	162	77	85	23	116	175
Ca	mg/L	-	-	1,000	71	76	153	94	81	85	84	75
Mg	mg/L	-	-	2,000	74	38	249	54	71	26	81	51
Na	mg/L	-	-	-	61	81	393	127	69	44	36	198
K	mg/L	-	-	-	10	5	20	6	10	8	13	4
Dissolved metals and metalloids												
Al	mg/L	0.055	20	5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
As	mg/L	0.024	2.000	0.500	0.001	<0.001	0.001	<0.001	<0.001	0.005	<0.001	<0.001
Cd	mg/L	0.0002	0.0500	0.0100	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0004	<0.0001
Cu	mg/L	0.0014	5.000	1.000	<0.001	0.025	0.002	<0.001	<0.001	0.002	0.005	<0.001
Fe	mg/L	-	10.00	-	0.06	<0.05	<0.05	<0.05	0.18	0.06	<0.05	0.13
Pb	mg/L	0.0034	5.000	0.100	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mn	mg/L	1.900	10.000	-	0.042	0.101	<0.001	0.016	0.676	0.397	0.470	0.960
Ni	mg/L	0.011	2.000	1.000	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001
Zn	mg/L	0.008	5.000	20.000	<0.005	<0.005	0.006	<0.005	<0.005	0.035	0.100	<0.005
Total metals and metalloids												
Al	mg/L	0.055	20.00	5.00	0.05	<0.1	<0.01	<0.01	<0.01	0.21	7.60	<0.1
As	mg/L	0.024	2.000	0.500	0.001	<0.001	0.001	<0.001	<0.001	0.006	0.008	0.001
Cd	mg/L	0.0002	0.0500	0.0100	0.0001	<0.0001	0.0001	0.0001	0.0001	0.0001	0.0013	<0.0001

		ANZECC			Bore number[1]							
Analyte	**Units**	**95% protection**	**Irrigation**	**Stock**	**MB1**	**MB2[2]**	**MB3**	**MB4**	**MB5**	**MB6**	**MB9D**	**SB1[2]**
Cu	mg/L	0.0014	5	1	<0.001	0.027	0.002	<0.001	<0.001	0.004	0.063	<0.001
Fe	mg/L	-	10.00	-	0.12	<0.05	<0.05	<0.05	0.19	0.32	11.00	0.14
Pb	mg/L	0.0034	5.000	0.100	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.093	<0.001
Mn	mg/L	1.900	10.000	-	0.049	0.088	<0.001	0.015	0.667	0.497	1.140	0.877
Ni	mg/L	0.011	2.000	1.000	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.019	<0.001
Zn	mg/L	0.008	5.000	20.000	<0.005	<0.005	<0.005	<0.005	<0.005	0.056	0.492	<0.005

1. Green = 95% protection exceedance, yellow = irrigation EV exceedance, orange = stock EV exceedance
2. Results for MB2 and SB1 were taken from November 2018 as they were not sampled in March 2019

d Modelling

Future numerical groundwater flow modelling will be done if new data becomes available that suggests sensitive receptors could be adversely impacted by groundwater drawdown.

As mining progresses, a need for predictive groundwater modelling will be assessed every two years based on quarterly reviews and groundwater monitoring data.

Where additional management strategies are needed in response to environmental performance, the new model will be used to test the effectiveness of mitigation measures prior to starting (to improve outcomes of the proposed measures).

3.1.3.7 Soil types, properties and productivity

a Soil types

Soil survey work done by Austral Asian Resource Consultants Pty Ltd (AARC) (2010) identified six soil management units (SMUs), which are dominated by Rudosols with small pockets of Calcarosols.

Rudosols are soils with negligible pedological organisation except for minimal development of an A1 horizon (topsoil) or the presence of less than 10% of B horizon (subsoil) in fissures in the parent rock or saprolite. The largest areas of these soils occur in the desert regions of arid central and north-west Australia and support low-intensity grazing. Fertile, alluvium variants can be used for cropping and improved pastures.

Calcarosols are soils that are calcareous at least directly below the A1 horizon or a depth of 0.2 m bgl. These soils generally occur in low rainfall, arid and semi-arid regions of Australia. In northern Australia, these soils are predominantly used for low-intensity grazing.

Red Plains soil management unit

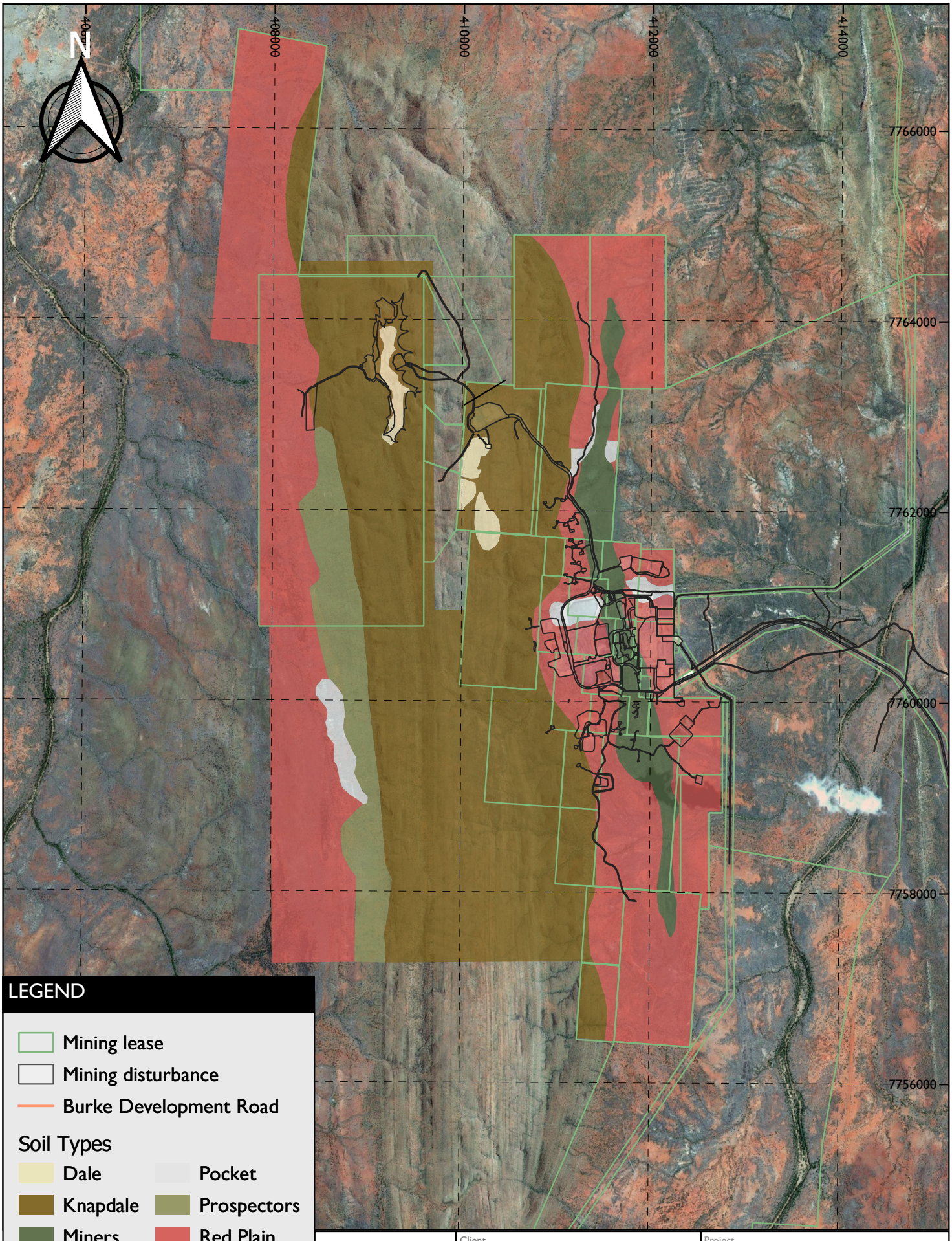
The Red Plains SMU consists of red sandy loams to sandy clay loams (red, yellowish-red or brownish-red) with a neutral to slightly acidic pH (Figure 6). These soils are Rudosols with weak pedality and a maximum depth of 0.5 m. They have low fertility with severe limitations to beef cattle grazing including low plant-available water, shallow soil depths and low nutrient levels. These soils have extreme limitations to rainfed broadacre cropping with the major limiting factor being low plant-available water.

Knapdale soil management unit

The Knapdale SMU consists of brown skeletal sandy clay loams with a neutral to slightly acidic pH (Figure 6). These soils are Rudosols and very shallow (less than (<)0.2 m thick). They are mostly found on the eastern and western slopes of the Knapdale Range (30-40° slopes). These soils have low fertility with extreme limitations for beef cattle grazing due to very low plant-available water and shallow soil depths. They have extreme limitations for rainfed broadacre cropping primarily due to very low plant-available water, shallow soil depths, rockiness, topography and water erosion potential.

Dale soil management unit

The Dale SMU consists of brown to reddish sandy loams with a slightly acidic pH increasing down the profile (Figure 6). Pedality ranges from weak to moderate with a depth of between 0.5-0.7 m. These soils are Rudosols and are generally found in depressions such as valley floors or plateaus in the Knapdale Range. Fertility is low with severe limitations for beef cattle grazing due to low plant-available water and nutrient concentrations. They have extreme limitations for rainfed broadacre cropping primarily due to low plant-available water.



LEGEND

- Mining lease
- Mining disturbance
- Burke Development Road

Soil Types

- Dale
- Pocket
- Knapdale
- Prospectors
- Miners
- Red Plain

Scale 1 : 55 000

0 1 2 km

SGM environmental	Client: MMG Limited	Project: Progressive Rehabilitation and Closure Plan	
	Design: SGM Environmental 24.02.2021 Scale: 1 :55,000 CRS: GDA94 / MGA zone 54	Title: Soil Map	FIGURE: 6

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Miners soil management unit

The Miners SMU consists of dark yellowish-brown sandy clay loams to silty loams with a slightly alkaline pH (Figure 6). Pedality is weak with a maximum depth of 0.2 m. These soils are Rudosols and are found on and immediately supporting the outcropping of the Dugald River deposit lode on the eastern side of the Knapdale Range. Fertility is low with severe limitations for beef cattle grazing due to very low plant-available water. They have extreme limitations for rainfed broadacre cropping primarily due to low plant-available water and water erosion potential.

Prospectors soil management unit

The Prospectors SMU consists of dark yellowish-brown clay loams with a slightly acidic pH (Figure 6). Pedality is weak with a maximum depth of 0.2 m. These soils are Rudosols and are found on the toe slope of the western side of the Knapdale Range. Fertility is low with severe limitations for beef cattle grazing due to very low plant-available water. These soils have extreme limitations for rainfed broadacre cropping primarily due to low plant-available water and water erosion potential.

Pocket soil management unit

The Pocket SMU consists of brown-grey sandy clay loams with an alkaline pH due to elevated levels of calcium carbonate (Figure 6). Pedality is weak. These soils are Calcarosols and are found in small pockets on the eastern and northern side of the Knapdale Range. Fertility is low with severe limitations for beef cattle grazing primarily due to very low plant-available water. These soils have extreme limitations for rainfed broadacre cropping primarily due to low plant-available water.

b Properties

Laboratory analysis of several soil parameters has been summarised for each SMU in Table 11. All soil types are suitable for stockpiling for later use in rehabilitation. The soil currently supports native vegetation communities and there are no detrimental elements in the soil that will limit that capacity in future.

Table 11 Median soil properties

Constituents	Unit	Soil sufficiency	Red Plain SMU	Knapdale SMU	Dale SMU	Miners SMU	Prospectors SMU	Pocket SMU
pH	pH units	6.0-7.5	6.5	6.4	5.7	7.6	6.5	8.8
EC	dS/m	<1.20	0.06	0.02	0.03	0.04	0.02	0.08
Chloride	milligrams per kilogram (mg/kg)	<800	4	6	7	8	7	10
Potassium	mg/kg	-	162	140	122	275	172	114
Nitrate	mg/kg	-	2	1	2	2	1	1
Phosphorus	mg/kg	>10	7	9	3	6	9	10
Organic carbon	%	1.0-1.8	0.5	0.4	0.3	0.5	0.7	0.5
Ca:Mg	-	>2.00	3.58	3.15	3.54	2.56	3.48	23.18
Cation exchange capacity	milliequivalents per 100 grams (meq/100g)	12.00-25.00	5.88	4.20	2.74	10.65	5.34	22.89
Exchangeable calcium	meq/100g	>5.00	3.92	2.68	1.76	6.93	3.48	21.94
Exchangeable magnesium	meq/100g	>1.00	1.30	0.90	0.50	1.43	1.06	0.93
Exchangeable potassium	meq/100g	>0.30	0.42	0.36	0.31	0.71	0.44	0.29
Exchangeable sodium percentage (ESP)	%	<6.00	0.60	1.75	1.70	0.90	1.30	0.50

1. Green = soil sufficiency exceedance.

c Productivity

Agricultural land classification

The *Guidelines for agricultural land evaluation in Queensland* (DSITI & DNRM 2015) outlines agricultural land classification (ALC) classes based on soil and landscape characteristics. The ALC classes are defined in Table 12.

Table 12 ALC classes

ALC class	Description
A	Land that is suitable for a wide range of current and potential crops with nil to moderate limitations to production.
B	Land that is suitable for a narrow range of current and potential crops. Land that is marginal for current and potential crops due to severe limitations but is highly suitable for pastures. Land may be suitable for cropping with engineering and / or agronomic improvements.
C	Land that is suitable only for improved or native pastures due to limitations which preclude continuous cultivation for production. Some areas may tolerate a short period of ground disturbance for pasture establishment.
D	Land not suitable for agricultural uses due to extreme limitations. This may be: undisturbed land with significant conservation and / or catchment values; land that may be unsuitable because of very steep slopes, shallow soils, rock outcrop, poor drainage, salinity, acidic drainage; or is an urbanised area.

All soils at the Mine were assessed as ALC Class D.

Land suitability class

Five land suitability classes are defined in the *Regional Land Suitability Frameworks for Queensland* (DSITIA & DNRM 2013) based on soil, climate and landscape characteristics. These classes are used to describe land for suitability for a particular land use (ie improved pasture) which allows optimum, sustainable production with current technology while minimising degradation to the land resource. The land suitability classes are defined in Table 13.

Table 13 Land suitability classes

Land suitability class	Description
1	Suitable land with negligible limitations. This is highly productive land requiring only simple management practices to maintain economic production.
2	Suitable land with minor limitations, which either reduce production or require more than simple management practices of class 1 land to maintain economic production.
3	Suitable land with moderate limitations, which either further lower production or require more than those management practices of class 2 land to maintain economic production.

Land suitability class	Description
4	Marginal land, which is considered unsuitable due to severe limitations. The long-term significance of these limitations on the proposed land use is unknown or not quantified. The use of this land is dependent upon undertaking additional studies to determine whether the effect of the limitation(s) can be reduced to achieve sustained economic production.
5	Unsuitable land with extreme limitations that preclude its use.

The land suitability classes for beef cattle grazing are given in Table 14.

Table 14 Land suitability for beef cattle grazing

Soil management unit	Land suitability class
Red Plains	4 — marginal land
Knapdale	5 — unsuitable land
Dale	4 — marginal land
Miners	5 — unsuitable land
Prospectors	5 — unsuitable land
Pocket	4 — marginal land

The land suitability classes for rainfed broadacre cropping are given in Table 15.

Table 15 Land suitability for rainfed broadacre cropping

Soil management unit	Land suitability class
Red Plains	5 — unsuitable land
Knapdale	5 — unsuitable land
Dale	5 — unsuitable land
Miners	5 — unsuitable land
Prospectors	5 — unsuitable land
Pocket	5 — unsuitable land

Areas of regional interest

Under the *Regional Planning Interests Act 2014* (RPI Act), an approval is required when a resource activity or regulated activity is proposed in an area of regional interest. Areas of regional interest are identified as:

- priority living areas (PLAs);
- priority agricultural areas (PAAs);
- strategic cropping areas (SCAs); and
- strategic environmental areas (SEAs).

The RPI Act also includes consideration of strategic cropping land (SCL).

There are no mapped PLAs, PAAs, SCAs, SEAs or SCL within or adjacent to the Mine. Therefore, no further assessment for these regional interests is required.

3.1.3.8 Land stability

a Pre-existing land degradation and erosion

The pre-mining erosion rate has been calculated using the revised universal soil loss equation (RUSLE). RUSLE is a calculation used to estimate average annual soil loss caused by sheet and rill erosion. The equation is limited to making precautions for long-term annual soil loss.

The RUSLE equation is:

$$A = R \times K \times LS \times C \times P$$

Where:

- A = the estimated average annual soil in tonnes per hectare (t/ha);
- R = the rainfall and runoff erosivity factor. This describes intensity and duration of rainfall in a given geographical area;
- K = the soil erodibility factor. K is related to soil physical and chemical properties that determine how easily soil particles can be dislodged;
- LS = a dimensionless topography factor determined by length and steepness of a slope. The LS factor is related to the velocity of runoff;
- C = the cover and management factor. Cover of any kind can help protect the soil from raindrop impact, can slow runoff and reduce and reduce its kinetic energy; and
- P = the factor for supporting practices. This factor considers specific erosion control measures.

Values for R, S, L and K have been taken from a Queensland Spatial Catalogue (Qspatial) data series given by DES which is based on the Australian Soil Resource Information System (ASRIS). Results have been calculated for a pasture system since this matches the pre-mining land-use. A C factor of 0.02 has been chosen assuming total pasture coverage and a P factor of 0.5 has been adopted assuming minimal land management. The resulting pre-mining erosion rates are shown in tonnes per hectare per year (t/ha/yr) in Table 16.

Table 16 Pre-mining erosion rates

Statistic	Erosion rate (t/ha/yr)
Minimum	0.1
Maximum	63.9
Median	0.9

It should be noted that the extremely high maximum rate was calculated along the Knapdale Range, which is characterised by steep slopes, causing a disproportionately high LS factor. This is clarified by the relatively low median rate.

There are few Australian studies that have attempted to quantify erosion rates. The prediction of *Sheet and Rill Erosion Over the Australian Continent, Incorporating Monthly Soil Loss Distribution* (Lu et al. 2001) is one such study. The study relied upon remote sensing technology to determine national and state averages of erosion and found, for Australia:

- the average rate of erosion is 6.3 t/ha/yr;
- a low rate of erosion is defined as less than (<) 0.5 t/ha/yr;
- a medium rate of erosion is defined as 0.5-10 t/ha/yr; and
- a high rate of erosion is defined as greater than (>) 10 t/ha/yr.

The pre-mining erosion indicates that the Mine had a medium rate of erosion before operations began.

b Predisposition to ongoing stability issues

An assessment of soil erosion susceptibility is given in Table 17, which lists influencing factors for the SMUs that have been identified.

Table 17 Soil erosion susceptibility

SMU	Soil type	Sodicity	Texture	Landform	Vegetation cover	Erosion susceptibility
Red Plains	Rudosol	Non-sodic	Sandy loam to sandy clay loam	Flatter plain areas	Cloncurry Box and Snappy Gum Open Woodland	Non-dispersive
Knapdale	Rudosol	Non-sodic	Sandy clay loam	Slopes of the Knapdale Range (30-40°)	Snappy Gum Open Woodland and Spinifex grass	Non-dispersive
Dale	Rudosol	Non-sodic	Sandy loam	Valley floors or plateaus in the Knapdale Range	Snappy Gum Open Woodland	Non-dispersive
Miners	Rudosol	Non-sodic	Sandy clay loam	Outcropping of the deposit lode	Cloncurry Box Open Woodland	Non-dispersive
Prospectors	Rudosol	Non-sodic	Clay loam	Toe slope of the Knapdale Range	Snappy Gum Open Woodland	Non-dispersive
Pocket	Calcarosol	Non-sodic	Sandy clay loam	Areas of low relief pockets (<5°)	Snappy Gum and Cloncurry Box Open Woodland	Non-dispersive

As the Mine is in a seasonal climate, soil erosion management shall be done in a two-season approach; wet season (December to March) and dry season (April to November). The erosion hazard, based on average monthly rainfall depth recorded by the weather station located at the Cloncurry Airport (station 029141) and referenced from the International Erosion Control Association's (IECA) *Best Practice Erosion and Sediment Control Guidelines* (IECA 2008), is given in Table 18.

Table 18 Erosion hazard based on average monthly rainfall

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
High	High	Moderate	V Low	V Low	V Low	V Low	V Low	V Low	V Low	Low	Moderate

Source: IECA 2008 Table 4.4.2

3.1.3.9 Vegetation communities and ecological data

a Matters of environmental significance

Matters of national environmental significance

No matters of national environmental significance (MNES) were identified on the Mine or in the region using the Department of Agriculture, Water and the Environment protected matters search tool.

Matters of state environmental significance

The following matters of state environmental significance (MSES) were identified on the Mine and in the region using the State Planning Policy (SPP) Interactive Mapping System (IMS):

- wildlife habitat (endangered or vulnerable);
- regulated vegetation (essential habitat); and
- regulated vegetation (intersecting a watercourse).

Matters of local environmental significance

No matters of local environmental significance (MLES) were identified in the *Cloncurry Shire Planning Scheme* (CSC 2016).

b Environmentally sensitive areas

The Department of Natural Resources, Mines and Energy (DNRME) environmentally sensitive areas (ESA) map identified no Category A ESAs within the Mine. One Category B ESA was identified within and adjacent to the Mine which was an 'Endangered Regional Ecosystem' under the Queensland biodiversity status. This ecosystem is defined as regional ecosystem (RE) 1.3.7a — River Red Gum (*Eucalyptus camaldulensis*) Riparian Woodland. Riverine wetlands or fringing riverine wetlands are identified within this RE. The overall condition of this RE is degraded by cattle grazing and weed invasion. Based on proposed disturbance plans and current infrastructure, <0.5 ha will be disturbed. It is unlikely the regional extent of this community will be affected by operations.

The powerline corridor crosses several rivers and creeks which have been identified as RE 1.3.7a. The community occurs in three separate areas along the access road corridor. Additional disturbance of RE 1.3.7a due to the powerline easement is estimated to be approximately 23 ha. As a result of the disturbance caused to the creek by the access road construction, a Queensland Government approved biodiversity offset at Lawn Hill pastoral station was established in 2014. Assuming mitigation measures are followed, the overall health and diversity of this community will be maintained. No additional clearing due to the access route was required.

c RE mapping

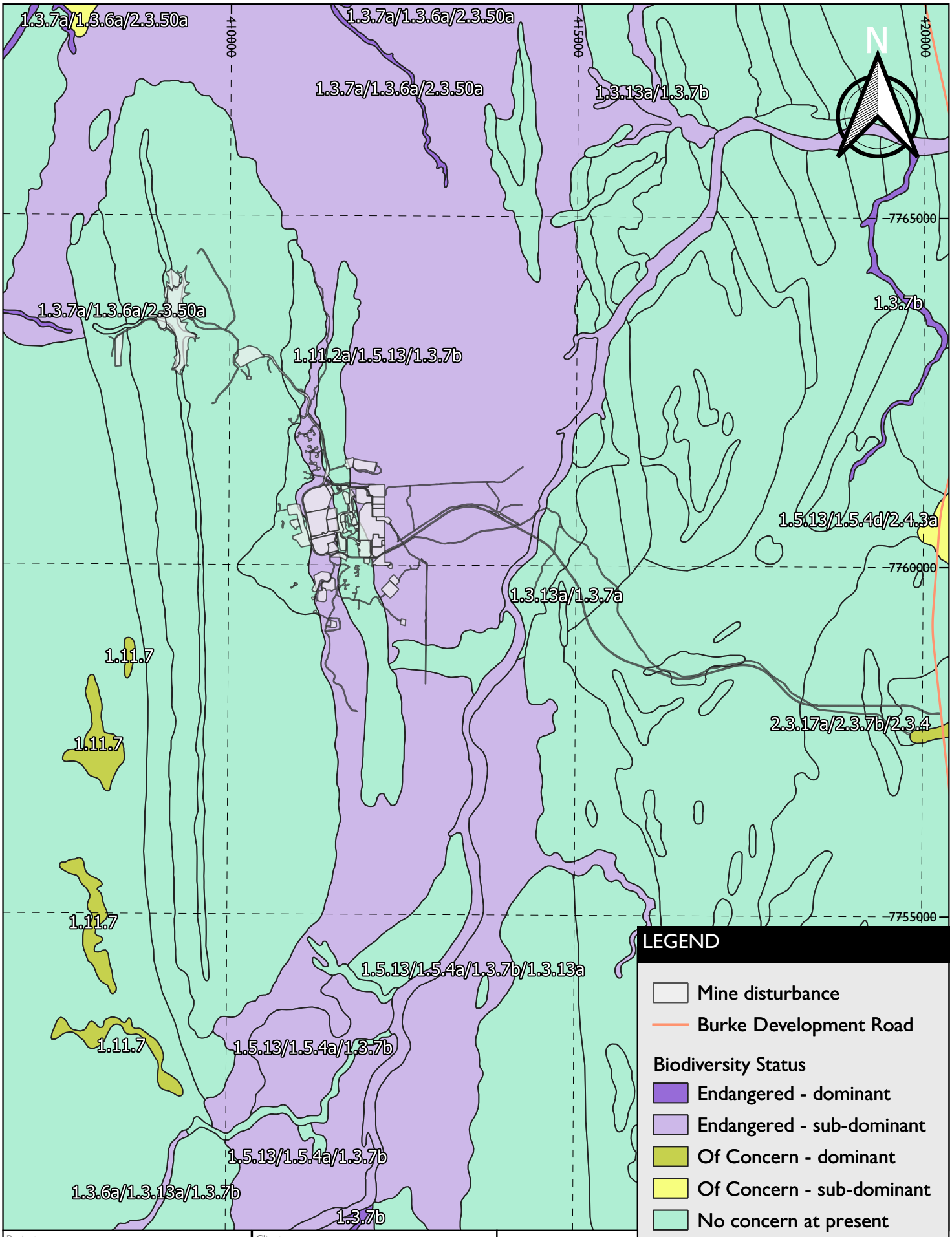
Assessment of current RE mapping identified the REs occurring within the Mine tenure. Table 19 provides a brief description on each of these ecosystems, along with their *Vegetation Management Act 1999* (VM Act) and *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) status. Figure 7 shows the location of REs at the Mine.

Table 19 Regional ecosystem descriptions

RE code	Description	VM Act status	EPBC Act status
1.3.4	*Acacia cambagei* low open woodland to woodland on alluvium, sometimes with *Eucalyptus leucophylla.*	Least concern	No concern
1.3.6	*Corymbia aparrerinja* and *Corymbia terminalis* woodland on sandy levees.	Least concern	No concern

RE code	Description	VM Act status	EPBC Act status
1.3.7	*Eucalyptus camaldulensis* woodland on channels and levees.	Least concern	Endangered
1.3.13	*Eucalyptus leucophylla* woodland on levees and minor drainage lines.	Least concern	No concern
1.5.3	*Eucalyptus leucophloia* low open woodland to woodland on sandy and gravelly red soils.	Least concern	No concern
1.5.4	*Eucalyptus leucophylla* and / or *Corymbia terminalis* low open woodland on red earths.	Least concern	No concern
1.5.13	*Eucalyptus pruinosa* low open woodland on older alluvial and residual soils.	Least concern	No concern
1.5.16	*Acacia cambagei* low woodlands on red earths.	Least concern	No concern
1.7.1	*Eucalyptus leucophloia* low open woodland on silcrete and lateritic surfaces.	Least concern	No concern
1.7.5	*Acacia shirleyi* low woodland on lateritic scarps and hills.	Least concern	No concern
1.7.7	*Corymbia capricornia* and / or *Eucalyptus leucophloia* or *Eucalyptus miniata* low open woodland on silcrete.	Least concern	No concern
1.11.2	*Eucalyptus leucophloia* low open woodland.	Least concern	No concern
1.11.3	*Corymbia terminalis* and / or *Eucalyptus leucophylla* low open woodland on metamorphics.	Least concern	No concern
1.11.7	*Acacia cambagei* low woodland on metamorphic hills.	Of concern	Of concern
1.11.8	*Terminalia aridicola* and / or *Corymbia aspera* low open woodland to low woodland, usually with vine-scrub species, on rock outcrops.	Least concern	No concern
1.12.1	*Eucalyptus leucophloia* low open woodland on granites.	Least concern	No concern
1.12.3	*Eucalyptus leucophylla* and / or *Corymbia terminalis* and / or *Corymbia aparrerinja* low open woodland on igneous rocks.	Least concern	No concern
2.3.3	*Astrebla squarrosa* and / or *Astrebla elymoides* and/or *Iseilema spp.* tussock grassland on active Quaternary alluvial plains.	Least concern	No concern
2.3.7	*Acacia cambagei* and / or *Eucalyptus microtheca* low woodland on fine-textured Quaternary alluvial plains.	Least concern	No concern
2.3.17	*Eucalyptus microtheca* and / or *Excoecaria parvifolia*, *Lysiphyllum cunninghamii* or *Atalaya hemiglauca* woodland fringing channels in fine-textured alluvial systems.	Least concern	Of concern
2.3.26	*Eucalyptus camaldulensis* and / or *Melaleuca spp.* woodland fringing sandy, seasonal channels.	Least concern	Of concern

RE code	Description	VM Act status	EPBC Act status
2.3.46	*Corymbia terminalis, Corymbia aparrerinja* and / or *Lysiphyllum cunninghamii* woodland on river levees in dry, southern parts of the bioregion.	Least concern	Of concern
2.3.50	Waterholes, bare sand and rock in the channels of major watercourses.	Least concern	Of concern
2.4.2	*Astrebla spp.*, *Iseilema spp.* and / or *Aristida latifolia*, *Eulalia aurea* tussock grassland on Tertiary clay deposits.	Least concern	No concern
2.4.3	*Acacia cambagei* low woodland on Tertiary clay deposits and shallow clay depressions on plateau surfaces.	Least concern	Of concern
2.5.12	*Eucalyptus pruinosa subsp. pruinosa* low woodland on plains and low rises on red and yellow earths.	Least concern	No concern
2.5.34	*Acacia cambagei* low woodland on gravelly deposits and deeply weathered surfaces.	Least concern	No concern



Project: Progressive Rehabilitation and Closure Plan		Client: MMG Limited	
FIGURE: 7	Title: Environmentally Sensitive Areas	Design: SGM Environmental 24.02.2021 Scale: 1 : 75,000 CRS: GDA94 / MGA zone 54	SGM environmental

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d Significant flora

During the EIS process, 125 flora species were identified at the Mine. No flora species of conservation significance were identified.

3.1.3.10 Fauna presence and populations

During the EIS process, a desktop assessment identified species which may occur in the broader Mine region. This was followed with field surveys which identified a combined total of 64 vertebrate fauna species during dry and wet season surveys, comprising 9 reptiles, 34 birds, 17 mammals and 4 fish. Table 20 outlines threatened flora and fauna species that were assessed as potentially occurring within the Mine's vicinity (AARC 2010). Significant fauna observed during field surveys is outlined in the following section.

Table 20 Threatened flora and fauna species that may occur within the broader region

Scientific name	Common name	EPBC status	NC Act status	Habitat requirements	Notes on presence in survey area
Fauna					
Birds					
Ardea alba	Great Egret	Marine (Ma)	Least concern (LC)	Great Egrets occur throughout most of the world. They are common throughout Australia, with the exception of the most arid areas. Known to prefer shallow water, particularly when flowing, but may be seen on any watered area, including damp grasslands.	Limited habitat occurs on Mine site, furthermore given the habitat associated with major watercourses in the region such as the Dugald River, it is likely the species would prefer these sites given their habitat suitability.
Apus pacificus	Fork-Tailed Swift	Ma, migratory (Mi)	Special least concern (SLC)	Breeds from central Siberia eastwards through Asia, wintering south to Australia. They are aerial birds.	May seasonally occur on Mine site, however despite extensive searches during the dry season survey, no species were observed.
Bubulcus ibis	Cattle Egret	Ma	LC	In Australia it is most widespread and common in north-eastern Western Australia across the Top End, Northern Territory, and in south-eastern Australia from Bundaberg, Queensland to Port Augusta, South Australia, including Tasmania. The species is found in grasslands, woodlands and wetlands, and is not common in arid areas. It also uses pastures and croplands, especially where drainage is poor. Will also forage at garbage dumps, and is often seen with cattle and other stock.	Limited habitat occurs on Mine site, furthermore given the habitat associated with major watercourses in the region such as the Dugald River, it is likely the species would prefer these sites given their habitat suitability.

Scientific name	Common name	EPBC status	NC Act status	Habitat requirements	Notes on presence in survey area
Charadrius veredus	Oriental Plover	Ma, Mi	SLC	The Oriental Plover has been recorded in all states but most common in coastal areas across northern Australia. The species is found generally inland; in open grasslands in arid and semi-arid zones; and less often in estuarine or littoral environments. Known to prefer flat inland plains, sparsely vegetated short grass with hard bare ground including claypans, playing fields, lawns and cattle camps.	May intermittently occur on the Mine site, however given the species range, the Project is unlikely to constitute an ecologically significant proportion of its habitat.
Glareola maldivarum	Oriental Pratincole	Ma, Mi	SLC	The Oriental Pratincole are birds of open country, and are often seen near water in the evening, hawking for insects. They are found in warmer parts of south and east Asia, breeding from northern India across to China and Europe, wintering in India, Indonesia and northern Australia.	Unlikely to occur on the Mine site given the lack of preferred habitat and highly transient behaviour.
Heteromunia pectoralis	Pictorella Mannikin	-	LC	Prefers tall grass in Acacia woodlands near water and grassy flats and occasionally Spinifex tuffs. Distributed in tropical northern Australia, noted to migrate coastward in dry season and inland in wet.	Some suitable habitat may occur on the Mine site. However, given the amount of surrounding habitat it is unlikely the Mine site constitutes critical habitat range. Furthermore, given the species range, it is unlikely that the Mine will have an adverse impact on this species should it occur intermittently.
Ephippiorhynchus asiaticus	Black-Necked Stork	-	LC	Prefers open freshwater environments, including the margins of swamps, shallow floodwaters over grasslands, wet shorelines, margins of mangroves, mudflats and estuaries.	Limited habitat occurs on the Mine site, furthermore given the habitat associated with major watercourses in the region such as the Dugald River, it is likely the species would prefer these sites given their habitat suitability.

Scientific name	Common name	EPBC status	NC Act status	Habitat requirements	Notes on presence in survey area
Haliaeetus leucogaster	White-Bellied Sea-Eagle	Ma	LC	White-Bellied Sea-Eagles are a common sight in coastal and near coastal areas of Australia. Often seen perched high in a tree, or soaring over waterways and adjacent land.	Unlikely to occur on the Mine site given the range of the species and the distance from the coast.
Melithreptus gularis	Black Chinned Honeyeater	-	LC	The Black-Chinned Honeyeater is found on mainland Australia from the Gulf Country of Queensland south to Cloncurry and is widespread in central and eastern Queensland. It is found in the upper levels of open eucalypt forests and woodlands dominated by box and ironbark eucalypts. It is often found along waterways, especially in arid and semi-arid areas.	Suitable habitat occurs on the Mine site. Although unlikely, given its scarcity, it is possible that this species may intermittently occur on the Mine site.
Merops ornatus	Rainbow Bee-Eater	Ma	LC	The Rainbow Bee-Eater is found throughout mainland Australia, as well as eastern Indonesia, New Guinea and, rarely, the Solomon Islands. In Australia it is widespread, found in open forests, woodlands and shrublands, and cleared areas, usually near water.	Suitable habitat occurs on the Mine site. However, the Mine is located outside of the species range so unlikely to occur on the Mine site.
Numenius minutes	Little Curlew	-	SLC	Prefers open country and grassy flats.	Unlikely to occur on the Mine site given the lack of preferred habitat and highly transient behaviour.
Rostratula australis	Australian Painted Snipe	Endangered (E), Ma	E	This species inhabits shallow inland wetlands, either permanent or temporary.	Limited habitat occurs on the Mine site, furthermore, given the habitat associated with major watercourses in the region such as the Dugald River, it is likely the species would prefer these sites given their habitat suitability.
Mammals					

Scientific name	Common name	EPBC status	NC Act status	Habitat requirements	Notes on presence in survey area
Petrogale purpureicollis	Purple-Necked Rock-Wallaby	-	V	All Rock-Wallabies favour habitat with cliffs, rocky slopes and outcrops or boulder piles. They are often found in outcrop formations, in association with dry Eucalypt (*Eucalyptus sp.*) and Wattle (*Acacia sp.*) woodlands and Spinifex (*Triodia sp.*) grasslands.	Suitable habitat potentially exists along sections of the Knapdale Range. Although no individuals were identified within the Mine site, it is possible populations may inhabit remote sections within the Knapdale Range. Individuals were sighted within the proposed powerline route.
Sminthopsis douglasi	Julia Creek Dunnart	V	E	Known only from Mitchell Grass downs country between Julia Creek and Moorrinya National Park in north Queensland.	No Mitchell Grasslands communities are present on the Mine site and the Mine is outside of the species currently known range, therefore it is unlikely this species inhabits the Mine site.
Freshwater species					
Crocodylus johnstoni	Freshwater Crocodile	Ma	LC	Known to inhabit freshwater lagoons, billabongs, lakes and ephemeral watercourses throughout northern Australia.	No suitable habitat occurs on the Mine site and therefore is unlikely to occur.
Pristis microdon	Freshwater Sawfish	V, Mi	-	A bottom-dweller of estuaries and the lower reaches of large river systems; sometimes penetrating substantial distances upstream.	No suitable habitat occurs on the Mine site nor is likely to occur in the event of seasonally high rainfall.
Flora					
Ipomea antonschmidii	Morning Glory Vine	Near threatened (NT)	-	Only four records exist for this vine species in the surrounding area of the Mine site, all of which are near creek lines or Lake Julius. The closest record is at the Lake Julius Dam Pumping Station, ~ 50 km west of the Mine. This species typically grows on shallow, red, stony soils in *E. leucophloia* woodland.	The habitat range for this species is not near the Mine. This species is unlikely to occur on the Mine site.
Ptilotus maconochiei	Mulla	-	-	*Eucalyptus* spp. woodland or open woodland not otherwise specified.	Habitat for this species is available on the Mine site, however it was not identified despite extensive field surveys.

The waterways within the Mine are typical of ephemeral creek systems within the broader region, with no permanent water bodies, and creeks flowing periodically after heavy rainfall events during the wet season (November-April). The aquatic flora and fauna are not considered to be diverse or unique. Although macro invertebrates and fish may opportunistically move into the upstream drainages of ephemeral creeks to forage, the drainage lines within the tenures are considered poor habitat for macro invertebrates and are unlikely to harbour long-term fish populations. Four aquatic vertebrate species were detected downstream of the Mine during a 2008 survey. No aquatic vertebrates of conservation significance were recorded.

a Significant fauna

Seven bird species listed as migratory and / or marine under the EPBC Act were observed at the Mine during the EIS and subsequent surveys. These species were:

- Wedge-tail Eagle (*Aquila audax*);
- Sacred King Fisher (*Todiramphus sanctus*);
- Rainbow Bee-eater (*Merops ornatus*);
- Black Falcon (*Falco subniger*);
- Whistling Kite (*Haliastur sphenurus*);
- Black Kite (*Milvus migrans*); and
- Brolga (*Grus rubicundus*).

Marine species are not considered significant for the Project given the nearest Commonwealth Marine Area is ~ 766 km east of the Mine.

Species considered significant for the Mine are;

- Carpentarian Antechinus (*Pseudantechinus mimulus*); and
- Purple-Necked Rock-Wallaby (*Petorgale purpureicollis*).

Management measures specific to these species is outlined in Section 3.6.1.8.

3.1.3.11 Pre-mining land use

a Regional

The Mine is located within the Mount Isa Mineral Province. This region of north-west Queensland is characterised by mineral exploration, mining and pastoral leases. Cloncurry and Mount Isa are located ~ 65 km south-east and 85 km south-west of the Mine respectively. Cloncurry's population is ~ 2,500 with the primary industries being cattle grazing and mining. Mount Isa is the administrative, commercial and industrial centre of northwest Queensland with a regional population of 33,000.

b Local

The Mine is located on Roseby Station pastoral leases, owned by Macmillan Holdings. The Roseby Station pastoral leases are currently, and have historically, been used for cattle grazing on unimproved pastures. The Roseby Station pastoral leases also includes a small number of abandoned mines. Human settlement in the region is sparse with the nearest resident being the McMillan family residence, ~ 6 km from the Mine.

The Mine itself is in the Kalkadoon People #4 native title claim. Part of the southern section of the powerline is in the Mitakoodi and Mayi People's native title claim. Agreements with both these groups have been made regarding cultural heritage management.

3.1.3.12 Identification of underlying landholders

The underlying landholders are given in Table 21.

Table 21 Lot and plan numbers

Lot	Plan	Ownership
3692	PH2168	Harold Henry McMillan
59	TG40	North Australian Pastoral Co Pty Ltd
27	B15753	MMG Australia Limited
28	B15753	Altona Mining Limited
35	B15753	MMG Australia Limited
36	B15753	MMG Australia Limited
211	SP136468	Queensland Rail
521	CP905413	Jersey Plains Pastoral Company
521	PH2265	Jersey Plains Pastoral Company
3635	PH2175	Cameron Creek Pastoral Co Pty Ltd
4025	PH173	Anita Maree and Grant James Telford AS TTE

3.1.3.13 Native title

Two native title groups have been recognised as owners of indigenous cultural heritage over the Mine and power line corridor. Both groups have approved their respective cultural heritage management plan (CHMP).

- the Kalkadoon People #4 (approved 28 June 2008); and
- the Mitakoodi and Mayi People (approved 28 May 2008).

The CHMPs clearly define how the Mine is managed to avoid harm to indigenous cultural heritage, and if harm cannot be reasonably avoided, to minimise any impacts.

3.1.4 Design for closure

This section describes how relevant activities are carried out in a way that maximises the progressive rehabilitation of the land to a stable condition as per the PRC plan schedule (Appendix A).

3.1.4.1 Location of mine features

a Protection of environmental values

The Mine has been developed to avoid major disruptions to most of the identified REs, which are found in close proximity to the local waterways.

b Surrounding land uses and proximity to sensitive receptors

The nearest sensitive receptors are given in Table 22, including the approximate direction and distance from the main processing plant. Based on the distances, only the Mt Roseby Homestead is potentially impacted from the Mine.

Table 22 Sensitive receptors

Receptor	Easting	Northing	Distance from processing plant (km)	Direction
Mt Roseby Homestead	413454	7754153	6	SE
Proposed Eva Copper Project	415796	7771726	11	NNE
Granada Homestead	433791	7777948	28	NE
Hillside Homestead	421466	7732788	29	SSE
Carsland Homestead	428490	7732524	32	SE

Notes: Coordinate reference system GDA 94 / MGA Zone 54

c Gradient of the footprint area

The Mine footprint is graded so that overland flow is directed toward the water management system. The water management system is partially gravity fed to reduce construction, management, and closure costs.

d Local and regional topography

Aside from the Knapdale Range to the east, the topography of the Mine is relatively flat with gently undulating areas. Therefore, local topography is of little concern with respect to achieving the PMLU of the MIA.

The TSF is located in a naturally long, narrow, branched valley running north to south on the western side of the Knapdale Range. Containment will be almost entirely provided by the valley topography. The only constructed containment features are the main western embankment, the eastern decant access embankment and the northern discharge bunds.

e Surface and ground water features

The planned groundwater use at the Mine is quite minor. Processing water is sourced mainly from the Lake Julius Pipeline and decant from the TSF. Owing to the apparent low permeability of the Dugald River Slate it is expected that only minor amounts of dewatering will be required as mining proceeds.

As it has been assessed that the aquifers at the Mine are either of low permeability or are locally more permeable along zones of structural weakness, it has been considered that construction of a numerical groundwater model is not warranted.

f Geotechnical conditions

There should be no groundwater inflows of any significance encountered during underground mining within the Dugald River Slate, apart from localised inflows of connate groundwater. Some inflows will occur and it is to be expected that the majority of these will occur above a depth of 150 m. Based on the hydrogeological evidence from both mineral and groundwater exploration drilling, it is concluded that significant groundwater inflows will not impact on underground mining at Dugald River.

g Competing water and land uses

Aside from the Mt Roseby Homestead, the region is mostly uninhabited with sparse vegetation and limited ground cover. The proposed Eva (formerly Roseby) Copper Project, owned by Copper Mountain Mining Corporation, will be located to the north-northeast of the Mine. It is unlikely that these landholders will compete for the land and water resources used by the Mine.

h Visual impact

Due to the remote location of the Mine, the lack of public viewing points and the distance from public transport routes, the visual impact of the Mine is highly unlikely to be of major concern. The only major public access road, the Burke Development Road, is ~ 10 km to the east of the Mine. Most of the Mine infrastructure is not visible from this road due to Mount Rose Bee forming a visual barrier.

The major features of the Mine that are still visible from the northern aspect of the Mine, will be the processing facilities and the WRDs. The processing facilities and both WRDs will be removed on decommissioning of operations and therefore are only a temporary addition to the landscape.

3.1.4.2 Size, shape and design of mine features

a WRD design

There are dedicated WRDs for the storage of PAF and NAF waste rock which are located on the western side of the processing area (Figure 3). The WRDs are located next to each other but drain to separate run-off dams and will be sized and managed in a way that best facilitates the closure and rehabilitation strategies, as well as the operational requirements of the Mine.

The PAF WRDs are being used for the temporary storage of PAF and high sulfur NAF waste rock, until it can be returned underground for stope fill. Depending on resource availabilities, the low sulfur NAF waste rock from the NAF WRD will be used where necessary in construction and rehabilitation (including as a cover media for the TSF) or may be returned underground.

b TSF design

Landform characteristics

Thickened tailings from the process plant are pumped to the paste plant to be filtered and mixed with cement prior to being used underground as stope fill. If not required underground, thickened tailings are pumped to the TSF which is located ~ 3.5 km north-west of the MIA, in a natural valley within the Knapdale Range.

The TSF will operate for the LOM and at closure, is expected to incorporate 62.9 ha of the valley. The characteristics of the tailings are expected to result in fast consolidation such that rehabilitation works can start within two years after deposition stops. As the tailings will be PAF, a suitable protective cover will be placed over the tailings to inhibit the potential for adverse environmental impacts such as acid generation to occur.

Cover design

At closure, the TSF is anticipated to be rehabilitated with an infiltration storage cover system, to limit rainfall seeping into the PAF tailings. Very little reprofiling of the TSF surface will be required other than the embankment which will be converted to a rock lined spillway. The spillway will move excess water (rainfall runoff and cover seepage) off the top surface of the rehabilitated landform, preventing ponding.

Cover column trials and a semi-calibrated model have indicated that the TSF cover will likely require a 1 m thick infiltration storage layer (ISL) to reduce the potential for seepage into the tailings (SGME 2019). Run-of-mine NAF waste rock blends will be used in the TSF final cover. The preferred cover option is yet to be scaled up to a field trial to validate the column results; however, this is planned to be completed by MMG during operations.

3.1.4.3 Mining method

Underground mining was chosen over open pit mining given the depth of the ore, which starts at 25 m below surface and extends to ~ 1,000 m deep. It is more economical to extract a resource such as this using underground methods, due to the amount of waste rock that would need to be removed if open cut methods were employed.

Underground mining techniques remove much less waste rock than open cut mining, provide underground voids for use in backfilling and produce much smaller land disturbance footprints. For these reasons underground mining methods also have less impact from an environmental perspective with a smaller disturbance footprint requiring rehabilitation.

a Subsidence management

The Mine's crown pillar and extraction method has been designed to ensure long-term stability and prevent surface and underground subsidence. The primary purpose of the crown pillar is to protect surface land users, the Mine, and all those who work within the Mine. Further, the Mine has adopted a sub level open stope mining method with backfill to increase long-term stability and ensure consolidation of voids. The crown pillar has been designed to prevent surface subsidence and underground stope design guidelines are in place to prevent cave-like failure underground.

From the geotechnical stability assessments done (Appendix C), post-closure underground stability and surface subsidence risk is low (based on weathering and groundwater profiles / controls). The Mine has a shallow weathering profile and shallow groundwater. Therefore, there is minimal influence of groundwater on the underground workings and crown pillar stability.

All stopes extracted underground have limited stope strikes and are cable bolted to increase short-term stability. They are all backfilled with either waste rock or cemented backfill to ensure long-term stability and confinement of voids, preventing long-term subsidence.

As an additional control, the critical mill infrastructure is located to the east of all underground workings and the surface water dams are to the west. In the event of an uncontrolled failure underground, no critical infrastructure is likely to be affected.

3.1.5 Rehabilitation and improvement planning

Progressive rehabilitation must be maximised by starting and finishing rehabilitation as soon as practicable after land becomes available. Land will become progressively available for rehabilitation throughout the life of the Mine. Land is considered available for rehabilitation when (Section 126D (5) of the EP Act):

- the land is no longer being mined;
- the land is no longer being used for operating infrastructure or machinery for mining including dams or water storages;
- the land is not needed for mining of a probable or proved ore reserve; or
- the land contains permanent infrastructure remaining for a PMLU.

It is expected that all disturbed land, which is available for rehabilitation, is progressively rehabilitated. The following (Sections 3.1.5.1-3.1.5.5) describe how and when to carry out rehabilitation and closure activities and identifies and justifies when land will become available for rehabilitation.

3.1.5.1 Identification of relevant activities

The relevant activities identified reflect the relevant activities in the PRC plan schedule:

- ancillary infrastructure and services;
- borrow pits and stockpiles;
- dams and diversion structures;
- exploration;
- mineralised waste;
- mining and processing area; and
- TSF and associated pipelines.

3.1.5.2 Size and extent of relevant activities

The size and extent of relevant activities are given in Table 23 and Figure 3.

Table 23 Size and extent of relevant activities

Relevant activities	Total rehabilitation area (ha)
Ancillary infrastructure and services	13.2
Borrow pits and stockpiles	15.9
Dams and diversion structures	34
Exploration	4.7
Mineralised waste	22
Mining and processing area	102.2
TSF and associated infrastructure	44.1
Total	**236.1**

3.1.5.3 Likely duration of relevant activities

The purpose of this section is to describe when land is available for rehabilitation and when it is practical to start the first milestone for a feature.

Progressive rehabilitation will occur through the life of the Mine, with final decommissioning expected to start in 2038. Staged rehabilitation treatments (progressive rehabilitation) will be applied as soon as land / features become available. Rehabilitation activities and lease relinquishment are anticipated to be completed by 2067.

Some rehabilitation has been completed along the raw water pipeline corridor, exploration pads and some minor construction disturbance. However, no major rehabilitation works have been undertaken to date.

Progressive rehabilitation may be constrained by the operational requirements of the Mine. Some land / features may be rehabilitated after construction works are finalised, but due to the nature of underground mining, there is likely to be only exploration areas available for progressive rehabilitation during mining operations. The schedule of land availability is given in Table 24.

Table 24 Schedule of land availability

Relevant activities	**Cumulative area available (ha)**								
Year land becomes available	**2022**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**	**2044**	**2045**
Ancillary infrastructure and services		13.2							
Borrow pits and stockpiles		7.8							15.9

Relevant activities	Cumulative area available (ha)				
Dams and diversion structures			15.7		34
Exploration	4.7				
Mineralised waste		22			
Mining and processing area (low intensity grazing / native habitat PMLU)		78.9			
Mining and processing area (low intensity grazing PMLU)		23.3			
TSF and associated infrastructure		0.3	1.5	44.1	

3.1.5.4 Progressive rehabilitation of relevant activities

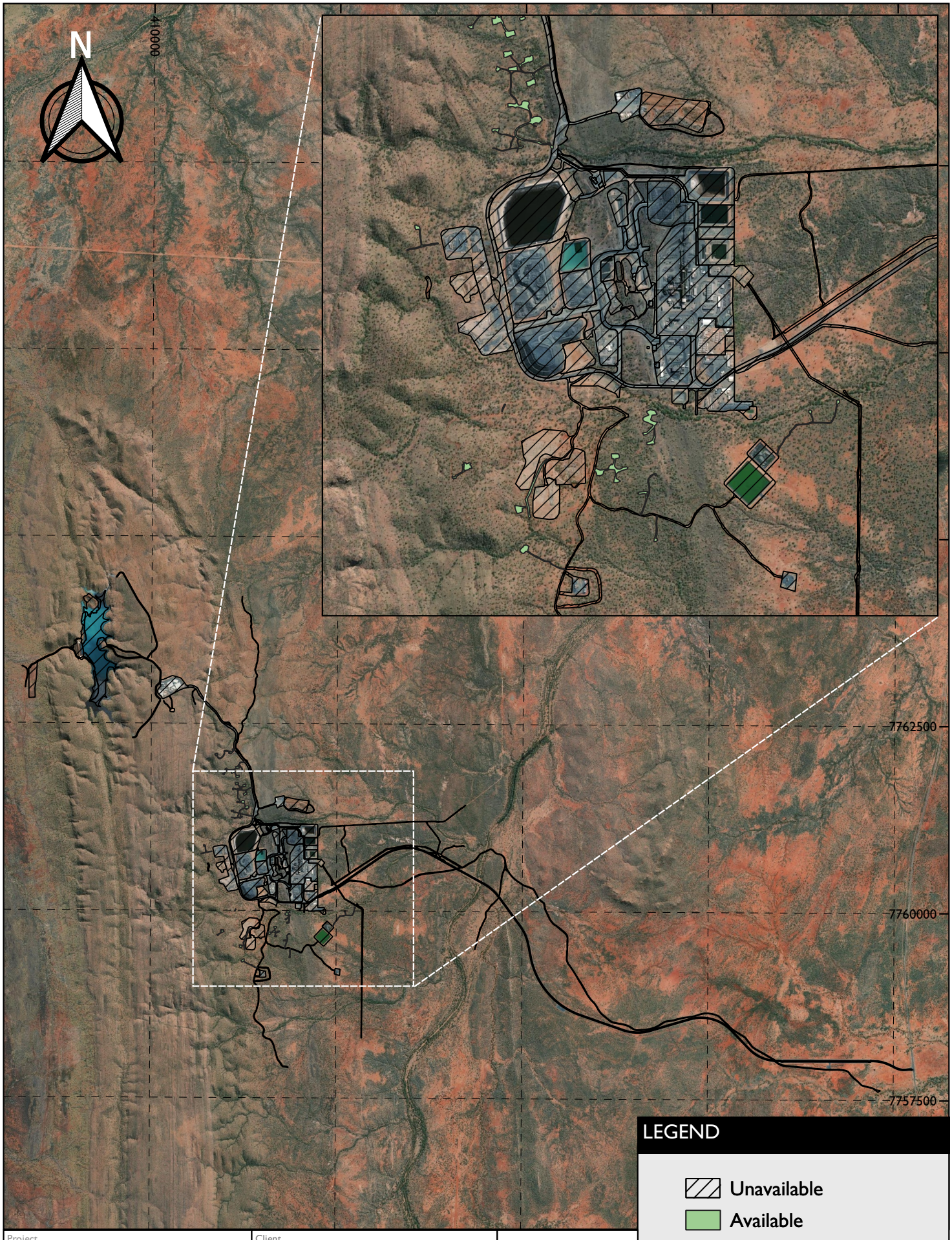
Exploration areas will be rehabilitated as they become available in line with EA conditions.

All of the mining and processing and ancillary infrastructure and services areas will become available at the completion of mining operations as these facilities will no longer be required. These areas will be decommissioned of all infrastructure prior to earthworks starting. The PAF and NAF waste rock dumps will also be available at this time. Rock from the PAF dump will be disposed of in line with licence conditions while NAF waste will be utilised in other rehabilitation areas.

Borrow pits will be available immediately following the cessation of mining while topsoil stockpiles will not be available until other rehabilitation areas are completed (2045). Some dams and diversion structures will be available in 2040 with time allowed to naturally evaporate water prior to rehabilitation commencing. The remainder of water infrastructure will remain in place and unavailable until rehabilitation of the surrounding area is completed (2044). This will provide effective erosion and sediment control mitigation during rehabilitation works.

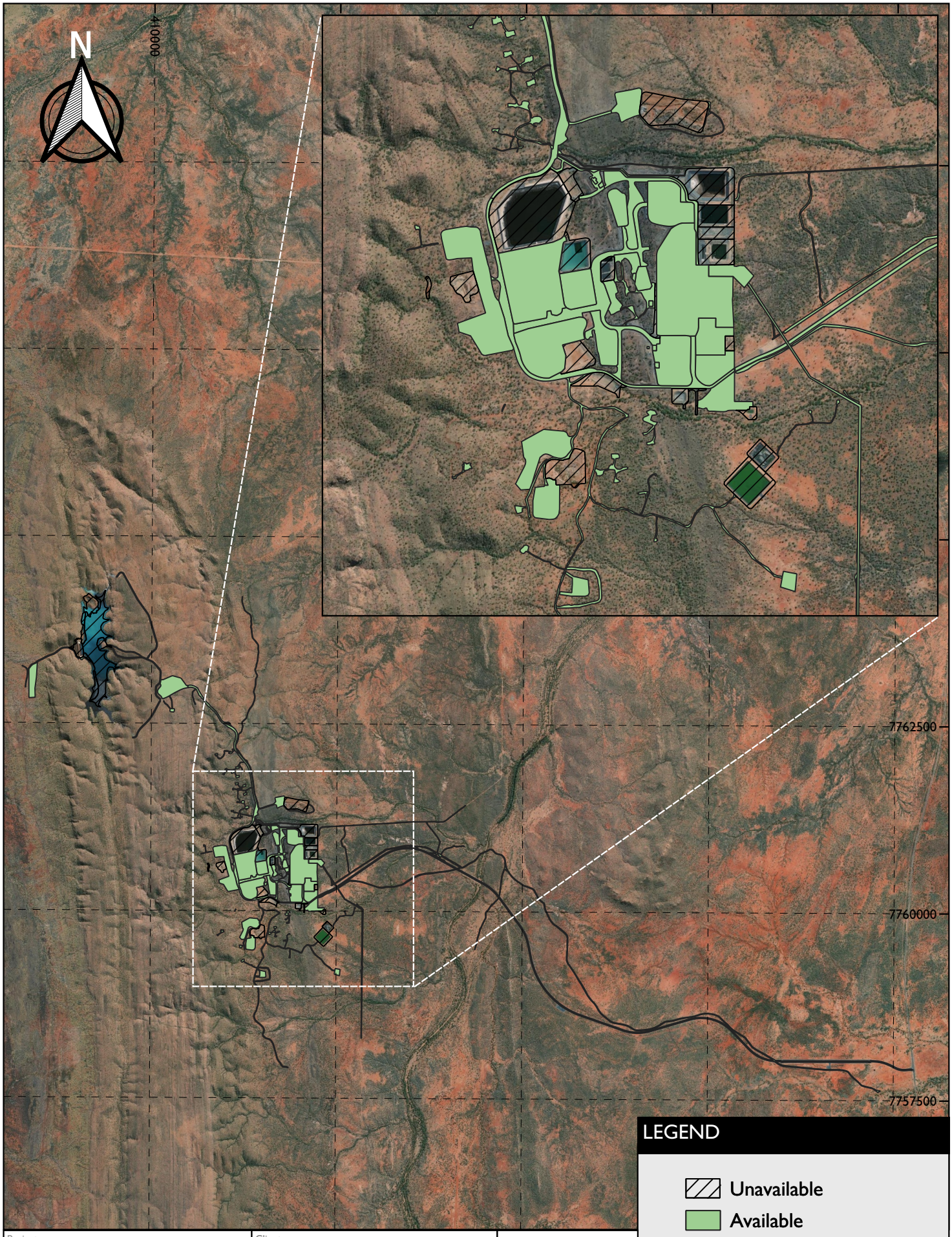
The TSF will be unavailable until 2040 when sufficient time has passed to allow the adequate solidification of deposited tailings. Seepage ponds and associated infrastructure will be rehabilitated in this period until the main TSF area is available in 2040.

The schedule of land availability is shown in Figure 8-Figure 13.



Project: Progressive Rehabilitation and Closure Plan		Client: MMG Limited	
Figure: 8	Title: Land available for rehabilitation - 2022-2037	Design: SGM Environmental Pty Ltd 09.09.2021 Scale: 1 : 70,000 CRS: GDA94 / MGA zone 54	SGM environmental

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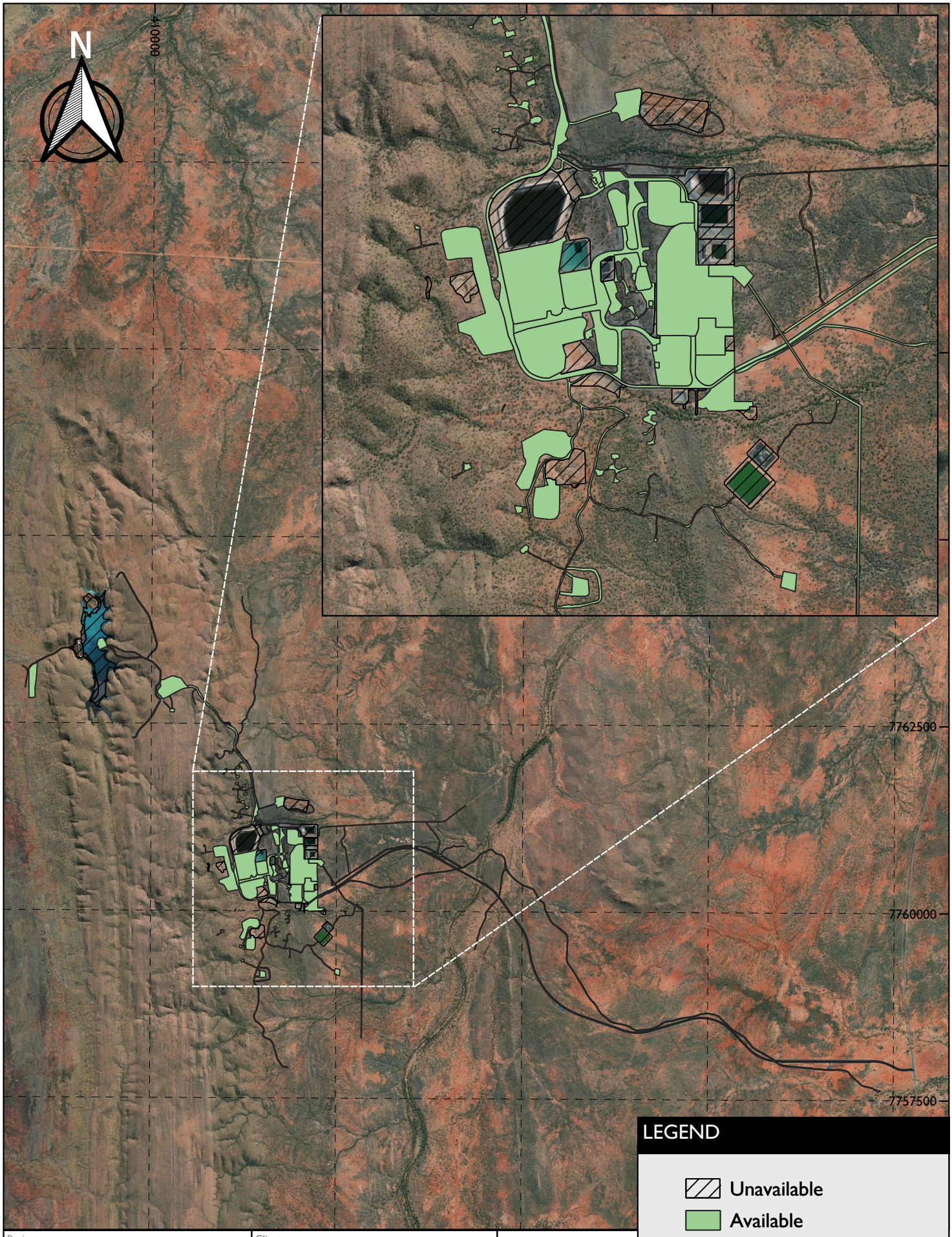
Available

Scale 1 : 70 000

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Project: Progressive Rehabilitation and Closure Plan		Client: MMG Limited	
Figure: 9	Title: Land available for rehabilitation - 2038	Design: SGM Environmental Pty Ltd 09.09.2021 Scale: 1 : 70,000 CRS: GDA94 / MGA zone 54	SGM environmental

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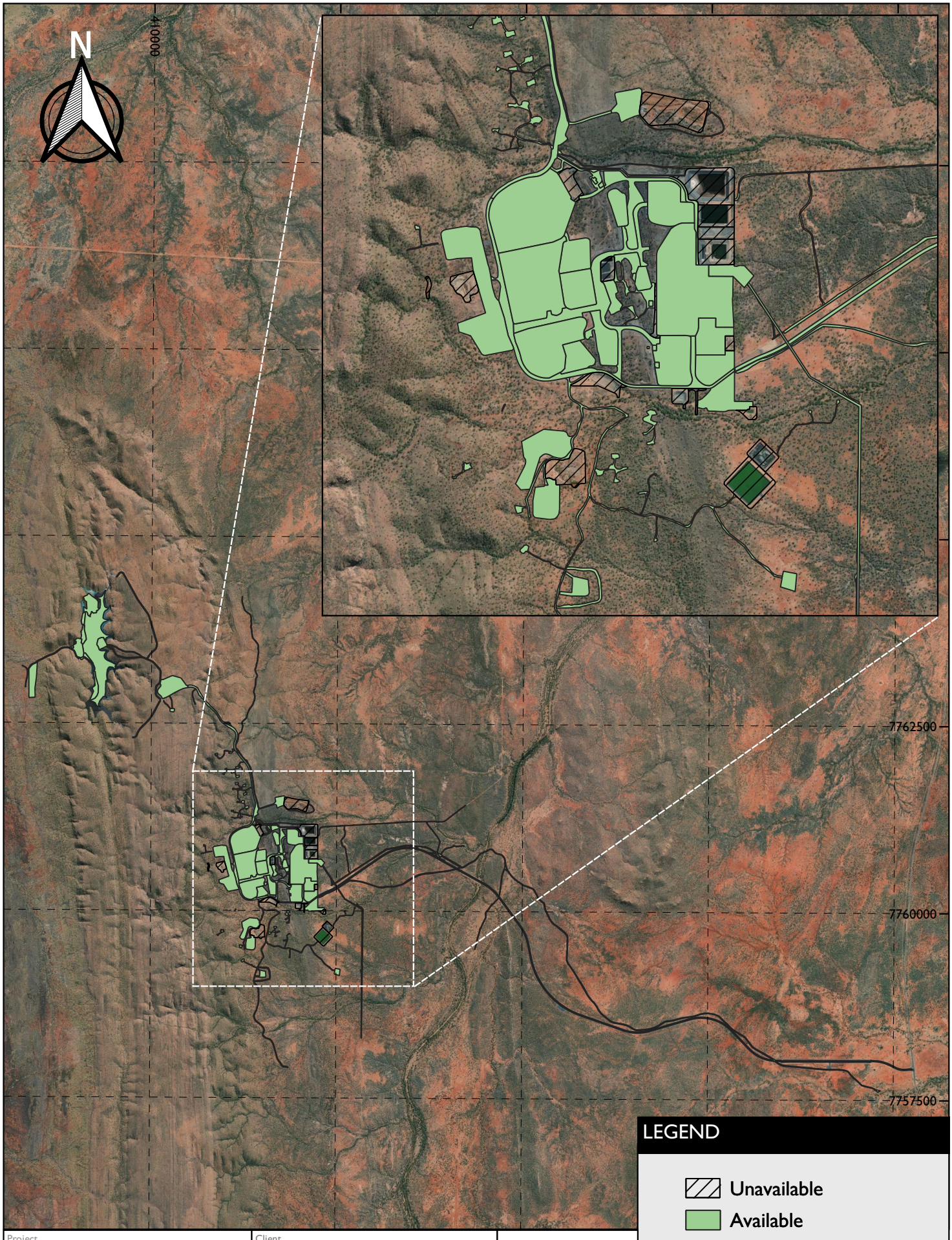
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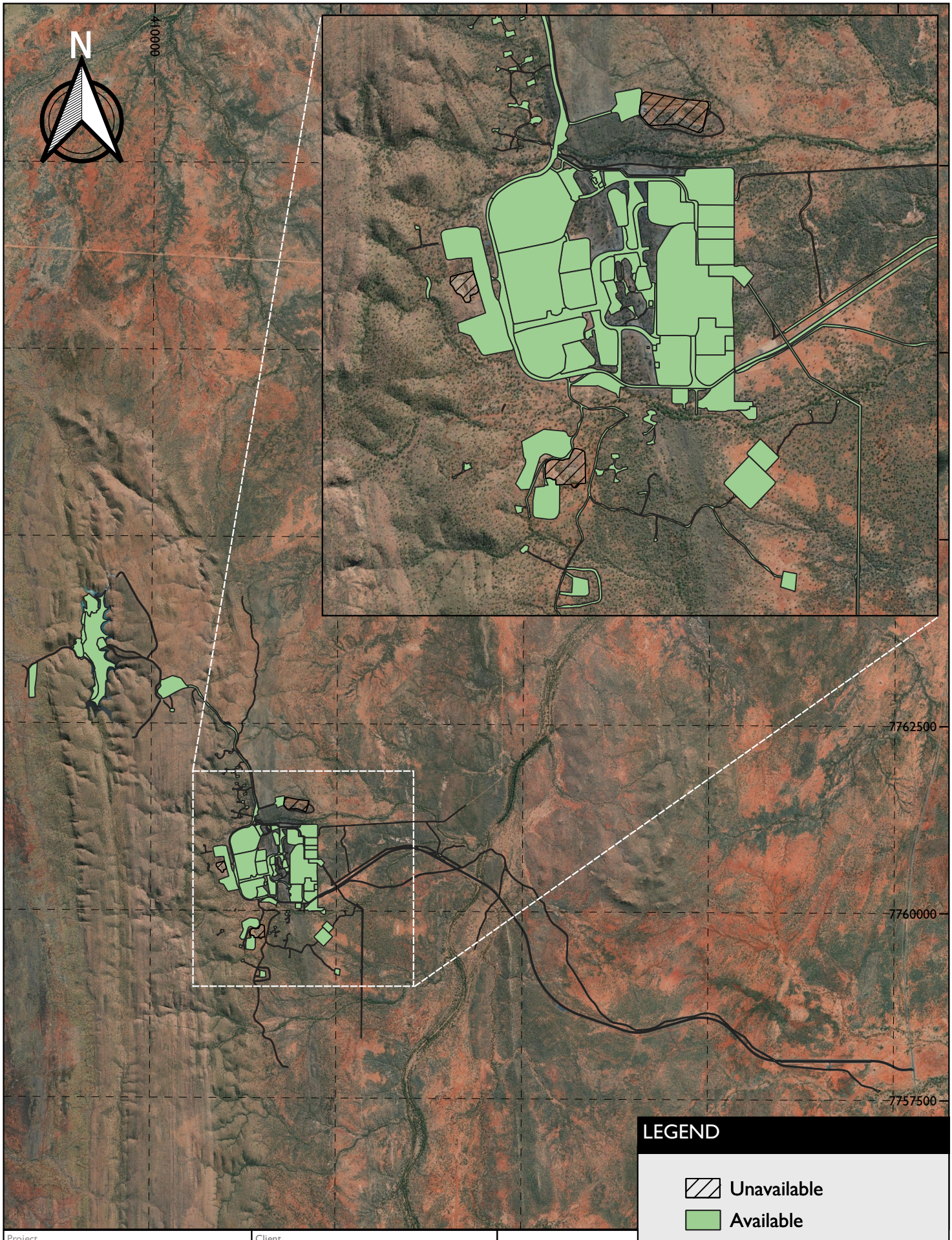
Project: Progressive Rehabilitation and Closure Plan		Client: MMG Limited	
Figure: 10	Title: Land available for rehabilitation - 2039	Design: SGM Environmental Pty Ltd 09.09.2021 Scale: 1 : 70,000 CRS: GDA94 / MGA zone 54	SGM environmental

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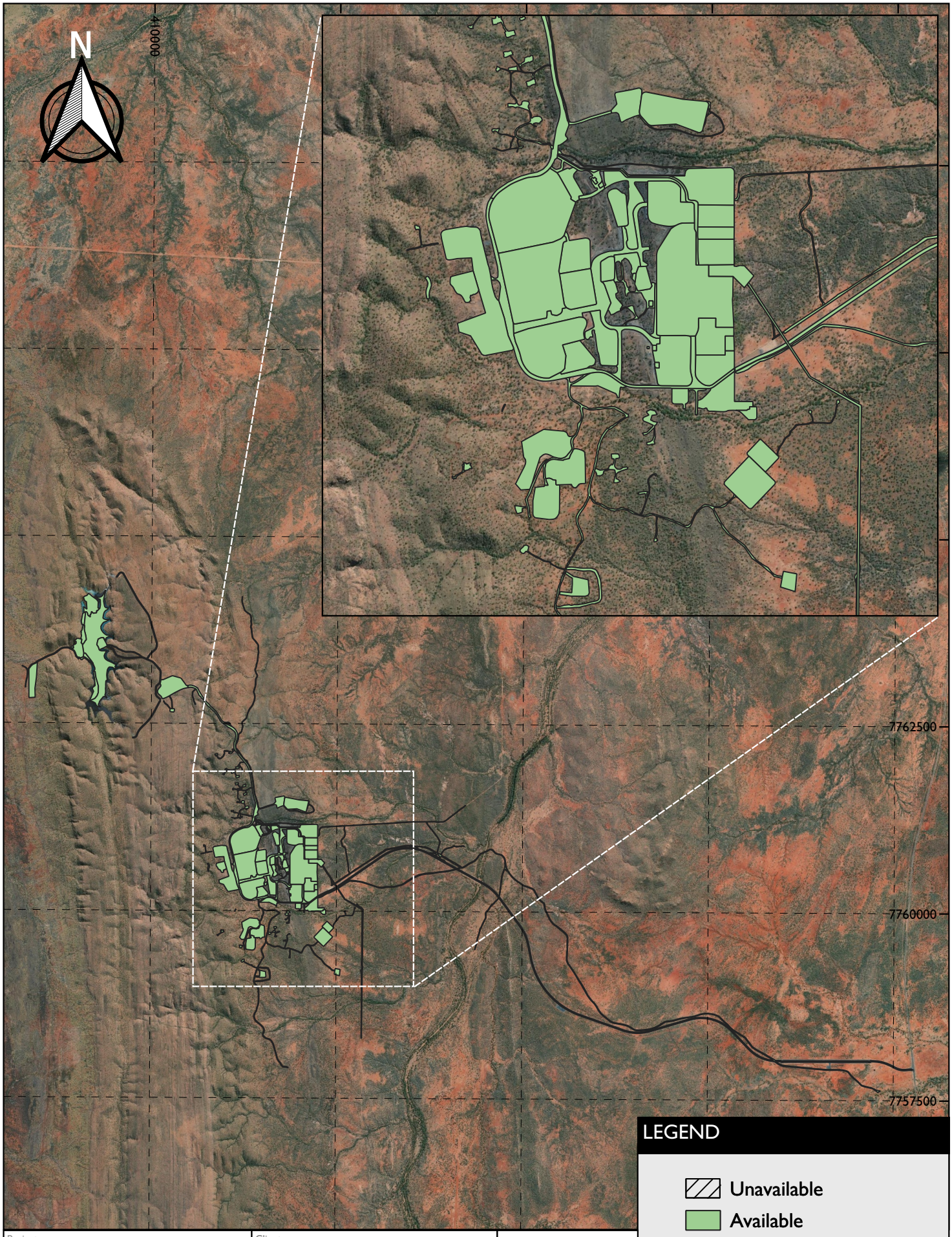
Project: Progressive Rehabilitation and Closure Plan		Client: MMG Limited	
Figure: 11	Title: Land available for rehabilitation - 2040	Design: SGM Environmental Pty Ltd 09.09.2021 Scale: 1 : 70,000 CRS: GDA94 / MGA zone 54	SGM environmental

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Project: Progressive Rehabilitation and Closure Plan		Client: MMG Limited	
Figure: 12	Title: Land available for rehabilitation - 2044	Design: SGM Environmental Pty Ltd 09.09.2021 Scale: 1 : 70,000 CRS: GDA94 / MGA zone 54	SGM environmental

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Project: Progressive Rehabilitation and Closure Plan		Client: MMG Limited	
Figure: 13	Title: Land available for rehabilitation - 2045	Design: SGM Environmental Pty Ltd 09.09.2021 Scale: 1 : 70,000 CRS: GDA94 / MGA zone 54	SGM environmental

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3.1.5.5 Implementation

Key personnel and the responsibility for implementing, monitoring and reviewing the PRC plan are given in Table 25.

Table 25 Key personnel and responsibility

Role	Responsibility
General Manager	Ensure that adequate resources are available to implement the PRC plan and that contractors meet all compliance requirements.
	Facilitate closure planning review and updates.
General Manager, Safety, Health, Environment and Community (SHEC) Superintendent, and Closure Team	Implement the PRC plan.
	Review, update and further develop the PRC plan annually or as required until the MLs are relinquished.
	Develop, review and update procedures as required.
	Facilitate the monitoring and implementation of measures outlined in the PRC plan.
	Report non-conformances to internal stakeholders and ensure corrective actions are closed out.
	Advise the General Manager or representative and other relevant management personnel on EA requirements and provide advice to assist with achieving compliance.
	Investigate incidents and liaise with the regulator where necessary / as required by legislation.
	Facilitate engagement as per the requirements of the PRC plan with relevant community members and stakeholders.
	Facilitate the works outlined within the PRC plan.
Employees	Be familiar with the PRC plan requirements relevant to their role.
	Ensure works are done in accordance with the PRC plan.

3.2 Post-mining land use

3.2.1 Operational domains

Operational domains are defined based on land management units, usually with unique operational and functional purpose and therefore similar geophysical characteristics. Sub-domains are used to provide further delineation of geophysical characteristics within operational domains.

Table 26 and Figure 3 summarise the operational domains, subdomains and their estimated total disturbance footprint over the LOM.

Table 26 Disturbance footprint of operational domains

Domain	Disturbance (ha)	Subdomain
Ancillary infrastructure and services	13.2	• Accommodation village • Pipeline and accommodation village road
Borrow pits and stockpiles	15.9	• TSF borrow pit A • Soil stockpile A • Soil Stockpile B
Dams and diversion structures	34	• Creek crossings • Diversion drains • Mine workshop runoff dam • NAF pad runoff dam • PAF pad runoff dams • Process plant runoff dam • Raw water dam • ROM runoff dam • Sediment dams • STP dams • Underground mine water collection dam
Exploration	4.7	• Drill holes and pads
Mineralised waste	22	• Temporary waste laydowns • PAF WRDs • NAF WRDs
Mining and processing area (grazing / native habitat PMLU)	78.9	• Sewage treatment plant (STP) • Barminco project area • Communication tower • Core yard • Emergency response training (ERT) • Explosives magazine • Laydowns • Mine support infrastructure • Office and administration services

Domain	Disturbance (ha)	Subdomain
		• Powerlines • Raw water pipeline • Roads and tracks • Switchyard • Workshop and vehicle maintenance • North decline • South decline • Ventilation shafts
Mining and processing area (grazing PMLU)	23.3	• ROM pad • ROM haul road • Processing plant and conveyor area
TSF	44.1	• TSF impoundment • TSF embankment • TSF seepage collection pond • TSF return water pump and substation • TSF pipeline
Total	**236.1**	

3.2.2 Assessment of PMLU options

3.2.2.1 Rehabilitation costs

The suitable PMLU options for the Mine are native habitat, low-intensity grazing and a combination of these two uses (native habitat / light grazing). Potential future uses of built PMLUs such as water storage, roads and services may also be possible depending on the outcome of ongoing community consultation. Due to these land uses requiring similar rehabilitation methods, the only notable difference in rehabilitation costs will be the direct seeding of each specific seed mix. Costs have been estimated using the standard rates defined in the *Estimated Rehabilitation Cost (ERC) Calculator for Mining* and are given for each domain in Table 27.

Table 27 Seeding cost analysis of PMLUs

		Direct seeding cost[1] ($)		
Domain	**Area (ha)**	**Native habitat ($per ha)**	**Low-intensity grazing ($per ha)**	**Native habitat / low-intensity grazing ($2,525 per ha)**
Ancillary infrastructure and services	13.2	47,982	18,678	33,330
Borrow pits and stockpiles	15.9	762,914	296,980	529,947
Dams and diversion structures	34	123,590	48,110	85,850
Exploration	4.7	17,085	6,651	11,868

Domain	Area (ha)	Direct seeding cost[1] ($)		
		Native habitat ($per ha)	Low-intensity grazing ($per ha)	Native habitat / low-intensity grazing ($2,525 per ha)
Mineralised waste	22	79,970	31,130	55,550
Mining and processing area (grazing / native habitat PMLU)	78.9	286,802	111,644	199,223
Mining and processing area (grazing PMLU)	23.3	84,696	32,970	58,833
TSF	44.1	160,304	62,402	111,353
Total	**236.1**	**1,563,341**	**608,563**	**1,085,952**

1. Estimated cost of acquiring, treating and applying the seed at an appropriate rate from the revegetation plan (Section 3.6.1.8)

3.2.2.2 Benefits

Both PMLU options provide specific economic, environmental and social benefits to the region. These benefits are described in Sections 3.2.2.2a-3.2.2.2c.

a Economic

Native habitat

Native trees can provide shade and shelter for stock animals. NSW agriculture has reported increases in milk and meat production where stock have had access to shade and shelter (Mullins 2002). This indicates that a mixed landscape of grazing and native habitat may provide increased production for agricultural enterprises.

The presence of a mixture of native trees, shrubs and grasses could also potentially provide revenue to landholders from the sale of forestry products, seeds, oils and flowers.

Low-intensity grazing

Establishing grazing pastures for the majority of disturbed landforms will result in a lower cost of direct seeding (Table 27) and a quicker establishment of adequate vegetation cover, potentially leading to an earlier relinquishment of the Mine tenures.

In addition, the future landowners for the Mine will likely be pastoralists. Rehabilitating a large percentage of the Mine to low-intensity grazing will result in an increase in the weight of stock, leading to a direct increase in the economic benefit to the landholder.

b Environmental

Native habitat

Re-establishing native vegetation will result in an increase in plant biodiversity. Through the selection of a variety of plant species, the habitat and subsequently the biodiversity of native fauna will also increase. Soil can be improved by native vegetation through nutrient cycling and more efficient use of water resources, while erosion and land degradation can be mitigated through the stabilisation of stream banks and landforms. Native vegetation provides indirect benefits through more efficient absorption of carbon dioxide, with large areas acting as carbon sinks that can absorb greenhouse gases.

Low-intensity grazing

Low-intensity grazing pastures will have a lower biodiversity than native habitat. However, this will result in a reduced fuel load and improved fire management.

The introduction of stock could benefit the soil and vegetation. Impacts may include the control of certain invasive species, nutrient cycling from manure, the distribution of seeds from cattle movement and breaking up soil surfaces due to 'hoof action'. While negative outcomes can also occur (ie soil compaction, erosion of stream / riverbanks and reduced groundcover), land management practices can reduce these impacts.

c Social

Native habitat

No social benefits from establishing native habitat have been identified.

Low-intensity grazing

The future land tenures will likely be pastoral holdings; therefore, returning the land to grazing pastures will be preferential. Most of the land underlying the Mine tenures was originally low-intensity grazing, as is most of the land in the surrounding region. This will result in a post-mining landform which is more consistent with regional land uses.

3.2.2.3 Limiting factors

a Physicochemical

The Mine is in a semi-arid region where ecosystems are limited by water availability and can have extremely weathered soil profiles, resulting in limited nutrient cycling potential and limited natural soil.

AARC performed a soil and land suitability assessment for the Mine in 2010 based on the *Planning guidelines: The identification of good quality agricultural land* (DPI & DHLGP 1993) and the *Land suitability assessment techniques guideline* (DME 1995d). The results from this assessment are given in Table 28. None of the soil management units identified on site were found to be good quality agricultural land (GQAL) due to limiting features.

Table 28 Physicochemical constraints

Soil management unit	Limiting features	Agricultural land class	Land suitability class (grazing)
Soil type 1 — Red Plain	Low plant-available water, relatively shallow and low nutrient levels.	D	4
Soil type 2 — Knapdale	Low plant-available water, shallow rocky soil, low nutrient levels and steep slopes.	D	5
Soil type 3 — Dale	This soil type may be suitable as pasture as it is between 50–70 centimetres (cm) deep; however, it still has low nutrient levels and is inaccessible due to steep slopes.	D	4
Soil type 4 — Miners	Shallow and rocky, rocky outcrops, low plant-available water and low nutrient levels.	D	5

Soil management unit	Limiting features	Agricultural land class	Land suitability class (grazing)
Soil type 5 — Prospectors	Low plant-available water, shallow soil and low nutrient levels.	D	5
Soil type 6 — Pocket	Low plant-available water, relatively shallow soil, low nutrient levels and slightly alkaline.	D	4

The main limitations of the soil for an improved land use are rockiness, nutrient levels and limited plant-available water. The PMLU is therefore limited to the pre-mining land uses of a mixture of native habitat and low-intensity grazing.

3.2.3 Relevant legislation, plans and strategies

3.2.3.1 Local government

a *North West Regional Plan* (DIP 2010)

The *North West Regional Plan* (DIP 2010), which provides the framework for integrating federal, state and local government planning agendas, mentions the following specific strategies about PMLUs:

- consider future uses of sites in post-mining site planning, particularly if located near an urban centre or area of potential agricultural significance;
- promote access to fossicking areas in the region for tourism and associated economic development opportunities;
- minimise, mitigate, rehabilitate and offset impacts of mining, energy and other extractive activities on the environment through regional innovation and opportunities; and
- establish a coordinated process for accumulating mining industry data and regular monitoring to assist in informing strategy development and delivery.

b *Cloncurry Shire Planning Scheme* (CSC 2016)

The *Cloncurry Shire Planning Scheme* (CSC 2016) states that mining centres and extractive industries in the region must utilise extractive and mineral resources in a sustainable manner, ensuring rehabilitation of sites is completed upon the conclusion of the development activity.

Specific outcomes listed in the *Cloncurry Shire Planning Scheme* (CSC 2016) regarding PMLUs include:

- visual intrusions on the landscape such as mining, extraction, or other forms of visually dominant development, are designed, located, operated and rehabilitated to mitigate negative scenic amenity impacts; and
- areas subject to resources extraction are rehabilitated to restore the environmental values of the land and offer a feasible future land use alternative consistent with the site's restoration and management plan.

3.2.3.2 State and Commonwealth legislation

The Commonwealth Government has limited responsibilities with regards to land-use planning. Influence on land use is largely dictated through State legislation.

Table 29 State and Commonwealth legislation

Legislation	Objective	General application	How it relates to the Mine
Planning Act 2016	The principal objective of this Act is to achieve ecological sustainability.	Where land is included on a ML pursuant to the *Mineral Resources Act 1989*, closure and rehabilitation activities done under an EA do not require a planning approval from the local government.	The *Planning Act 2016* only applies if a built structure that is entered onto the *Queensland Heritage Register* is found. Therefore, the Planning Act does not apply to development in the ML authorised under the *Mineral Resources Act 1989*.
Local Government Act 2009	The purpose of this Act is to provide for the way a Local government is constituted and the nature and extent of its responsibilities and powers. Local laws are made under the Act.	Local laws may apply to the owner of land as defined under the *Mineral Resources Act 1989*.	The review of potential PMLUs did not identify the need for local government approvals (Section 3.2.2).
Environmental Protection Act 1994	To protect the environment while allowing development that improves the total quality of life and ecologically sustainable development.	General environmental 'duty of care' to be observed to guarantee that any potential environmental impact from the Mine is minimised.	The potential impacts to environmental values (EVs) have been assessed as part of the EA amendment application. Duty of care is demonstrated for rehabilitation by preparing the PRC plan in accordance with the PRC plan guideline.
State Development and Public Works Organisation Act 1971	To provide state planning and organisational legislation that aids in the delivery of ecologically sustainable development.	Commitments during the EIS phase may impact on closure and rehabilitation of the Mine.	The potential impacts to EVs have been assessed as part of the EA amendment application. Duty of care is demonstrated for rehabilitation by preparing the PRC plan in accordance with the PRC plan guideline.

Legislation	Objective	General application	How it relates to the Mine
Transport Infrastructure Act 1994	The overall objective of the Act is to provide a regime that allows for and encourages effective integrated planning and efficient management of a system of transport infrastructure.	Approval from the Department of Transport and Main Roads (DTMR) is needed under the Act if the Mine interferes with a State Controlled Road.	The Mine does not propose any modification to State Controlled Roads. Consequently, approvals for works under *Section 33* of the Act is not needed.
Aboriginal Cultural Heritage Act 2003 which give rise to *Duty of Care Guidelines, 2004*	Provide effective recognition, protection and conservation of Aboriginal cultural heritage.	All practical measures need to be taken to make sure closure activities do not harm Aboriginal cultural heritage, ie. demonstrate 'cultural heritage duty of care'.	The *Aboriginal Cultural Heritage Act 2003* (ACH Act) requires that, when carrying out an activity, all reasonable and practicable measures are taken to make sure that the activity does not harm Aboriginal cultural heritage. This is referred to as the cultural heritage duty of care.
Land Act 1994	Relates to the administration and management of non-freehold land and deeds of grant in trust and the creation of freehold land, for related purposes.	Regulates the opening and closing of road reserves and land dealings relating to changes in land tenure.	The *Land Act 1994* provides a framework for the allocation of State land as leasehold, freehold or other tenure and provides for its management. This Act further regulates the grant, lease and permitting of Unallocated State Land and reserves and roads. No action is needed to satisfy this Act.
Stock Route Management Act 2002	The main purpose of this Act is to provide for stock route network management.	Regulates the management and use of stock routes.	The Mine will not intersect existing stock routes. Consequently, no agreements to alter stock routes or reserves are needed.
Water Act 2000 (and Water Resource (Fitzroy Basin) Plan, 2011 Fitzroy Basin Resource Operations Plan, 2011)	Provide for the sustainable management of water and other resources and the establishment and operation of water authorities and for other purposes.	Utilisation of groundwater and rehabilitation of bore holes.	No make-good agreements associated with disturbance to water quality, volume or water supply infrastructure are anticipated and therefore do not impact on the proposed PMLU.

Legislation	Objective	General application	How it relates to the Mine
			No creek diversions or off-lease works are proposed; therefore, no action is needed.
Nature Conservation Act 1992	To provide a framework for the protection of state listed threatened species	Rehabilitation strategies may need to include any State listed threatened species or communities that occur in the ML.	Rehabilitation strategies should include State listed threatened species or communities that could occur in the ML.
Vegetation Management Act 1999	Regulates clearing of vegetation to guarantee appropriate management and conservation.	The Mine to comply with State and regional vegetation management plans and policies and comply with vegetation management practices on leased and freehold land.	Clearing native vegetation is exempt from requiring a clearing permit when it is conducted within a ML. No works are proposed outside of the ML. As such no development approvals are needed.

3.2.4 Statutory constraints

DNRME biodiversity status lists River Red Gum Riparian Woodland (RE 1.3.7a) as being 'Endangered'. As a result of the disturbance caused to the RE by the Mine access road construction, a Queensland Government-approved biodiversity offset at Lawn Hill pastoral station was established in 2014.

The land contained some conservation values pre-mining; however, nothing of significance that is not common in the region. Some land on the Mine was previously disturbed from cattle grazing and historical exploration works that had already taken place. The Mine is neither rare nor unique and would not warrant conservation as a primary land use.

3.2.5 Community consultation

The proposed PMLU's for the Mine are consistent with the original EIS submission. Existing land uses are predominantly native vegetation, low-intensity grazing or a combination of native and grazing. Community consultation for rehabilitation planning is still in its early stages given the Mine has only been fully operational in the past few years. Due to the extensive mine life remaining some stakeholders have expressed their preference to be consulted closer to closure. No objections have been raised in respect to the proposed PMLU's and consultation feedback to date has focused on ensuring the PMLU is consistent with the surrounding land and economically productive for future land owners. Therefore, the proposed PMLU is consistent with stakeholder engagement thus far because it is:

- consistent with the land use prior to the start of mining;
- consistent with the surrounding land use; and
- compatible with, and beneficial to, the current underlying landholder activities.

Landholders have expressed a desire to return the Mine footprint to productive grazing land, where possible. Areas not considered suitable for grazing (TSF and accommodation village), and therefore of no economic benefit to future landholders, will have a PMLU of native habitat. This is again consistent with the surrounding land as areas not suited to pasture grazing are currently left as native vegetation areas. Areas of potentially useful infrastructure for future land users may not be rehabilitated and may be retained if future agreements can be developed.

3.2.6 Description of the PMLU

Mining is a temporary use of land. Suitable land / features will be returned to low intensity grazing while other land / features will be returned to native habitat, which is consistent with EA conditions regarding rehabilitation (ie Conditions I13-I21). There may be land / features of the disturbance footprint (ie. water storages, roads and services) where rehabilitation will not be required due to landholder agreements. Due to the long time period before operations cease no formal agreements have yet been agreed to. Relevant stakeholders will continue to be engaged in accordance with the CEP, with a view to developing future agreements where appropriate.

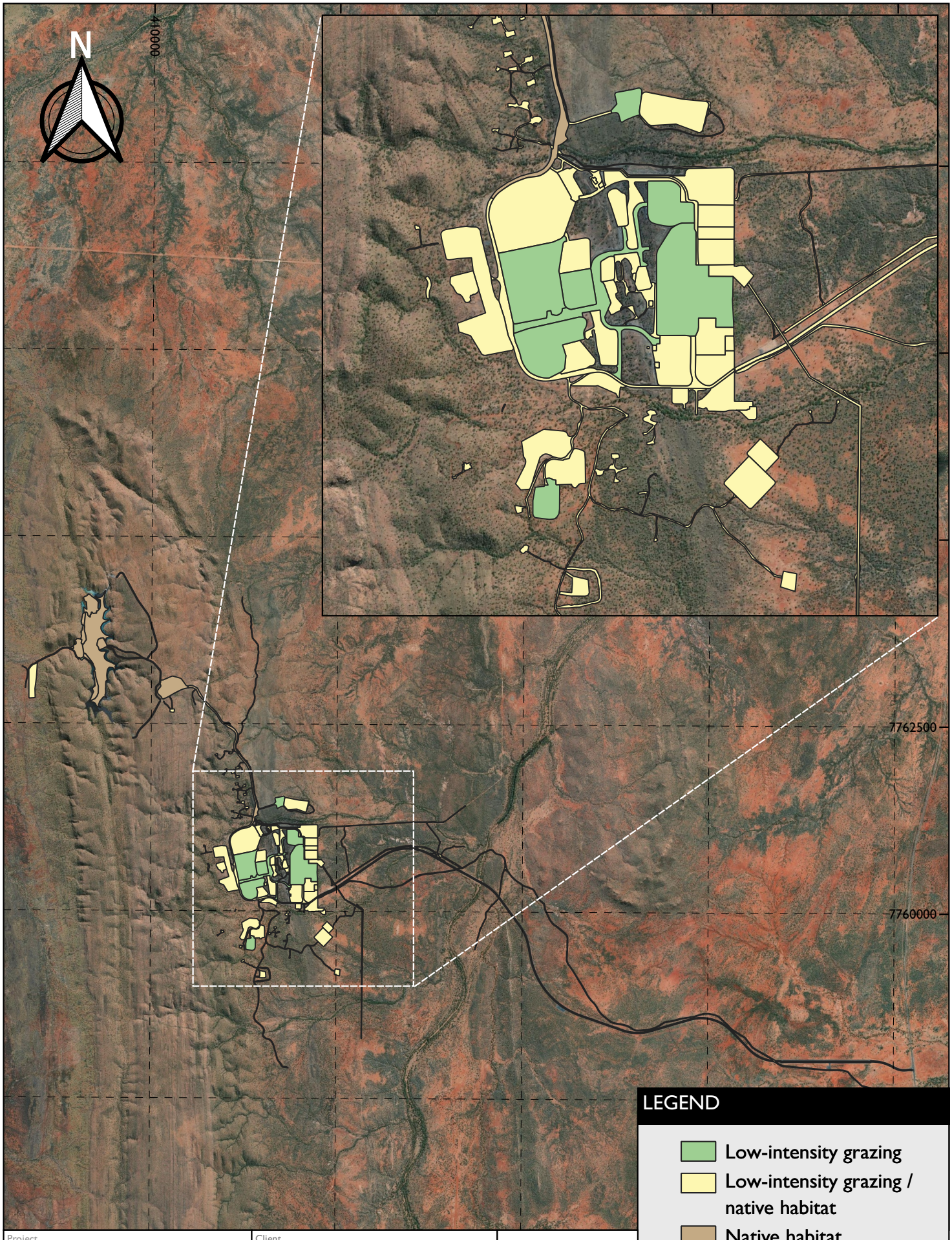
The strategy for how this is to be achieved is described in Section 3.5. The proposed PMLUs for the Mine include:

- low-intensity grazing; and
- native habitat.

Table 30 gives the total estimated area for each PMLU. Figure 14 shows the spatial distribution of the PMLUs. Figure 24 shows the final PMLU including undisturbed areas.

Table 30 Feature PMLU

Final land use	Domains	Area (ha)
Low-intensity grazing	• Mineralised waste • ROM pad • ROM haul roads • Processing plant and conveyor area	45.3
Native habitat	• Ancillary infrastructure and services: – accommodation village – TSF	57.4
Low-intensity grazing / native habitat	• Borrow pits and stockpiles • Dams and diversion structures • Exploration • Mining and processing area • Road and tracks • Laydown areas • Support infrastructure	133.5
Undisturbed (low-intensity grazing)	• Undisturbed	16,855.5
Total excl. disturbed		**236.1**
Total incl. disturbed		**17,091.6**



LEGEND

- Low-intensity grazing
- Low-intensity grazing / native habitat
- Native habitat

Scale 1 : 70 000

0 1 2 km

Project: Progressive Rehabilitation and Closure Plan		Client: MMG Limited	
Figure: 14	Title: Post Mining Land Uses	Design: SGM Environmental Pty Ltd 09.09.2021 Scale: 1 : 70,000 CRS: GDA94 / MGA zone 54	SGM environmental

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3.2.7 Completion criteria

PMLU completion criteria have been developed using current knowledge of rehabilitation practices and success in similar mine environments. These PMLU completion criteria will be the basis for the milestone criteria in the PRC plan schedule and are given in Table 31. PMLU completion criteria have been developed based on a review of existing criteria in the approved closure plan. PMLU completion criteria will be subject to periodic review in consultation with relevant stakeholders as described in the community consultation plan in Section 3.5.2.

Amendments to the PMLU completion criteria will be subject to regulatory approval. The process for amending final rehabilitation criteria is described in the PRC plan guideline.

The PMLU completion criteria need to demonstrate that the closure objectives and PMLUs have been achieved. Determining whether they have been met depends on the trending of measurements over time compared to pre-mining or reference site conditions.

Table 31 PMLU completion criteria

Rehabilitation milestone	Completion criteria	Justification of completion criteria
Infrastructure decommissioning and removal	All site services will be decommissioned.	All services must be disconnected before infrastructure is decommissioned and removed.
	All road materials (bitumen and gravel) removed.	No roads are to remain as a PMLU.
	All pipelines drained and removed.	All pipelines must be drained and removed.
	All fencing is removed.	No fencing is to remain as a PMLU.
	All buildings will be removed.	No buildings are to remain as a PMLU.
	All drill holes, sumps, exploration tracks and gridlines decommissioned.	Any remaining drill holes, sumps, exploration tracks and gridlines will be capped and rehabilitated as required.
	Consultation with stakeholders and legal agreements developed with landholders for any infrastructure to be retained	No infrastructure can remain unless identified in an executed legal agreement
Remediation of contaminated land	Carry out preliminary and intrusive contaminated land investigations with a site investigation report prepared by an AQP	A site investigation report under the EP Act must be prepared to identify any further work that is required in relation to contaminated land to make sure that the land is suitable for the PMLU.
	Removal or on-site treatment of contaminated water	Contaminated water must be remediated or disposed of appropriately
	Removal or appropriate disposal of contaminated materials	Contaminated materials must be remediated or disposed of appropriately
	Conduct validation testing to confirm that contaminated materials have been removed or remediated	Validation testing will confirm contaminated material has been correctly identified and remediated / disposed of
	Certification from an AQP that all contaminated land has been either remediated or removed	Certification must be given to make sure that all contaminated land has been removed and disposed of in accordance with licence conditions.
	All major earthworks completed.	involves major earthworks.
Landform development and reshaping / re-profiling	Finalise engineering and design plans	Engineering and design plans must be agreed and finalised prior to earthworks starting
	Bulk earthworks to achieve landform and slopes as per the agreed design	Bulk earthworks are required to achieve landform development and reshaping / re-profiling
	General reshaping and trimming to achieve final landform as per agreed design	Reshaping and trimming is required to prepare surface for topsoiling
	Fill dams	Dams must not be left unrehabilitated unless a signed legal agreement is in place
	Backfill and seal shafts, portals / adits	Unfilled shafts, portals or adits represent a safety risk and a risk to groundwater and must be sealed
	Install erosion and sediment control systems	Some erosion and sediment control systems may be required as vegetation establishes
	Verification from an AQP that the final constructed landform is consistent with reference sites and as per the agreed design	The final landform will be shaped to a slope angle consistent with reference sites. The final landform design has been selected based on its ability to provide stable slopes, a favourable land outcome and management of potential impacts on environmental values.
Installation of cover	Conversion of operational TSF spillway and embankment wall to the final closure rock lined spillway as per the agreed design	The spillway is required to remove excess water from the landform surface
	Installation of a capillary break layer over the TSF surface	TSF material is potentially acid producing and requires a capillary break layer to reduce the risk of solute rise

Rehabilitation milestone	Completion criteria	Justification of completion criteria
	Installation of a reduced permeability layer (RPL) over the capillary break layer	TSF material is potentially acid producing and requires an RPL to reduce the potential for seepage into the tailings and for solutes to rise from the TSF
	Installation of infiltration storage layer (ISL) over the RPL	The ISL protects against surface erosion of the RPL and can be reshaped for effective drainage
	Certification by an AQP that the TSF cover layers and spillway have been installed in accordance with the approved design	TSF material is potentially acid producing and requires certification from an AQP to ensure the cover system is constructed as per design and minimises the risk to the receiving environment
Surface preparation	Remediate any erosion or subsidence	Eroded and subsided areas should be remediated prior to topsoiling
	An assessment of soil health and suitability will be completed by an AQP to confirm soil is suitable for target vegetation establishment.	A soil health and suitability assessment should be completed by an AQP to make sure soil is suitable for target vegetation establishment and specify any requirements for amelioration.
	Placement of 200mm of soil / growth medium.	Soil / growth medium will be applied with an adequate thickness to allow for ripping and vegetation growth.
	Application of ameliorants as per requirements of the soil health and suitability assessment.	Ameliorants may be required because of the soil health and suitability assessment.
	Ripping completed as per the agreed specification	Surfaces need to be ripped prior to seeding.
Revegetating (pasture grazing and / or native habitat)	Completed seeding of target species at a rate consistent with the revegetation plan in the PRC plan	Recommended seeding rates have been determined by an AQP but will be refined during trials and results of rehabilitation monitoring
	Application of fertiliser as per soil and health suitability assessment	Fertiliser may be required because of the health and suitability assessment
	Install stock fencing to protect rehabilitated area	Rehabilitated areas may benefit from exclusion of grazing animals as vegetation establishes
Achievement of surface requirements (pasture grazing and / or native habitat)	Average total ground cover (all ground cover categories aggregated) is no less than the 15th percentile of equivalent control sites	Rehabilitated areas with groundcover comparable to reference sites and is considered stable and to have acceptable erosion rates.
	Average soft spinifex cover estimates are no less that the 15th percentile of equivalent control sites	Soft spinifex is a dominant species across all PMLU's and should be present in amounts comparable to reference sites
	Buffel grass cover estimates exceed no more than the 70th percentile of equivalent control sites (native habitat)	Buffel grass is desirable in pasture land but may inhibit the growth of other species and should be minimised in native habitat areas where possible
	Kapok bush cover estimates exceed no more than the 70th percentile of equivalent control site	Kapok Bush is poisonous to cattle and should be minimised in rehabilitation despite being established in the area
	A minimum of 70% of target species as per the revegetation plan have been established	Other species may naturally occur in harvested topsoil or be imported from neighbouring areas and displace target species. 70% establishment of desired species is considered adequate to establish the target vegetative community
	Erosion gullies are less than or equal to 1 m deep.	Erosion gullies must be less than or equal to 1 m and are considered stable ie. is not active erosion.
	Certification by an AQP that revegetation is comparable to reference sites, erosion and drainage is acceptable and weeds and pest species are in densities no greater than at reference sites.	Verification is required that rehabilitated sites are comparable to reference sites with regard to erosion, vegetation and weed and pest species density
Achievement of PMLU to a stable condition (pasture grazing and / or native vegetation)	The rehabilitated landforms can sustain the agreed PMLU as certified by an AQP	The land is safe and structurally stable, the land can sustain the PMLU and there is no environmental harm being caused by anything on or in the land.

Rehabilitation milestone	Completion criteria	Justification of completion criteria
	The rehabilitated landforms have achieved a suitable factor of safety as certified by an AQP	The landform must be geotechnically stable. A landform is considered geotechnically stable when it achieves a suitable factor of safety.
	The rehabilitated landforms have a maximum erosion rate of <10 t/ha/yr as certified by an AQP	The landform will have an acceptable erosion rate when the maximum erosion rate is less than 10 t/ha/yr.
	Develop a post closure land management plan for future landholder in consultation with them	Rehabilitated land will require a level of management similar to surrounding land. A management plan developed in consultation with the future landholder will identify and outline management requirements
	Surface water quality at downstream compliance sites DR-18 and DR-22 complies with the following: • pH is between 6 and 9 or 95th percentile of reference, whichever is higher; • electrical conductivity (EC) is ≤ 5970 microsiemens/centimetre (µS/cm) or 95th percentile of reference, whichever is higher; • sulphate is ≤1000 milligrams/litre (mg/L) or 95th percentile of reference, whichever is higher; • fluoride is ≤2 mg/L or 95th percentile of reference, whichever is higher; • aluminium is ≤ 5 mg/L or 95th percentile of reference, whichever is higher; • arsenic is ≤ 0.5 mg/L or 95th percentile of reference, whichever is higher; • cadmium is ≤ 0.01 mg/L or 95th percentile of reference, whichever is higher; • copper is ≤ 1 mg/L or 95th percentile of reference, whichever is higher; • lead is ≤ 0.1 mg/L or 95th percentile of reference, whichever is higher; • nickel is ≤ 1 mg/L or 95th percentile of reference, whichever is higher; and • zinc is ≤ 20 mg/L or 95th percentile of reference, whichever is higher.	Rainfall runoff / or seepage must be of acceptable characteristics for the receiving environment to support the PMLU. Limits are based on the; *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ 2018) (Stock water guidelines) *Environmental Authority - EPML00731213*
	Groundwater quality at MB2 and MB4 complies with the following: • pH is between 6 and 9 or 95th percentile of reference, whichever is higher; • electrical conductivity is ≤2000 µS/cm or 95th percentile of reference, whichever is higher; • sulphate is ≤1000 mg/L or 95th percentile of reference, whichever is higher; • fluoride is ≤2 mg/L or 95th percentile of reference, whichever is higher; • aluminium is ≤5 mg/L or 95th percentile of reference, whichever is higher; • arsenic is ≤0.5 mg/L or 95th percentile of reference, whichever is higher; • cadmium is ≤0.01 mg/L or 95th percentile of reference, whichever is higher; • copper is ≤1 mg/L or 95th percentile of reference, whichever is higher; • lead is ≤0.1 mg/L or 95th percentile of reference, whichever is higher; • manganese is ≤1.9 mg/L or 95th percentile of reference, whichever is higher; • nickel is ≤1 mg/L or 95th percentile of reference, whichever is higher; and • zinc is ≤20 mg/L or 95th percentile of reference, whichever is higher. • All metals and metalloids measured as total (unfiltered)	Groundwater must be of acceptable quality that is like pre-mining conditions. The trigger limits have been determined from baseline groundwater monitoring and follow the *Environmental Authority Conditions (EPML00731213)*.

3.3 Non-use management areas

There are no non-use management areas (NUMAs).

3.4 Voids in floodplains

The Mine is an underground operation and as such no voids will be present during or following operations.

3.5 Community consultation

3.5.1 Community consultation register

A consultation register for the Mine has been kept and is detailed in online community consultation software (Boréalis). This software assists in the development and management of the Mine's community engagement, while tracking past consultation and any external complaints. The consultation register will be continually updated throughout the LOM.

Table 32 Community consultation register

Consultation date(s)	Community member(s)	Description of consultation type (workshop, quarterly meetings, etc)	Information provided to the community	Issues raised / discussed by the community	How the issues have been considered	Decisions / outcomes of engagement	Commitments made by MMG
20 Jan 21	Station Property Owners	Face to face meeting — Mt Roseby Station	Seeking input on post mining land uses and potential infrastructure to be retained	Closure is far away, consultation will be more meaningful and relevant closer to closure date.	MMG will consult with landholder every 5 years in relation to the PRCP.	MMG will continue to consult	Continue to keep informed

Consultation date(s)	Community member(s)	Description of consultation type (workshop, quarterly meetings, etc)	Information provided to the community	Issues raised / discussed by the community	How the issues have been considered	Decisions / outcomes of engagement	Commitments made by MMG
21 Jan 21	Cloncurry Shire Council	Face to face — Council Chambers	Seeking input on post mining land uses	None raised	NA	NA	Continue to keep informed
22 Jan 21	Kalkadoon people	Face to face meeting — Kalkadoon Office, Mt Isa	Seeking input on post mining land uses	None raised	NA	NA	Continue to keep informed

3.5.2 Community consultation plan

MMG has developed a Queensland Operations Community Engagement Strategy that provided guidance to the development of a site-specific *Community Engagement Plan* (CEP). A CEP (Appendix D) has been developed for the Mine and is used to engage and consult with the community on all aspects of Mine construction, operation and closure planning. In future consultation sessions, specific closure issues relevant to individual community members will be identified and recorded to ensure community perspectives, goals and knowledge are gathered to inform closure processes. No issues or input specific to closure have been received as yet.

A community consultative committee (CCC) has been established which meets quarterly. The CCC acts as a conduit between the Mine and key members of the community, for information sharing, review and feedback and is currently the most effective local community engagement forum for the Mine. The CCC includes the following members:

- Commerce North West;
- Cloncurry Business Committee Representatives from the local government;
- representatives from the Kalkadoon, Mitakoodi and Mayi traditional owners; and
- pastoralists / landholders.

Additionally, a community forum was established in Cloncurry during initial construction and development of the Mine and was open to all residents. Similar forums will be held throughout the operational and closure phase.

MMG has established a community office in Cloncurry to continue to facilitate an open dialogue with residents and other community members, which is used on an 'as-needed' basis.

The onsite Community and Stakeholder Advisor manages these relationships in accordance with the CEP, including management of incident reports received by external parties.

3.5.2.1 Objectives

The aim of the CEP is to:

- provide community members with information on the Mine;
- keep community members informed of relevant activities and progress at the Mine until relinquishment is achieved;
- identify potential impacts, both positive and negative, on the surrounding community;
- identify community values and interests with reference to impacts that the Mine may have upon the surrounding environment;
- work with community members to develop control strategies for key concerns;
- mitigate potential adverse effects of the Mine, thereby providing confidence that the Mine will be delivered in an environmentally responsible manner;
- communicate with the community and evaluate sentiment towards the Mine; and
- capitalise on any positive opportunities that are identified during the CEP process.

3.5.2.2 Community profile

The population of Cloncurry at the 2016 census was 2,254 persons. This is a decrease from the 2001 census (2,748 persons). There are slightly more males than females, 52.5% and 47.5% of the population respectively. The population tends to be made up of younger generations, with the 25-34 years age group having the highest representation.

The largest industry of employment in Cloncurry is the mining industry, which is well above the state average (22.8% versus 1.7%). The most common occupations in Cloncurry are technicians, trades workers and machinery operators.

The most common educational level attained after secondary school is Certificate III or IV. Years 10 and 12 were the most common ages to leave school; however, the percentage of people leaving school in year 12 is lower than the state average and the percentage of people leaving school in year 10 is higher than the state average.

3.5.2.3 How the community will be engaged / information released for community consultation

Community members will have varying levels of influence or interest in the closure and rehabilitation processes. Consequently, different communication media will be needed for each level of influence or interest in the Mine. These concepts are outlined in Table 33.

Table 33 Community interest levels and communication methods

Level of influence or interest	Communication tier and method
High	Involve: • face-to-face meetings / dialogue; • internal workshops; and • supplementary email updates / broadcasts.
Medium	Consult: • meetings; and • targeted supplementary email updates / broadcasts.
Low	Inform: • newsletters; and • updates.

a Involve

The highest tier are community members who need to be 'involved' and who have the potential to be directly impacted by Mine operations. This tier includes those who have a direct and influential role in local government, key state government agencies, cultural heritage groups, adjacent landholders and selected internal business units. The best method of engagement for this tier is regular face-to-face meetings enabling candid discussions to occur. With some internal business units, meetings or workshops could be followed by regular, targeted supplementary internal email updates / broadcasts.

b Consult

The middle tier are community members who should be 'consulted'. They will have a direct interest and will want to both be informed and to provide feedback. This tier includes selected internal business units, neighbouring operators and the majority of government stakeholders (excluding key regulators). Meetings will be held with these stakeholders so that concerns and issues can be teased out and practical solutions or actions identified. Targeted supplementary email updates / broadcasts might also be used.

c Inform

The lowest tier of community members are those who should be 'informed'. They are typically local individuals or groups with a broader and more general interest in the future of the Mine. They generally only want to know 'what is going on'. Newsletters and updates are suitable communication media. MMG will provide objective and balanced information to assist these stakeholders to understand what is planned and the progress being made with these plans.

3.5.2.4 Identified community members

An initial listing of all potential community members that have an interest in, or have been affected by, the Mine has been compiled. These community members and their relationship to the Mine are given in Table 34.

Table 34 Key community members

Key community members	Relationship to Mine
High influence or interest in the Mine	
Harold Henry McMillan (Mt Roseby Homestead)	Holder of land directly under the Mine tenements and under the grid connection corridor
Kalkadoon People	Native title claim over the Mine
Mitakoodi and Mayi People	Native title claim over the Grid Connection Line
Carpentaria Land Council Aboriginal Corporation	Aboriginal representative group over the Mine
Queensland South Native Title Services	Native Title Service Provider
Cloncurry Shire Council	Local government in jurisdiction over the Mine
Mount Isa City Council	Local government in jurisdiction over neighbouring area
North Australian Pastoral Co Pty Ltd	Holder of land directly under the Mine tenements
DNRME — Cloncurry Regional Office	Administers leases, state land and natural resource planning
Medium influence or interest in the Mine	
Department of Communities: Aboriginal and Torres Strait Islander Partnerships (Mt Isa)	Administers agreements and partnerships
Department of Transport and Main Roads – North West District	Department responsible for roads, future roads and upgrades in the North West Region
Department of Communities: Community Capacity and Service Quality	Liaison with local Indigenous groups
Southern Gulf Catchment Group	Member of the National Heritage Trust
Altona Mining Limited (formerly Universal Resources Limited)	Tenements immediately adjacent to the Mine and tenements underlying the access road, the powerline and the water pipeline for the Mine
Jersey Plains Pastoral Company	Holder of land underlying grid connection corridor
Cameron Creek Pastoral Co Pty Ltd	Holder of land underlying grid connection corridor
Anita Maree and Grant James Telford AS TTE	Holder of land underlying grid connection corridor
China Yunnan Copper Australia Limited	Holder of tenements underlying the grid connection corridor
Exco Resources Limited	Holder of tenement underlying the grid connection corridor

Key community members	Relationship to Mine
Cudeco Limited	Holder of tenements underlying or adjacent to the grid connection corridor
Mount Isa Mines	Holder of tenements underlying the grid connection corridor
Sunwater	Supplier of water for the Mine
CS Energy	Supplier of electricity to the Mine
Low influence or interest in the Mine	
Jamie Hacon — Manager Cubbaroo Station	Station within region of Mine or power corridor
Alan Abdy — Station Owner Hillside Station	Station within region of Mine or power corridor
Tom McMillan — Station Owner Jessievale Station	Station within region of Mine or power corridor
Mark McMillan — Station Owner Carsland Station	Station within region of Mine or power corridor
Anthony McMillan — Station Owner Corella Park Station	Station within region of Mine or power corridor
Dan Lynch — Property Owner Tara Station	Station within region of Mine or power corridor

3.5.2.5 Information provision

The CEP ensures MMG provides clear, concise and credible information to identified community members at appropriate intervals suited to each group and / or individual. It also identifies the key messages to be relayed to each of the identified community members.

3.5.2.6 Resource requirements

A range of company personnel is involved in engagement activities as described in the CEP. The key units and / or individuals required to provide input into the preparation and delivery of communication materials are described in the CEP.

3.5.2.7 Documentation

All engagement activities with external community members will be recorded and uploaded into Boréalis. The following minimum information will be recorded:

- invitations, attendance lists and minutes for site inspections;
- invitations, attendance lists and minutes for meetings;
- summaries of informal community interactions (ie with neighbours);
- copies of email updates (ie. broadcasts);
- records of discussions (for opportunistic or planned face-to-face dialogue); and
- copies of any media statements.

3.5.2.8 Proposed consultation frequency

Consultation should occur prior to any PRC plan schedule amendments that are likely to impact the community and the register should be updated when this consultation is finished.

Ongoing community consultation will continue throughout all stages of the LOM so that progressive rehabilitation and the socio-economic and environmental impacts related to closure can be discussed with the community. The forum for this consultation will continue to be via the CCC.

3.5.2.9 How feedback / comments will be considered

Once feedback / comments have been received and logged, MMG will make an initial assessment to identify, classify and / or investigate the root cause and identify any actions needed to address it. The community member will be asked about their expectations and suggestions for resolution. MMG will report back to community members on how feedback is received and addressed.

MMG will continue to carry out consultation in relation to the activities carried out under the PRC plan. MMG will regularly review and revise the CEP and community consultation register as needed.

3.6 Rehabilitation and management methodology

3.6.1 General rehabilitation practices

3.6.1.1 Hydrogeology

The existing hydrogeological conceptual model has been developed for the Mine as part of the regular compliance reporting (Appendix B). This conceptualisation represents current mining conditions and is shown in Figure 15.

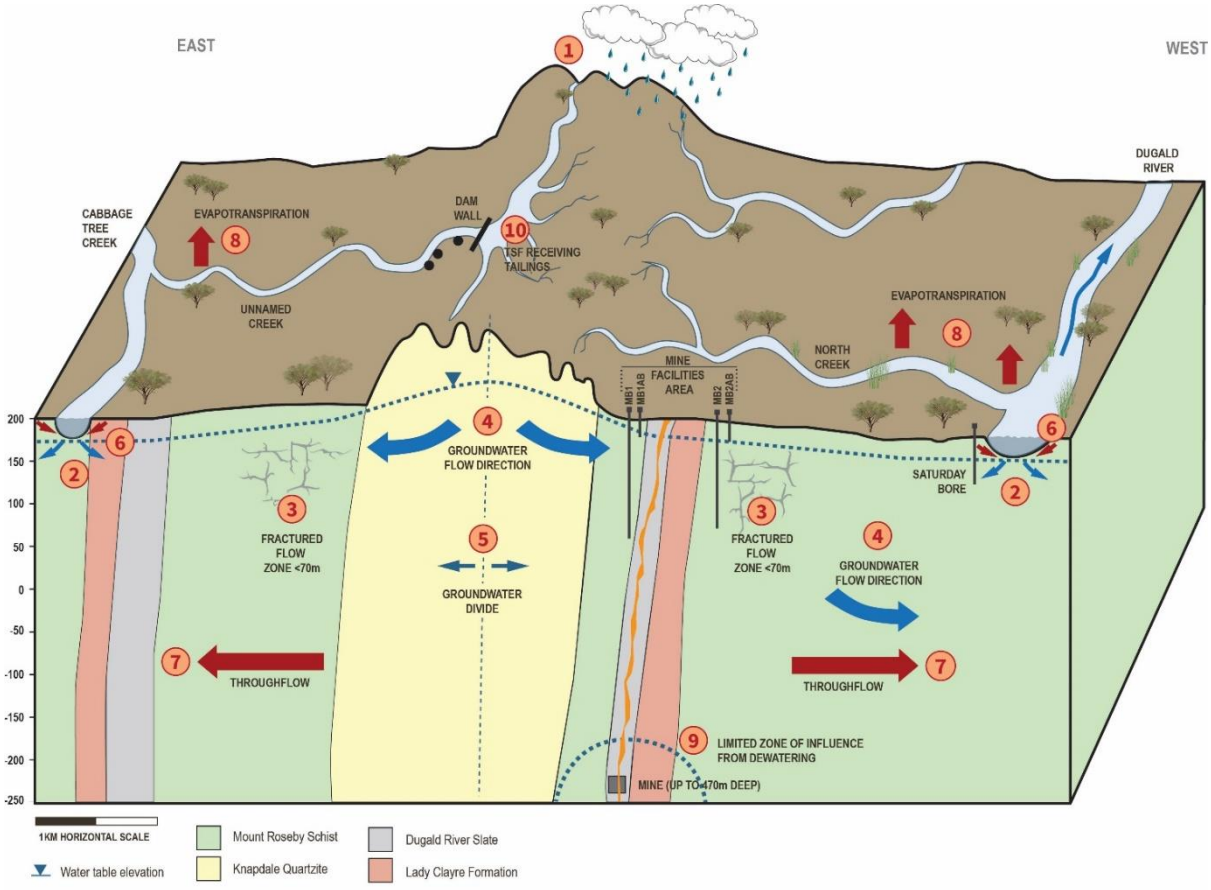


Figure 15 Conceptual hydrogeological model (CDM Smith 2019)

a Interaction between groundwater and surface water

Groundwater does not discharge to the surface in the vicinity of the Mine, nor is there any evidence it did prior to the start of mining. Water extracted from the Mine is contained and reused in mining operations. Closure planning includes sealing off underground infrastructure so that groundwater in the voids will be effectively disconnected from the surface. In addition, it is unlikely that groundwater levels / pressures after mining will recover back to surface (ie. higher than pre-mining levels / pressures).

b Drawdown impacts

The degree of current depressurisation around the Mine is unknown but likely to be minimal due to the very low permeability. By the end of the LOM (17 years from now) this is unlikely to have changed significantly (ie. dewatering of the overburden back to surface is very unlikely). There is currently no evidence of water table decline due to existing Mine dewatering operations. Based on observed groundwater dewatering rates and estimates of recharge, groundwater mining is occurring in association with the mining operation. It is expected that groundwater recovery (involving filling of the Mine voids remaining at closure and re-pressurisation of the groundwater systems) is expected to take more than 100 years, after which groundwater filling the voids may start to move away from the workings.

c Groundwater contamination

If groundwater that eventually begins to move away from the former workings is impacted by AMD, the risk posed to possibly sensitive groundwater receptors is considered low because:

- there is no existing use of groundwater for stock and domestic purposes;
- the high neutralisation capacity of the hydro stratigraphy through which flow will occur; and

- the expected long-residence time of groundwater moving between the former Mine and possible downstream receptors.

A groundwater monitoring strategy for the Mine has been developed to detect any groundwater contamination. Groundwater monitoring will continue through the closure phase of the Mine until bores are closed and rehabilitated or until relinquishment.

Compliance with the EA trigger values has generally occurred at the Mine. In the *Dugald River Mine Biennial Groundwater Review* (Appendix B) contaminant exceedances were assessed against the EA trigger values and contaminant limits, as well as the reference bores. The majority of analytes were below contaminant limits, with some contaminant exceedances observed as follows:

- Zn at MB6 requires further investigation;
- Cu at MB2 should be assessed using control charting, Fluoride at MB2 (within natural variation); and
- Pb at MB9D (potentially due to high suspended sediment in the bore).

3.6.1.2 Flooding

Flood impacts were considered as part of the *Dugald River Project Surface Water Assessment* done in 2010 (Appendix E). This assessment focused mainly on the susceptibility of the Mine to flooding, in particular site access and operational areas. A subsequent hydraulic impact assessment was carried out by ATC Williams Pty Ltd in 2021 to further assess the flooding risk profile of the Mine and potential impacts to the TSF (Appendix F).

a Flood history

The MIA is not susceptible to flooding from the Dugald River; however, the main access road could be inundated. During the period 1969-2020 several significant floods were recorded in the Dugald River, at the Railway Crossing. The largest flood during the period was in January 2019 and recorded a peak discharge of 1,347 cubic metres per second (m^3/s). Based on observation and recorded water levels at the Silvermine Creek gauge site, no part of the Mine was inundated; however, the main access road was cut off intermittently for about two months. The average recurrence interval (ARI) of the 2019 flood event is 50-100 years.

The peak annual discharge recorded at the Railway Crossing gauge site was obtained from the DNRME website and gives the flood frequency analysis discharge estimates (Table 35).

Table 35 Flood frequency analysis results, Dugald River at Railway Crossing (WRM 2010)

ARI (years)	Estimated peak discharge (m^3/s)
2	128
5	536
10	737
20	950
50	1,250
100	1,492

The Mine access road and water pipeline are susceptible to flooding from the local creeks.

b Preliminary hydraulic modelling

Preliminary hydraulic monitoring was carried out as part of a surface water assessment in 2010. The worst-case scenario flood levels were modelled for the Dugald River, Silvermine Creek and the various tributaries across

the Mine (Appendix E). Worst-case scenario flood levels refer to the peak flood level under each modelled scenario. Due to different catchment sizes, two scenarios were developed:

- Scenario 1 — 100-year ARI discharge in Dugald River and 10-year ARI discharge in Silvermine Creek and the tributaries; and
- Scenario 2 — 10-year ARI discharge in Dugald River and 100-year ARI discharge in Silvermine Creek and the tributaries.

Scenario 1 produces the worst-case flood levels in Dugald River and the lower reaches of the tributaries. Scenario 2 produces the worst-case flood levels in the upper reaches of Silvermine Creek and the tributaries.

Model cross sections were developed from survey data to provide a broad understanding of flood levels throughout the Mine. The design flood levels for the worst-case scenarios are given in Table 36.

Table 36 Design flood levels, worst case scenario

Waterway	Worst case flood level (m)
Dugald River	181.55 (minimum) 190.76 (maximum)
Silvermine Creek	184.60 (minimum) 218.12 (maximum)
Silvermine Creek Tributary A	184.68 (minimum) 213.06 (maximum)
Dugald River Tributary A	185.39 (minimum) 186.51 (maximum)

The flood study of the Dugald River and Silvermine Creek indicates that the mining operations and infrastructure are located above the 100-year ARI flood levels along these waterways. Therefore, most of the Mine would not be impacted by flooding at least up to the 100-year ARI flood event. It is understood that surface subsidence from underground mining is not significant (Appendix C). Therefore, any subsidence impacts on flooding behaviour along local waterways would be insignificant.

The main access road is susceptible to flooding at four locations from the Dugald River and its tributaries. Due to the low level (causeway) design of the road crossings, they would be overtopped whenever a significant runoff event occurs in these catchments. The road connecting the Mine operations to the accommodation camp is susceptible to flooding at seven locations from Silvermine Creek and several of its minor unnamed tributaries. The crossings at these locations have been designed to provide a 100-year ARI flood immunity.

c Flood impact on the TSF

Preliminary design of the TSF final landform has adopted a self-shedding cover system, with a nominal gradient of 1.5%, and a modified embankment. A spillway channel will be added, to achieve the following;

- prevent water from ponding against the upstream face of the embankment;
- prevent flow over the top of the embankment;
- divert flows away from the toe of the embankment; and
- reconnect catchment flows with the downstream watercourse.

The flood modelling, presented in Appendix F, has demonstrated that the proposed spillway design is suitable to safely convey design events up to and including the PMF. Flooding from the downstream tributary and Cabbage Tree Creek does not affect the TSF embankment. Notwithstanding, modelled results indicated that a backwater effect was exhibited on the downstream toe of the TSF embankment, as a result of the spillway outflows. Re-

alignment of the spillway channel, to properly convey catchment flows to the downstream tributary, will be required during detailed design of the spillway.

d Flooding risk profile

The modelling outputs, presented in Appendix F, show that the mine portals are not located below the 0.1% AEP flood level and are therefore not located within the floodplain. Further, both portals are at very low risk from flooding. The North Portal and the South Portal are not subject to inundation in any events up to and including the PMF.

Flood mapping shows that the portals are clear of local flooding and are outside of the floodplain, but there are small drainage lines in the area. These drainage lines are artefacts of the original topography prior to any mine disturbance and not a definitive representation of the final landform. Local topography and drainage will be modified during closure, to ensure that local runoff is directed away from the portals and will aim to reconnect drainage lines with downstream watercourses.

It should also be noted that the mine portals will be capped at closure, to prevent water entering the mine workings.

3.6.1.3 Soil and capping material assessment

a Soil types disturbed

The total Mine disturbance needing rehabilitation is estimated to be 236.1 ha as per Table 26. Soil types, properties and productivity is given in Section 3.1.3.7 and Figure 6.

b Soil stripping

Appropriate soil management is critical to the successful rehabilitation of the Mine. Soil is the preferred growth media for rehabilitation. In areas where a subsoil layer was identified, topsoil and subsoil were stripped and stockpiled separately. Soil stripping was done in a manner that maximises topsoil available for rehabilitation while minimising degradation.

The following was adhered to during soil stripping:

- allow 48 hours for drainage and evaporation after saturation of soils (ie >25 mm rainfall in 24 hours) before commencing stripping;
- identify the soil in reference to the soil management units and strip to the recommended depth outlined in the *Soil Management Plan: Dugald River* (SMP);
- storing soil in the correct stockpile for the identified SMU; and
- handle soils in accordance with the impact mitigation measures listed in *Table 5* of the SMP.

c Stockpile management

The following stockpile management measures have been adhered to:

- constructed to a maximum height of 2 m with 2(height (H)):1(vertical (V)) batters to minimise erosion and allow machinery access for contour ripping;
- placed more than 2 m (preferably 5 m) from existing vegetation, concentrated water flow, roads and hazard areas;
- constructed on the contour as low, flat, elongated mounds to minimise erosion;
- where left in place for extended periods, stockpiles have been stabilised following the *Dugald River: Erosion and Sediment Control Strategy* (Landloch 2018) to improve the cover and reduce the potential for erosion;
- diversion structures on the upslope side to divert water around stockpiles (ie. minimise catchment); and
- sediment fences 1-2 m downslope of stockpiles to capture eroded sediment.

The soil resources have been stockpiled into distinct categories. These are described in Table 37 along with their estimated current volumes. The volumes of the separate stockpiles are surveyed annually and updated in the stockpile register.

Table 37 Current volumes of stockpiles

Stockpile category	Description	Current volume[1] (m^3)
TsH	High quality soil, almost entirely covered by regrowth, with high species diversity.	0
TsM	Medium quality soil with moderate regrowth visible and some species diversity.	5,003
TsL	Low quality soil, combined with subsoil, with some regrowth visible.	80,858
SkS	Skeletal soil (abundant rocks) with little to no regrowth.	35,329
Vg	Predominantly vegetation stockpiles.	5,652
Rock	NAF WRD (regolith)	30,361
	Total	**157,203**

1. The lowest quality category was chosen for mixed stockpiles

Stockpiled soil will be reused for progressive and final rehabilitation. The method and depth of soil applied will largely be determined by the availability of soil reserves. If a preliminary depth of 0.2 m is assumed for establishment of the chosen PMLUs, then a total soil volume of 472,200 m^3 would be needed to rehabilitate the disturbance area. As the soil balance is currently deficient, soil will need to be sourced from nearby locations or substituted with growth media created from the amelioration of the existing surface or low sulfur NAF waste rock. Site trials will be undertaken to identify the most effective method for addressing the deficit (Section 3.7.5).

d Erosion and sediment control

A Dugald River: Erosion and Sediment Control Strategy (Landloch 2018) has been developed for the Mine. The strategy focuses on three management topics:

- reducing concentrated flows using drainage controls;
- minimising erosion from raindrop impact with various surface covers; and
- trapping displaced sediment through constructed bunds and dams.

The set of standards used in the strategy enable flexibility in selecting controls to effectively deal with the degree of land disturbance, seasonal and environmental risks. The performance of the controls will be measured and incorporated into audit reviews to ensure the controls are still applicable and effective.

e Quantity and quality of available resources required to achieve the capping design

A cover design is required for the surface treatment of the TSF to reduce seepage into the PAF tailings (see Section 3.6.1.6). At this stage, the preferred cover options are cover option 1 and 2 (noting that the final cover will be determined from cover trials). The quantity of material required for each cover option 1 and 2 are given in Table 38 and Table 39.

Table 38 Quantity required for cover option 1

Layer	Thickness (m)	Quantity required (t)
Topsoil	0.2	213,860
Infiltration storage layer (ISL)	1.0	1,031,560
Reduced permeability layer (RPL)	0.5	726,495
Capillary break (CB)	0.4	359,788

Table 39 Quantity required for cover option 2

Layer	Thickness (m)	Quantity required (t)
Topsoil	0.2	213,860
ISL	1.0	1,031,560
CB	0.3	260,406
RPL	0.5	713,915
CB	0.3	260,406

Topsoil

Soil fertility was assessed by AARC (2010) as part of the land suitability assessment for the environmental approval for the Mine (the land suitability assessment). The land suitability assessment identified six SMUs (see Section 3.1.3.7). All soil types display circum-neutral pH (AARC 2010) and do not require pH correction before vegetation can be established.

Stockpiled topsoil has similar chemical properties to pre-disturbance soils (SGME 2019). It is expected that the stockpiled topsoil will be non-saline and exhibit low to moderately low soil fertility; it is not expected to limit vegetation establishment (SGME 2019). Fertiliser may be applied to ameliorate low macronutrients.

Borrow subsoil

It is expected that the borrow subsoil will exhibit low soil nutrition but is not anticipated to limit vegetation establishment (SGME 2019):

- The borrow subsoil is moderately to strongly alkaline (pH 8.4-8.6) which is consistent with topsoil at the Mine. Exchangeable Ca is elevated indicating the source of alkalinity is from calcium carbonates. The pH range is not expected to restrict plant growth (SGME 2019).
- EC is moderate to high with most of the salinity coming from soluble carbonates and sulfate salts (and not chloride). It is important to note that sulfate salinity is generally better tolerated than chloride salinity. EC is unlikely to restrict plant growth (SGME 2019).
- Total N levels are very low while soluble nitrite and nitrate are below sufficiency levels in two out of the three samples. Nitrogen deficiency may be a restriction to plant growth.
- P (Colwell) is below sufficiency levels for all samples indicating that P may be a restriction to plant growth (SGME 2019).

NAF waste rock

NAF waste rock was first geochemically analysed by AGC Woodward-Clyde (1991) followed by AARC (2008) with further analysis completed by EGi (2010). NAF waste rock at the Mine is most likely associated with calc-silicate, mafic feldspar porphyry, white mica schist lithologies and footwall limestone lithology. Further, the calc-

silicate and footwall limestone are likely to have a high to very high ANC ranging from 80-222 kilograms of sulfuric acid per tonne (kg H_2SO_4/t) (EGi 2010). NAF waste rock leachate is:

- expected to be neutral to moderately alkaline (pH 7.6-8.4);
- have moderate alkalinity (21-54 mg/L);
- low to moderate sulfate (4-46 mg/L); and
- low Ca concentrations (7-17 mg/L).

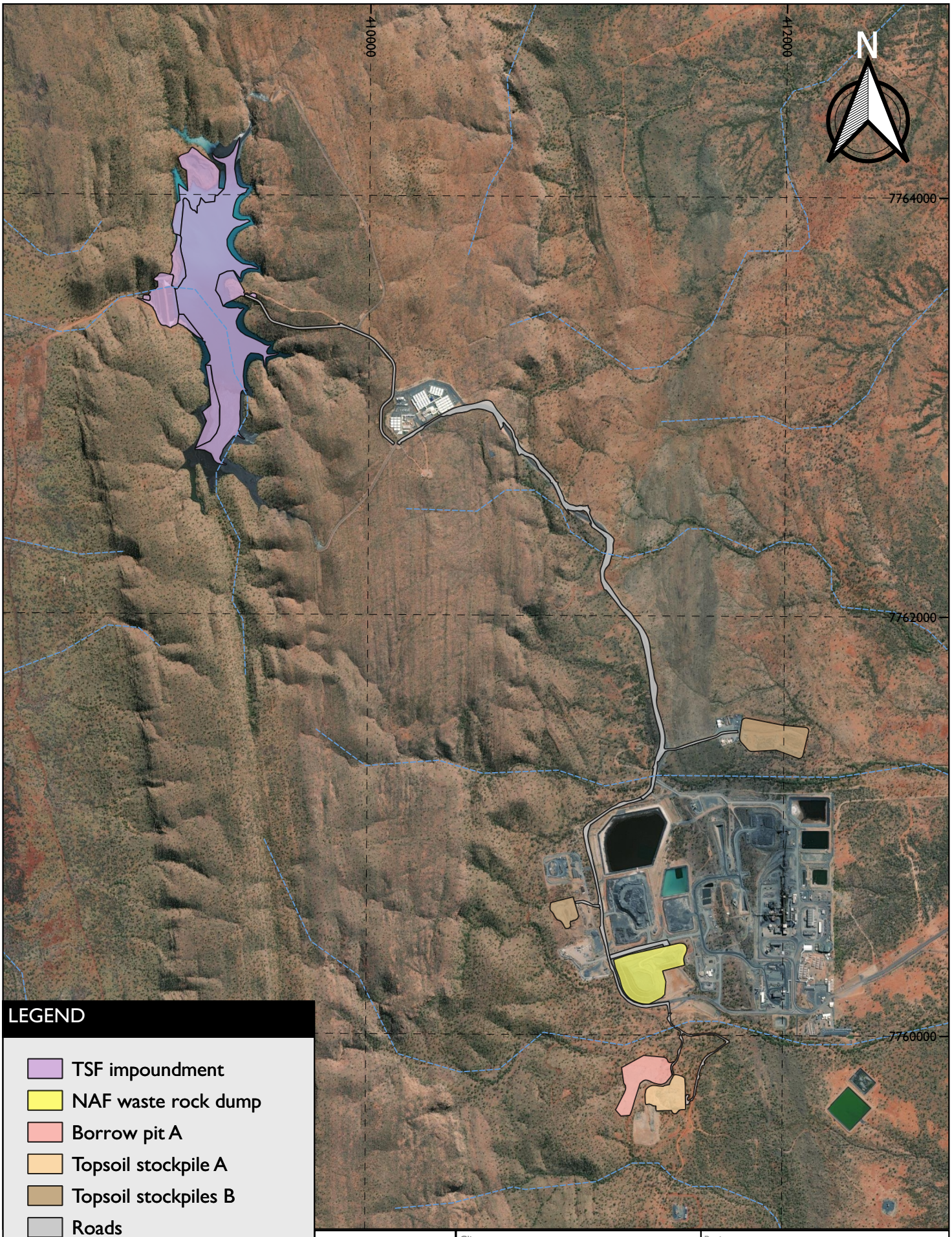
NAF waste rock is therefore expected to be geochemically suitable for use in rehabilitation.

f Location and accessibility of cover material

The location of the cover materials is shown in Figure 16. The haul distance to the TSF is given in Table 40. The cover materials are located on the Mine tenure and therefore no other approvals are required. The soil balance is currently in deficit and therefore soil will need to be sourced from nearby locations or substituted with low sulfur NAF waste rock.

Table 40 Location and accessibility of cover material

Stockpile	Haul distance (m)
Topsoil A	6,115
Topsoil B (west)	4,781
Topsoil B (north)	4,095
Borrow A	5,728
NAF WRD	5,205



LEGEND

- TSF impoundment
- NAF waste rock dump
- Borrow pit A
- Topsoil stockpile A
- Topsoil stockpiles B
- Roads

Scale 1 : 25 000

0 0.5 1 km

SGM environmental

Client: MMG Limited	Project: Progressive Rehabilitation and Closure Plan	
Design: SGM Environmental 26.03.2021 Scale: 1 :25,000 CRS: GDA94 / MGA zone 54	Title: Location and Accessibility of Cover Material	FIGURE 16

© SGM Environmental. While every care is taken to ensure the accuracy of this data, SGM Environmental makes no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and disclaims all responsibility and liability (including without limitaiton liability in negligence) for all expenses, losses, damages (including indirect consequential damage) and costs which might be incurred as a result of the data being inaccurate or incomplete in any way and for any reason.

g Ameliorants and fertilisers for each resource type

Topsoil / subsoil

The pH and ESP test results for soil indicate that they are neither strongly acidic (pH <5.5) nor sodic (ESP ≥6%). Therefore, the application of lime and gypsum onto stockpiles is not required for plant growth and stabilisation.

Fertiliser is used to provide readily available source of nutrients to supplement fertility, maximise the growth of seeded areas and establish plants on rehabilitated land. Fertiliser will be spread at 100 kg/ha (proposed) or as determined by rehabilitation trials to address low soil fertility.

NAF waste rock

NAF waste rock is considered geochemically suitable for use in the cover (SGME 2019; EGi 2010). No amelioration is required.

h Relationship between soils and vegetation ecosystems for the PMLU

The Mine is in a semi-arid region where vegetation ecosystems are limited by water availability and can have extremely weathered soil profiles, resulting in limited nutrient cycling potential and limited natural soil. None of the soil management units identified on site were found to be GQAL due to limiting features (see Section 3.2.2.3). The main limitations of the soil for an improved land use are rockiness, nutrient levels and limited plant-available water. The PMLU is therefore limited to the pre-mining land uses of a mixture of native habitat and low-intensity grazing.

i Contaminated land management

Before operations began, the Environmental Management Register (EMR) and the Contaminated Land Register (CLR) were searched for all properties underlying the Mine to help identify locations that are potentially, or have been proven to be, contaminated. No land was found to be listed on the EMR or CLR.

If contaminated soils or other potential sources of contamination are found during the decommissioning and removal of infrastructure, it will be preferentially treated at the Mine. If contamination cannot be treated, then it will be disposed of at an authorised facility. Treatment versus off-site disposal will depend on whether the land is listed on the CLR and EMR (and whether it is deemed appropriate to have them removed from the registers as part of the rehabilitation process).

On cessation of operations, a site contamination assessment (SCA) will be done at all sites potentially contaminated during mining. The SCA will be conducted in accordance with the Guideline for contaminated land professionals (DEHP 2012) and will consist of the following:

- an AQP will complete a stage 1 and / or stage 2 contaminated land assessment;
- if there is no contamination then the AQP will produce a report for submission to DES requesting that the land be removed from the CLR; or
- if the contaminated site still contains contaminated soil, but it is being appropriately managed, then the AQP can reflect this in their report — this may still allow the land to be removed from the CLR.

The process for assessing and removing land from the EMR will need to be confirmed with DES at the time of rehabilitation because the system is currently under review. It is however likely that following a report from an AQP, an additional review and report will be required from one of DES's authorised third-party reviewers to verify the initial report.

3.6.1.4 Waste characterisation

a Mineral waste volumes

To date, three studies of the Mine's waste rock have been conducted by AGC Woodward-Clyde (1991), AARC (2008) and EGi (2010 – Appendix G). These three studies provide a combined total of 211 samples for the geochemical investigation and were representative of the lithologies given in Table 41.

Table 41 Waste rock lithologies

	Distribution of waste rock samples			
Lithology	**AGC-WC (1991)**	**AARC (2008)**	**EGi (2010)**	**Total**
Calc-silicate	0	23	8	31
Mafic feldspar porphyry	0	3	4	7
White mica schist	0	13	4	17
Hanging wall slate	6	38	8	52
Lode waste	0	10	8	18
Footwall slate	8	16	20	44
Footwall limestone	4	18	20	42

The tonnages of the various waste rock units generated by the Mine were estimated by EGi (2010) to be 0.46 Mt of hanging wall slate, 0.66 Mt of lode waste, 2.88 Mt of footwall slate and 3.11 Mt of footwall limestone.

The geochemical abundance index (GAI) was calculated for 15 samples, two from each lithology and three from the hanging wall slate, to provide an indication of elemental enrichments that may have environmental significance. As a rule, the samples were chosen to include one with a sulfur content toward the top of the concentration range, with the other having a sulfur content that was typically around the mid-range.

Samples representing calc-silicate, mafic feldspar porphyry and white mica schist were relatively free of significant (GAI ≥3) enrichments. For these lithologies, the only significant enrichment identified was sulfur in one calc-silicate sample. However, many samples representing hanging wall slate, footwall slate and lode waste were significantly enriched with one, or a range, of environmentally important elements. In addition to sulfur, many samples from these lithologies were significantly enriched with As, Cd and Zn while small numbers of samples enriched with Cu, Pb, Hg, and Se.

b AMD potential

The AMD potential was tested through measurements of existing pH, total sulfur content, acid neutralising capacity (ANC), net acid producing potential (NAPP) and net acid generation (NAG) capacity. Table 42 give the screening criteria used in the assessment, with the AMD potential of each lithology given in Table 43.

Table 42 AMD potential screening criteria

Classification	NAPP (kg H_2SO_4/t)	NAGpH
PAF	>10	<4.5
PAF-low capacity (PAF-LC)	0-10	<4.5
NAF	Negative	≥4.5
Acid-consuming (AC)	Less than -100	≥4.5
Uncertain (UC)	Positive	≥4.5
	Negative	≤4.5

Table 43 Acid base accounting and NAGpH summary (EGi 2010)

Lithology	Existing pH	Total S (%)	Maximum Potential Acidity (MPA) (kg H_2SO_4/t)	ANC (kg H_2SO_4/t)	NAPP (kg H_2SO_4/t)	Classification based on NAPP only	NAG (kg H_2SO_4/t)	NAGpH	Classification based on NAPP and NAGpH
	median (minimum / maximum)								
Calc-silicate	8.4 (7.7 / 8.5)	0.03 (0.01 / 1.57)	0.5 (0 / 48)	170 (62 / 261)	-151 (-261 / -48)	75% — AC 25% — NAF	0	8.6 (7.4 / 9.5)	75% — AC 25% — NAF
Mafic feldspar porphyry	8.4 (8.2 / 8.5)	0.01 (0.01 / 0.77)	0 (0 / 24)	124 (72 / 187)	-120 (-187 / -56)	50% — AC 50% — NAF	0	8.2 (7.5 / 8.9)	50% — AC 50% — NAF
White mica schist	8.3 (8.2 / 8.7)	0.07 (0.05 / 0.29)	2 (2 / 9)	10.5 (9 / 15)	-9 (-13 / 0)	75% — NAF 25% — PAF-LC	0 (0 / 6)	5.5 (3.5 / 7.2)	75% — NAF 25% — PAF-LC
Hanging wall slate	8.3 (7.8 / 8.9)	0.92 (0.01 / 4.81)	28 (0 / 147)	175 (9 / 455)	-136 (-423 / 52)	75% — AC 25% — NAF	0 (0 / 43)	7.7 (2.4 / 8.1)	75% — AC 12.5% — NAF 12.5% — PAF
Lode waste	8.2 (7.4 / 8.6)	4.72 (1.90 / 13.94)	144.5 (58 / 427)	27 (5 / 398)	63 (-175 / 352)	75% — PAF 25% — AC	19 (0 / 73)	2.3 (2.0 / 8.4)	63% — PAF 25% — AC 7% — UC (NAF)
Footwall slate	8.5 (7.6 / 8.9)	1.12 (0.57 / 7.88)	34.5 (17 / 241)	107 (11 / 548)	-74 (-512 / 220)	55% — NAF 30% — AC 10% — PAF 5% — PAF-LC	0 (0 / 37)	7.8 (2.0 / 9.3)	55% — NAF 30% — AC 10% — PAF 5% — PAF-LC
Footwall limestone	8.3 (7.6 / 8.7)	0.91 (0.10 / 1.87)	27.5 (3 / 57)	374 (107 / 516)	-334 (-492 / -55)	98% — AC 2% — NAF	0	8.0 (7.2 / 9.6)	98% — AC 2% — NAF

The results from the AMD assessment indicated that waste rock from the calc-silicate, mafic feldspar porphyry, white mica schist lithologies associated with the mining of Cu ore, and also waste rock from the footwall limestone lithology, will be NAF. The calc-silicate and footwall limestone are further classified as AC due to their high to very high ANC.

Waste rock from within the lode zone will likely be PAF and have a high to very high capacity for acid generation if exposed to atmospheric conditions. It is also likely that some slate waste rock from the adjoining hanging wall and footwall will be pyritic and strongly PAF (noting that hanging wall slate ranged from strongly PAF to AC). Including past assessments, approximately 54% of the hanging wall slate samples tested, and 20% of the footwall slate samples tested were classified as PAF.

Waste rock quantities

Based on the waste rock characterisation results, MMG have provided an estimate of the quantities of PAF and NAF waste rock to be produced for the remaining LOM. Both PAF and NAF waste rock will be progressively used during operation by being returned underground as stope fill or used in construction and rehabilitation (NAF waste rock). PAF waste rock is prioritised over NAF for returning underground. The estimated waste rock generation is given in Table 44.

Table 44 Estimated waste rock

Waste rock type	Volume (t)
Total waste produced (brought to surface)	
PAF	3,517,958
NAF	3,717,646
Total	7,235,604
Waste consumed during operation	
PAF (underground fill)	3,517,958
NAF (construction and / or rehabilitation)	TBA[1]
Total	3,517,958[1]
Waste remaining on surface	
PAF	0
NAF (rehabilitation and / or underground fill)	TBA[1]
Total	**0**[1]

1. Current mine plan (MMG 2015) — Final materials balance under review.

Tailings characterisation

The chemical composition including the GAI of the tailings liquor and solids is given in Table 45.

Table 45 Chemical composition of tailings

Analyte	Unit	Tailings liquor	Unit	Tailings solids	GAI
Physicochemical					
pH	pH units	7.3	-	-	-

Analyte	Unit	Tailings liquor	Unit	Tailings solids	GAI
Alkalinity	mg/L	53	-	-	-
EC	µS/cm	767	-	-	-
Sulfate	mg/L	1,310	-	-	-
Cl	mg/L	714	-	-	-
Fluoride	mg/L	2.4	-	-	-
Ca	mg/L	75	%	2.10	0
K	mg/L	44	%	4.2	1
Mg	mg/L	31	%	0.63	0
Na	mg/L	175	%	0.27	0
Dissolved metals and metalloids					
Ag	mg/L	0.040	milligrams per kilogram (mg/kg)	34.0	6
Al	mg/L	0.020	%	5.1	0
As	mg/L	<0.001	mg/kg	476.0	5
B	mg/L	0.130	-	-	-
Ba	mg/L	0.098	mg/kg	160.0	0
Be	mg/L	<0.001	mg/kg	3.6	0
Bi	-	-	mg/kg	5.6	4
Cd	mg/L	0.0011	mg/kg	54.0	6
Co	mg/L	0.002	mg/kg	20.0	0
Cr	mg/L	<0.001	mg/kg	535.0	2
Cu	mg/L	0.030	mg/kg	164.0	1
Fe	mg/L	0.110	%	8.0	0
Hg	mg/L	<0.0001	mg/kg	0.79	3
Mn	mg/L	1.100	mg/kg	2930.0	0
Mo	mg/L	0.012	mg/kg	85.0	4
Ni	mg/L	0.001	mg/kg	353.0	2
P	mg/L	<1	mg/kg	1250.0	0
Pb	mg/L	0.330	mg/kg	9890.0	6
S	-	-	%	7.9	6
Sb	mg/L	0.018	mg/kg	36.0	4

Analyte	Unit	Tailings liquor	Unit	Tailings solids	GAI
Se	mg/L	<0.010	mg/kg	3.0	2
Si	mg/L	2.800	-	-	-
Sn	mg/L	0.001	mg/kg	2.9	0
Sr	mg/L	0.970	mg/kg	359.0	0
Th	mg/L	<0.001	mg/kg	7.2	0
U	mg/L	<0.001	mg/kg	15.0	2
Zn	mg/L	0.250	%	2.6	6

The main environmentally important metals that were released from the tailings during the column leach test were Zn, Mn, Pb and Cd. These concentrations are typically one or two orders-of-magnitude higher than the corresponding metal concentrations reported for the tailings liquor and thereby represent significant mobilisation from the solid phase due to sulfide oxidation and the initial acidification of the tailings.

Acid generation potential

The acid forming potential of the tailings solids is given in Table 46.

Table 46 Acid forming assessment

Analyte	Unit	Tailings solids
Total S	%	7.9
Reactive S	%	6.9
ANC	kg H_2SO_4/t	54
MPA	kg H_2SO_4/t	241
Total acid generated	kg H_2SO_4/t	140
NAPP	kg H_2SO_4/t	86
AMD classification	-	PAF

The column test results indicate that the reactivity of some sulfides within the tailings is of such high magnitude that the rate of acid generation when tailings are first exposed to atmospheric conditions exceeds the reactivity of the carbonates contributing to the moderately-high ANC. While the tailings are likely to generate some acid when initially exposed to atmospheric conditions, they were found to recover to a near-neutral pH within months. This behaviour has been observed with Zn tailings at other sites. The dissolved metals followed a similar trend, declining substantially from Week 4 to Week 52 during the column test. This can be attributed to the lower acidity during the later weeks of the test.

The return to pH neutrality can primarily be attributed to a slowing in the rate of sulphide oxidation to the point where the rate of acid formation was compatible with the reactivity of the ANC. However, given that the tailings sample tested had strongly positive NAPP and NAG values it is expected that the tailings would eventually re-acidify with long-term exposure to atmospheric conditions. Based on the rate of sulfate leaching in Week 52, it is estimated that the tailings could remain pH neutral for at least another seven years (assuming an effective residual ANC of at least 30 kg H_2SO_4/t) and that following this lag stage the tailings would be likely to re-acidify to a pH <4 and continue to generate leachate with elevated sulphate for a number of decades.

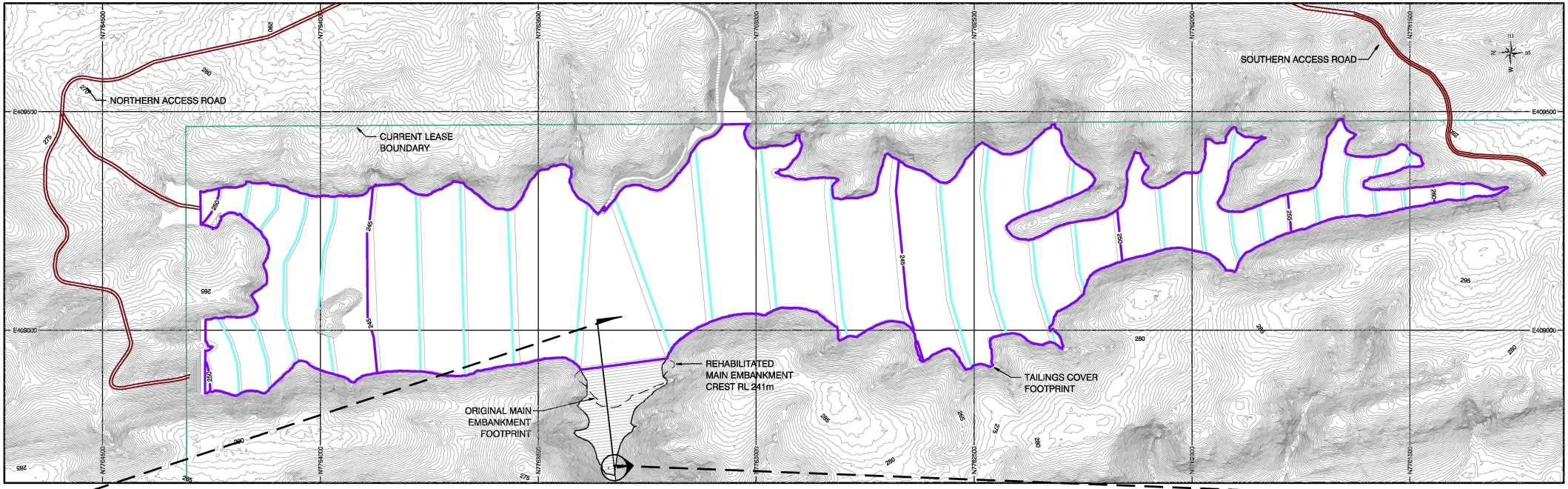
3.6.1.5 Landform design

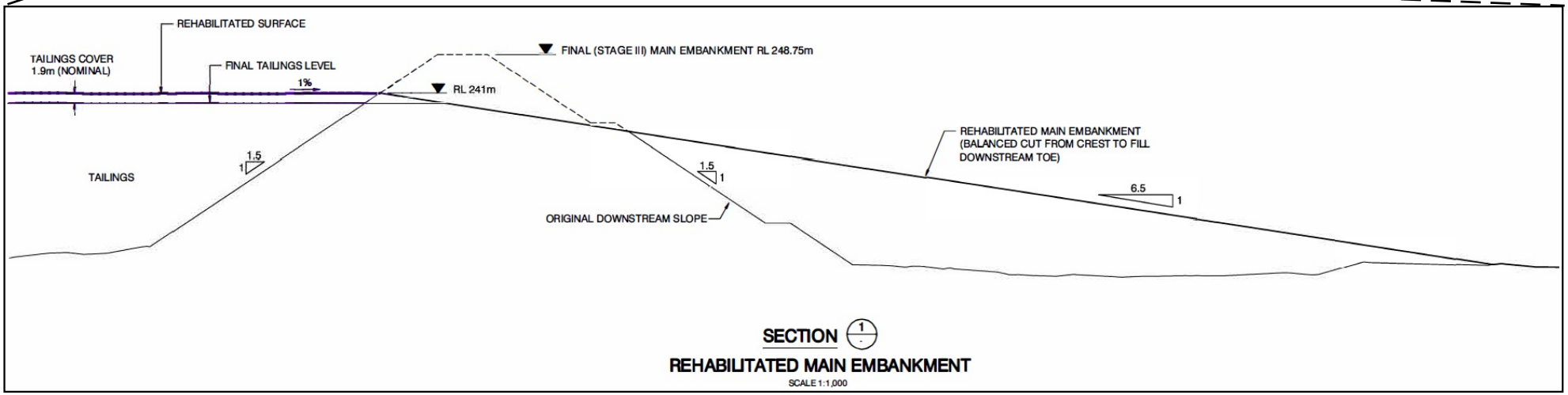
The final landform design is a key component of rehabilitation and closure planning. As no waste rock dump is to left after closure, the only final landform requiring detailed design will be the TSF.

The following sections describes how the TSF will be rehabilitated for the PMLU (native habitat) to a safe and structurally stable condition.

a Design plans for the final landform

A conceptual closure and rehabilitation plan for the final landform of the TSF is given in Figure 17. The intent of the final landform is to create a gentle sloping landform suitable for native habitat which blends into the surrounding landscape.





SECTION 1

REHABILITATED MAIN EMBANKMENT

SCALE 1:1,000

Scale 1 : 10 000

0 200 400 600 m

SGM environmental

Client	MMG Limited
Project	Progressive Rehabilitation and Closure Plan
Design: ATC Williams 09.06.2010	
Scale: 1 : 10,000	
CRS: GDA94 / MGA zone 54	
Title	Final Landform Visualisation
FIGURE	17

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b Method for determining final landform design

Six TSF sites were considered, including locations within, to the west and to the east of the Knapdale Range. Criteria for the assessment of the sites included physical characteristics, capital and operating costs, sterility and the potential for expansion.

The Knapdale valley site was chosen with regard to all assessment criteria, particularly the total cost, potential sterilisation and expandability for future mining plans.

c Key considerations

Two of the significant advantages of the Knapdale Valley TSF are that the final tailings surface forms a 'natural' profile that sheds rainfall without the need for any re-shaping, and that access to the surface should be available relatively quickly after the end of operations (Appendix H).

The valley also has a large catchment (335 ha), which is a benefit of the site in that it can be used to collect and temporarily store runoff during the wet season for use in the process plant.

The Knapdale Ranges consist of competent, hard quartzite rock of low permeability. No significant groundwater resource is present within the Knapdale Range, and there is no practical means of hydrogeological connectivity with the Cabbage Tree Creek catchment area to the west.

d Stability of final landform

The proposed final landform designs for both the rock spillway and the TSF flat top underwent landform evolution modelling (LEM) to predict erosion potential over a 100-year period by SGME (2020) (Appendix I).

A 100-year synthetic climate file was generated using the CLIGEN stochastic weather generator which was used in the LEM. The water erosion prediction project (WEPP) rainfall / runoff model was run using desktop data and final landform designs, to estimate the potential annual erosion rate for a variety of surface conditions and vegetation cover scenarios.

The LEM predicts that for the proposed final landform of the rock spillway, the maximum annual erosion rate will be 0.52 t/ha/y (average of 0.1 t/ha/y). Predictions for the preferred flat top design showed the average annual erosion rates under all surface conditions is likely to be <5 t/ha/y. While most surface conditions showed a low maximum annual erosion rate (<10 t/ha/y), the soil and waste rock mix performed better in extreme climatic events (<0.35 t/ha/y with 60% groundcover) than bare soil alone. It is therefore recommended that a soil and waste rock mix is used for the infiltration storage layer of the infiltration storage cover, which will also halve the amount of soil required. Vegetation establishment and sustainability will be investigated as part of the PMLU rehabilitation trials (Section 3.7.5).

Two main embankment options have been considered for the TSF, a clay core or a geomembrane sealing system (GSS). On the basis of capital costs, construction efficiency, materials availability and future expandability, the GSS option was selected as the preferred configuration for the main embankment.

Using the US Army Corps of Engineers (USCE) seismic screening approach (USCE 1984), the GSS embankment option was found to comply in terms of all static and seismic loading cases. The minimum factor of safety (FS) for the upstream slope was found to be 1.41 during Stage 1, whilst for the downstream slope a minimum FS of 1.41 was also obtained when the embankment is raised to Stage III. Given that a FS of 1.0 using the USCE method indicates negligible rockfill deformation, these results are considered satisfactory (Appendix H).

e Quality assurance / quality control requirements

Key risks associated with final landform construction include a failure to follow the design, construction materials not conforming to specifications, poor or inadequate construction quality and the failure of quality assurance and quality control (QA/QC) to identify construction inadequacies. Final landform construction management, technical supervision and QA/QC will be done by an AQP who can make sure that construction is carried out

in accordance with the design plan. A QA/QC document will be prepared by an AQP to verify final landform design has been done in accordance with the design plan and is stable.

f Methodology to verify the predicted success

A geotechnical assessment will be prepared by an AQP to verify that the final landform is in a stable condition and has an acceptable factor of safety with no signs of significant erosion.

Successful rehabilitation of the final landform will be assessed through the completion criteria and monitored following the plan described in Section 3.8. DES must be satisfied with the rehabilitation before it will certify that the final landform is successfully rehabilitated and accept the surrender of the EA.

g Limitation and assumptions of the final landform design

The final landform design has the following limitations:

- the accuracy of soil availability and quality at closure;
- effects of climate change on future rainfall event intensities, durations and / or frequencies; and
- nature of the final waste material.

The final landform design has the following assumptions:

- there is sufficient cover material available;
- the nature of the cover and waste material is similar to current assessments; and
- progressive rehabilitation will begin during operations as soon as land becomes available.

3.6.1.6 Cover design

Cover column trials and a semi-calibrated model (SGME 2019) were performed on a number of cover options for the TSF. The cover assessment showed that the TSF will likely require a 1 m thick infiltration storage layer (ISL) to reduce the potential for seepage into the potentially contaminating tailings. Cover options 1 and 2 are therefore considered the preferred options at this stage.

Cover option 1 consists of:

- a 0.4 m capillary break (CB) layer of gap-graded NAF waste rock above the tailings at a density of 1.43 t/m^3;
- a 0.5 m reduced permeability layer (RPL) of borrow subsoil above the CB layer at a density of 2.31 t/m^3;
- a 1 m ISL of borrow subsoil above the RPL at a density of 1.64 t/m^3; and
- a 0.2 m topsoil layer above the ISL at a density of 1.7 t/m^3.

Cover option 2 consists of:

- a 0.3 m CB layer of gap-graded NAF waste rock above the tailings at a density of 1.38 t/m^3;
- a 0.5 m RPL of borrow subsoil above the CB layer at a density of 2.27 t/m^3;
- a 0.3 m CB layer of gap-graded NAF waste rock above the RPL at a density of 1.38 t/m^3;
- a 1 m ISL of borrow subsoil above the CB layer at a density of 1.64 t/m^3; and
- a 0.2 m topsoil layer above the ISL at a density of 1.7 t/m^3.

Closer to the date of closure, borrow material assessments should be done to confirm adequate resources for cover material. Once an area of the TSF becomes available, large field trials will be established and monitored to inform the final cover design.

3.6.1.7 Water management

The management of surface and groundwater is an important consideration in achieving long-term rehabilitation success.

The *Water Management Strategy: Dugald River* describes a surface water management network to ensure water is efficiently and effectively managed to achieve water and sediment related quality objectives in accordance with regulatory requirements and MMG standards.

The surface water management system has been designed so that:

- clean runoff water produced off the MLs is diverted away from operational areas;
- drains within operational areas have been designed to direct runoff to designated containment or sediment dams, dependant on the potential contaminants present; and
- water storages are assessed and classified as either hazardous (regulated structures) dams, non-hazardous dams or containment dams.

In accordance with EA Condition A7, the *Water Management Strategy: Dugald River* is scheduled for review by an AQP every two years to ensure continued protection of environmental values.

The surface water management system will continue to control runoff until inspection by an AQP deems that rehabilitation is established and catchment of runoff is no longer required.

a Contaminants that pose risk to environmental values

The following contaminants pose a risk to the environmental values of the receiving environment:

- TSF and mineralised waste:
  - dissolved metals and salts;
  - total dissolved solids and sediment;
- ancillary infrastructure and services and mining and processing area:
  - hydrocarbons as total petroleum hydrocarbons, total recoverable hydrocarbons and benzene, toluene, ethylbenzene, p-xylene and naphthalene (TPH, TRH and BTEXN); and
  - total dissolved solids and sediment.

b Source, pathway and fate of contaminants

CDM Smith prepared a technical memorandum in 2021 (Appendix J) which considers:

- the potential of AMD to occur within the Mine and access infrastructure during mining and after closure;
- revision to the existing hydrogeological conceptual model;
- description of the current groundwater condition; and
- a description of existing closure plans and anticipated post-mining groundwater conditions at the Mine and down hydraulic gradient of the Mine.

TSF

The potential exists for groundwater quality to be altered by a release of contaminants to shallow groundwater. That is, subsurface contaminants may be released by infiltration and subsequent recharge from the TSF.

It is unlikely that AMD seepage from the TSF would significantly impact groundwater given;

- the very low permeability of the Knapdale Quartzite (the base of the TSF);
- the low permeability sediments at the base of the TSF;
- the low hydraulic conductivity of the downgradient rocks;
- the flat hydraulic gradient in the valley; and

- the proposed TSF cover system.

The cover of the TSF will include a 1 m thick infiltration storage layer to reduce seepage into the PAF tailings. Further, the downstream (western) embankment will be will be reshaped to form the rock spillway to move excess water (rainfall runoff and cover seepage) off the top surface of the rehabilitated landform precenting ponding.

Mineralised waste

All runoff from the PAF waste rock dumps is directed to and collected in Stage 1 PAF Pad Run Off Dam and the Stage 2 PAF Pad Run Off Dam (CDM Smith 2021). The PAF waste rock dumps were constructed with a 1 m layer of well compacted low sulfur NAF waste rock at the base of the WRD. At closure, all PAF and high sulfur NAF waste rock within the PAF WRD will have been removed and disposed of underground as part of operational stope-filling. The risk of AMD conditions developing during operation is low. Some desaturation of PAF materials hosting the ore body could occur (CDM Smith 2021). However, given the neutralising capacity of the surrounding formations, particularly down the hydraulic gradient of the Mine, any migration of acidic groundwater that may arise away from the Mine is unlikely.

Ancillary infrastructure and services

The main threat to groundwater quality during mining will be from any spills of potentially contamination substances such as hydrocarbons. This is addressed by good housekeeping practices, hydrocarbon storage standards and appropriate spill response and reporting procedures.

The ancillary infrastructure and services feature will be decommissioned to form a stable landform. Any contaminated soils will be removed and taken to an appropriate disposal site followed by a contaminated site clean-up validation assessment to confirm required standards have been met. At rehabilitation, all runoff will be clean water. No further water management / segregation is required.

Mining and processing area

The potential for the generation of AMD to impact groundwater filling the Mine voids exists (CDM Smith 2021). Whilst recovery is occurring, potentially impacted mine water quality will be hydraulically contained (by pressure gradients) and only after recovery has occurred will this Mine waste have the potential to move away from the filled Mine voids under established hydraulic gradients (CDM Smith 2021). If this water continues to be impacted by acidity after decades of accumulation in the voids, the risk posed to possibly sensitive groundwater receptors is low given that:

- groundwater does not discharge to the surface in the vicinity of the Mine;
- groundwater is not used to support stock and domestic water supplies in the area of the Mine; and
- groundwater may discharge to downstream aquatic ecosystems associated with Dugald River but only after very long flow paths through hydrostratigraphy having:
  - very low permeability (ie very long residence time); and
  - large excess of acid neutralising capacity.

c Infiltration and seepage intervention and collection controls

The TSF will be rehabilitated with an infiltration storage cover system to limit rainfall seeping into the PAF tailings. The TSF embankment will be converted to a rock lined spillway. The rock lined spillway will move excess water (rainfall runoff and cover seepage) off the top of the surface of the rehabilitated landform, preventing ponding.

After rehabilitation, all runoff will be clean water. No other collection controls (ie further water management / segregation) will be needed at that time.

d Surface water diversions and long-term management requirements

Several operational strategies for surface water management will be done during the closure phase including:

- minimisation of the disturbance, thus minimising the volume of dirty or contaminated runoff;
- containment of dirty water on site via low hazard storages or sediment ponds, dependant on the toxicity of contaminants likely to be generated; and
- controlled release of water stored in proposed stormwater management storages, within the EA release limits, and during appropriate natural flow events in the receiving watercourse.

Water and drainage management at the Mine will continue through closure, including the implementation of the *Receiving Environment Monitoring Program* (REMP). Further, general data collection and analysis will be done leading up to and during closure for the following aspects:

- flow event monitoring;
- stormwater drainage catchments and diversion channels; and
- mineral waste management and regulated dams.

No long-term management requirements are anticipated.

e Groundwater management

Since the underground workings are below the local water table, groundwater inflow is expected to occur after dewatering activities have stopped. Groundwater recharge into the underground workings is unlikely to be a significant risk due to the lack of groundwater to surface water interaction, the very low permeability of the stratigraphy, and the lack of surrounding groundwater users (ie stock or drinking).

f On-going water management and reduction requirements

There are no on-going (long-term) water management or reduction (treatment) requirements for the Mine after rehabilitation is finished. Therefore, water management structures will be decommissioned and rehabilitated to a stable condition. Notwithstanding, it is likely that the five creek crossings, the raw water dam and the sediment dams will be retained post-closure for use by landholders through a formal agreement outlining management responsibilities.

3.6.1.8 Revegetation

Revegetation activities have been developed to establish self-sustaining vegetation communities that are appropriate for the PMLU. The Mine has proposed three PMLU's with the majority of land being returned to low-intensity grazing / native habitat or a combination of these uses as per existing land use, community consultation and licence conditions. Rehabilitation methodology and processes are very similar across the PMLU's. These processes are outlined in the following section.

a Objectives

The revegetation objectives for the site can be summarised as follows;

- to establish self-sustaining vegetation consistent with the PMLU and nominated completion criteria;
- to establish self-sustaining vegetation in native habitat areas that supports species endemic to the area including the Carpentarian Antechinus and the Purple-necked rock-wallaby;
- to establish self-sustaining vegetation in grazing areas that is productive, comparable to surrounding grazing areas and supports the commercial interest of future land holders;
- to establish self-sustaining vegetation in native habitat / low intensity grazing areas that supports endemic species but is also productive for cattle grazing;
- to monitor and manage weed and pest species which are detrimental to the establishment and persistence of key flora and fauna species.

To date limited rehabilitation has been completed due to a lack of areas not being available. Existing areas are limited to exploration areas and drill pads. Because of this the scope of rehabilitation monitoring is limited. The monitoring methodology and rehabilitation planning for these areas is contained in Appendix J.

b Key flora species

Existing key flora species have been identified and are given in Table 47. Species of conservation significance are discussed in Section 3.1.3.9. In general, the RE 1.11.2 (*Eucalyptus leucophloia* low open woodland) is dominant in area along with a variety of other, less represented RE's. Key flora species and the relevant PMLU are also outlined in Table 47.

Table 47 Key flora species

Vegetation community and associated RE's	Soil management unit	Dominant trees	Dominant shrub	Dominant groundcover	Relevant PMLU
Silver Box and Cloncurry Box Open Woodland (RE 1.5.4x3)	• Red Plain (SMU 1)	*Eucalyptus pruinosa, Eucalyptus dichromophloia, Eucalyptus leucophylla, Acacia cambagei*	*Hakea chordophylla, Carissa lanceolata, Acacia lysiphloia, Atalaya hemiglauca*	*Triodia pungens, Cenchrus ciliaris*[1]*, Aristida contorta, Aristida ingrata, Aristida inaequiglumis, Enneapogon spp.,*	Native habitat / low-intensity grazing
Gidgee Open Woodland (RE 1.3.4)	• Red Plain (SMU 1) • Prospectors (SMU 5)	*Acacia cambagei*	*Senna artemisioides subsp. oligophylla, Eremophila latrobei, Carissa lanceolata, Eremophila mitchellii, Santalum*	*Cenchrus ciliaris*[1]*, Echinochloa colona*[1]*, Sporobolus actinocladus, Enteropogon ramosus, Astrebla pectinata, Cenchrus pennisetiformis*[1]*, Cenchrus setigerus*[1]*, Triodia*	Native habitat / low-intensity grazing
Cloncurry Box Open Woodland (RE 1.11.3.b, and RE 1.11.3x1)	• Red Plain (SMU 1) • Miners (SMU 4) • Prospectors (SMU 5) • Pocket (SMU 6)	*Eucalyptus leucophylla, Corymbia terminalis, Eucalyptus leucophloia*	*Atalaya hemiglauca, Acacia chisholmii, Acacia holosericea*	*Triodia pungens, Cenchrus ciliaris*[1]	Native habitat / low-intensity grazing
Snappy Gum Open Woodland (RE 1.11.2a and RE 1.5.3)	• Red Plain (SMU 1) • Knapdale (SMU 2) • Dale (SMU 3) • Miners (SMU 4) • Prospectors (SMU 5) • Pocket (SMU 6)	*Eucalyptus leucophloia, Corymbia terminalis, Eucalyptus leucophylla, Corymbia capricornia*	*Acacia lysiphloia, Acacia chisholmii, Terminalia aridicola, Carissa lanceolata, Eremophila longifolia, Acacia orthocarpa, Atalaya hemiglauca, Acacia holosericea, Denhamia cunninghamii*	*Triodia pungens, Triodia molesta, Triodia longiceps, Eriachne mucronata, Themeda triandra, Enneapogon lindleyanus, Eulalia aurea, Aristida contorta*	Native habitat / low intensity grazing

Vegetation community and associated RE's	Soil management unit	Dominant trees	Dominant shrub	Dominant groundcover	Relevant PMLU
River Red Gum Riparian Woodland (RE 1.3.7a)	• Red Plain (SMU 1) • Knapdale (SMU 2) • Dale (SMU 3) • Miners (SMU 4) • Prospectors (SMU 5) • Pocket (SMU 6)	*Eucalyptus camaldulensis, Lophostemon grandiflorus, Corymbia aparrerinja, Lysiphyllum cunninghamii, Melaleuca*	*Atalaya hemiglauca, Acacia bidwillii, Ficus opposita, Vitex benthamiana, Flueggea virosa, Acacia holosericea,*	*Cenchrus pennisetiformis, Cenchrus ciliaris*[1]*, Echinochloa colona*[1]*, Cenchrus setigerus, Cenchrus pennisetiformis*[1]*, Heteropogon contortus, Xanthium occidentale*[1]	Native habitat / low-intensity grazing
Snappy Gum/ Cloncurry Box Mixed Bloodwood Woodland (RE 1.3.6)	• Miners (SMU 4) • Pocket (SMU 6)	*Lophostemon grandifloras, Terminalia aridicola, Corymbia terminalis, Corymbia aparrerinja, Eucalyptus pruinose, Lysiphyllum cunningamii, Eucalyptus camaldulensis*	*Acacia retivenea, Acacia holosericea,* *Atalaya hemiglauca, Carissa lanceolata, Acacia chisholmii, Eremophila longifolia*	*Triodia pungens, Cyperus dactylotes, Sehima nervosum, Cenchrus pennisetiformis*[1]*, Triodia* *longiceps, Heteropogon contortus, Aristida hygrometrica*	Native habitat

1. Denotes exotic species which have been identified in the nominated Regional Ecosystem

c Key fauna species and habitat requirements

Identification of fauna of conservation significance is addressed in Section 3.1.3.10. The species considered for habitat requirements are:

- Carpentarian antechinus (*Pseudantechinus mimulus*); and
- Purple-necked rock-wallaby (*Petorgale purpureicollis*).

Animals will usually colonise rehabilitated areas if the composition and structure of the rehabilitated vegetation is comparable with the surrounding areas (Australian Government 2016).

Carpentarian antechinus

The Carpentarian antechinus is known to occur within the Knapdale Range which borders the Mine site; in particular, the TSF is located within the Knapdale Range. Outside of the Knapdale ranges, the tenement contains little to no rock and is unlikely to support Carpentarian antechinus (OLEC 2015). Hummock grasses such as *Triodia spp*. are commonly associated with habitat for the Carpentarian antechinus as spinifex habitats often support termites, which are an important prey species for the species. To mitigate the potential impacts of the Mine on the species a management plan was developed by Open Lines Environmental Consulting (OLEC) in 2015 (Appendix L). The management plan includes measures to tailor rehabilitation for fauna use including;

- establishing rock piles through rehabilitation area at a density of at least 2 per ha. Piles should be a minimum of 3x3 m in area and consist predominantly of rocks >30 cm in diameter;
- seeding using native ground cover species, particularly endemic spinifex;
- excluding Buffel Grass in native habitat areas; and
- excluding exotic woody species (trees or shrubs).

These measures will be relevant to the rehabilitation of the TSF and the accommodation village only given their proximity to the Knapdale ranges.

Purple-necked rock-wallaby

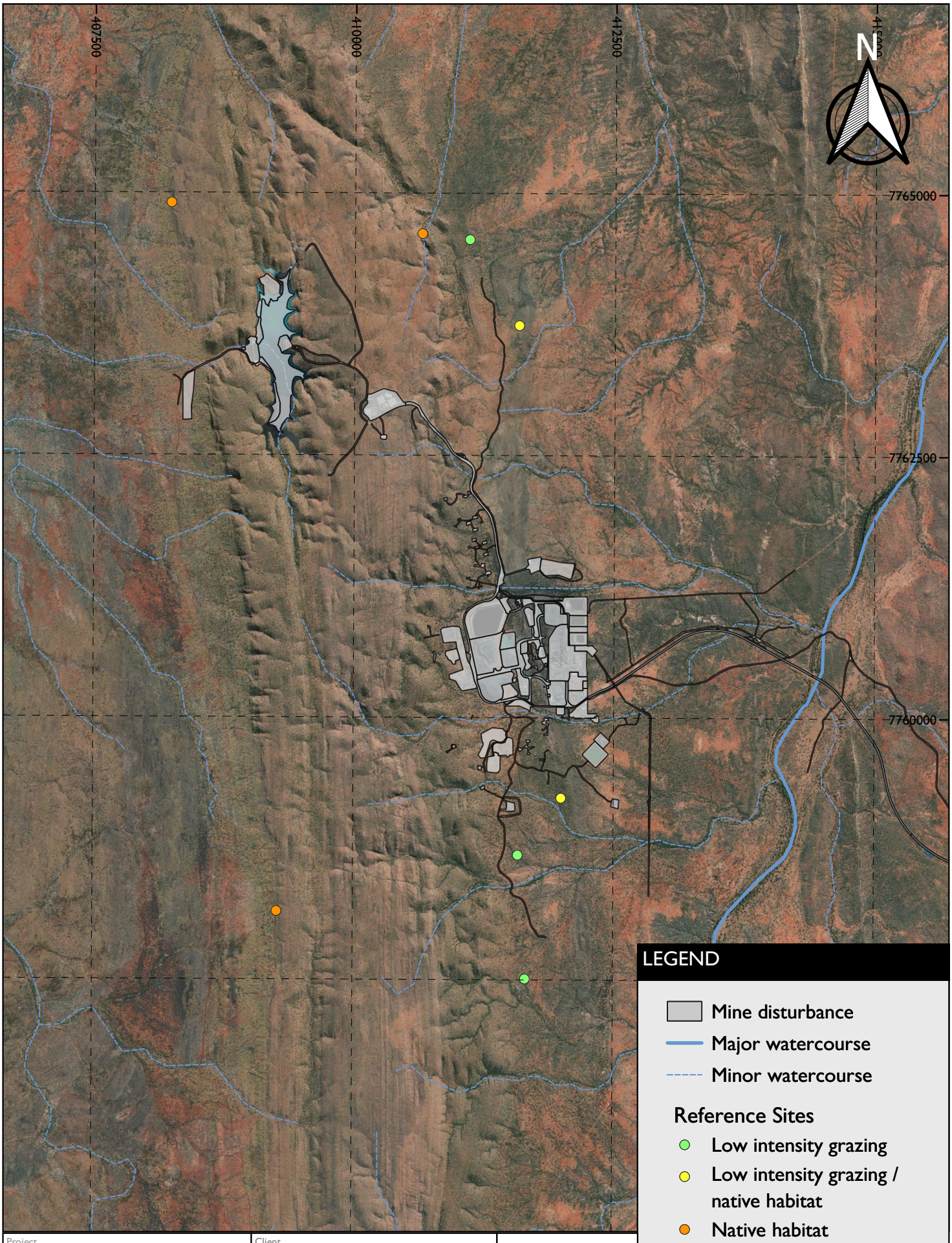
The purple-necked rock-wallaby (PNRW) was the only listed threatened species identified during field surveys (AARC 2010; AARC 2011). A monitoring program for the PNRW is required under the EA and is currently in place (MMG 2018) (Appendix M).

Foraging habitat for the PNRW is planned to be incorporated into rehabilitated areas. Foraging habitat includes hummock grassland and mulga with green vegetation, especially grasses (Menkhorst and Knight, 2011). Further information is required to refine the more specific vegetation and habitat requirements for the PNRW. Other types of habitat features that may be incorporated into rehabilitated areas will be informed by surveys of representative monitoring sites as part of the PNRW monitoring program. This may include the placement of rock structures or other suitable key habitat features.

d Analogue sites

Analogue or reference sites will be monitored to provide a comparison to rehabilitated areas. Analogue sites may also allow refinement of closure and acceptance criteria over time. A minimum of three analogue sites relevant to each PMLU will be established in undisturbed areas for monitoring of rehabilitation against milestone criteria. An outline of rehabilitation monitoring methodology is given in Appendix K.

The proposed reference sites are given in Table 48 and shown in Figure 18.



Project: Progressive Rehabilitation and Closure Plan		Client: MMG Limited	
Figure: 18	Title: Rehabilitation Monitoring Reference Sites	Design: SGM Environmental Pty Ltd 27.09.2021 Scale: 1 : 50,000 CRS: GDA94 / MGA zone 54	SGM environmental

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Table 48 Analogue monitoring site locations

Site ID	Easting	Northing	Relevant PMLU
Native 1	409269	7758149	Native habitat
Native 2	408235	7764903	Native habitat
Native 3	410646	7764613	Native habitat
Low Intensity Grazing 1	411657	7757509	Low-intensity grazing
Low Intensity Grazing 2	411583	7758689	Low-intensity grazing
Low Intensity Grazing 3	411102	7764558	Low-intensity grazing
Low Intensity Grazing / Native Habitat 1	411581	7763739	Native habitat / low-intensity grazing
Low Intensity Grazing / Native Habitat 2	411997	7759234	Native habitat / low-intensity grazing
Low Intensity Grazing / Native Habitat 3	412016	7757895	Native habitat / low-intensity grazing

1. GDA94 MGA z54.

e Site preparation and works

PMLU's of grazing and native habitat both require similar site preparation which is reflected in the rehabilitation milestones. Site preparation is associated with milestones RM1-RM5. RM1 (site infrastructure removal), RM2 (remediation of contaminated land) and RM3 (landform development and reshaping) require the same treatment for each PMLU. RM4 (cover installation) is a specific milestone related to the TSF (native vegetation) and does not have relevance to any grazing areas.

RM5 (surface preparation) first requires the remediation of any erosion or subsidence. Given the long timeframe for completing earthworks in RM3 and cover installs in RM4 some areas may have been left for extended periods and require remediation prior to further works. This may be particularly relevant if areas have been exposed to large rain events.

Previous assessments of soil health and suitability are discussed in detail in Section 3.1.3.7. Further discussion on the potential use of ameliorants is given in Section 3.6.1.3. In summary, topsoil is neither strongly acidic or sodic and does not require bulk amelioration (lime or gypsum); however, the addition of fertiliser is desirable to encourage vegetation establishment. Fertiliser application is a requirement of RM6. There is however a known topsoil deficit for the completion of rehabilitation works. To address this deficit the Mine proposes to conduct field scale trials of subsoil / waste material treatment (gypsum, lime, organic material etc. application) to assess its suitability as a growth medium. These trials will be carried out as suitable areas become available.

Topsoil will be spread by mechanical means at a target thickness of 200 mm. This value may be adjusted as data becomes available from rehabilitation trials during operations. The application methodology and thickness will be used for areas rehabilitated using the gypsum treated subsoil / waste material. This value may also be adjusted based on rehabilitation trial information.

Once the growth medium is in place the area will be ripped by mechanical means to loosen compacted soil and provide furrows and rills to facilitate vegetation establishment. Where the rehabilitation area is located on a slope, ripping will be carried out perpendicular to the slope (ie on the contour) to minimise the risk of gullying. In some circumstances, ripping may be carried out at the same time as seeding. This will be dependent on the type of machinery used for ripping / seed application and the planned timing of seeding.

The existing land use of the Mine is predominantly grazing which includes both pasture and native species. As such the species present are considered suitable and productive for cattle. With this in mind areas designated for a PMLU of low-intensity grazing or native habitat / low-intensity grazing will be allowed to lie fallow for a period of 12 months following growth medium application and ripping. The existing seed bank within the soils is expected to be sufficient to allow for natural revegetation. Areas on slopes or otherwise deemed to be at a high risk of erosion will be directed seeded to ensure ground cover establishment and subsequent erosion protection. Should suitable revegetation not occur within the 12-month period direct seeding will be employed. Areas nominated as native habitat will be direct seeded by mechanical means. If direct seeding is not possible, seeds will be manually broadcast. The species requirements and application rate for each PMLU are discussed further in this Section.

A weed management plan will be implemented to ensure revegetation initiatives are balanced with managing any existing weed species or those which are established due to land disturbance.

f Seed mix, sourcing and application

A separate seed mix for each nominated PMLU has been developed considering key species in the region, those that are good colonisers and those that are readily available. The seed mixes and application rates may be further refined based on rehabilitation trials, analogue site monitoring or stakeholder engagement. While seed mixes have been chosen based on many factors, including their suitability to the area, not all species may successfully establish. The establishment of a minimum of 70% of target species is considered adequate given the large number of species selected.

Native habitat seed mix

The native habitat seed mix is given in Table 49.

Table 49 Native habitat seed mix

Species type	Species	Rate (kg/ha)
Tree	*Eucalyptus leucophloia*	0.15
	Corymbia terminalis	0.15
	Eucalyptus leucophylla	0.15
	Corymbia aparrerinja	0.15
	Eucalyptus camaldulensis	0.15
	Lophostemon grandiflorus	0.15
	Lysiphyllum cunninghamii	0.15
Shrub	*Acacia lysiphloia*	0.05-0.20
	Acacia chisholmii	0.05-0.20
	Terminalia aridicola	0.05-0.20
	Carissa lanceolata	0.05-0.20
	Eremophila longifolia	0.05-0.20
	Atalaya hemiglauca	0.05-0.20
	Acacia holosericea	0.05-0.20
	Acacia bidwillii	0.05-0.20

Species type	Species	Rate (kg/ha)
	Ficus opposita	0.05-0.20
Groundcover	*Triodia pungens*	0.5-3.0
	Triodia molesta	0.5-3.0
	Triodia longiceps	0.5-3.0
	Eriachne mucronata	0.5-3.0
	Themeda triandra	0.5-3.0
	Enneapogon lindleyanus	0.5-3.0
	Eulalia aurea	0.5-3.0
	Aristida contorta	0.5-3.0

Low-intensity grazing seed mix

The low-intensity grazing seed mix is given in Table 50.

Table 50 Low-intensity grazing seed mix

Species type	Species	Rate (kg/ha)
Tree	*Eucalyptus leucophylla*	0.15
	Corymbia terminalis	0.15
	Eucalyptus leucophloia	0.15
	Lophostemon grandiflorus	0.15
	Terminalia aridicola	0.15
	Corymbia apparrerinja	0.15
	Lysiphyllum cunninghamii	0.15
	Eucalyptus camaldulensis	0.15
Shrub	*Atalaya hemiglauca*	0.05-0.10
	Acacia chisholmii	0.05-0.10
	Acacia holosericea	0.05-0.10
	Acacia retivenea	0.05-0.10
	Carissa lanceolata	0.05-0.10
	Eremophila longifolia	0.05-0.10
Groundcover	*Triodia pungens*	0.5-3.0
	Cenchrus ciliaris	0.5-3.0
	Cyperus dactylotes	0.5-3.0

Species type	Species	Rate (kg/ha)
	Sehima nervosum	0.5-3.0
	Cenchrus pennisetiformis	0.5-3.0
	Triodia longiceps	0.5-3.0
	Heteropogon contortus	0.5-3.0
	Aristida hygrometrica	0.5-3.0

Native habitat / low-intensity grazing seed mix

The native habitat / low-intensity grazing seed mix is given in Table 51.

Table 51 Native habitat / low-intensity grazing

Species type	Species	Rate (kg/ha)
Tree	*Eucalyptus leucophylla*	0.15
	Corymbia terminalis	0.15
	Eucalyptus leucophloia	0.15
	Lophostemon grandiflorus	0.15
	Terminalia aridicola	0.15
	Corymbia apparrerinja	0.15
	Lysiphyllum cunninghamii	0.15
	Eucalyptus camaldulensis	0.15
Shrub	*Atalaya hemiglauca*	0.05-0.10
	Acacia chisholmii	0.05-0.10
	Acacia holosericea	0.05-0.10
	Carissa lanceolata	0.05-0.10
	Eremophila longifolia	0.05-0.10
Groundcover	*Triodia pungens*	0.5-3.0
	Triodia molesta	0.5-3.0
	Triodia longiceps	0.5-3.0
	Eriachne mucronata	0.5-3.0
	Themeda triandra	0.5-3.0
	Enneapogon lindleyanus	0.5-3.0
	Heteropogon contortus	0.5-3.0
	Cenchrus ciliaris	0.5-3.0

Seed sourcing

Where possible seed stock will be sourced from suitable areas of the Mine. If insufficient or unsuitable stock is available on site, seed will be sourced from local suppliers to ensure varieties are consistent with local conditions. Local suppliers in the Mount Isa and Cloncurry region include:

- Mount Isa Home and Garden Centre;
- The Rose Garden Nursery; and
- Leichardt River Nursery.

The collection of seed mixes will commence two years prior to the seeds being used. This will ensure the correct volume is available when rehabilitation works commence and to mitigate unfavourable weather that may cause failure of seed production in any one year. After collection, the seeds will be cleaned and stored in a dark, dry and cool location to maintain maximum viability over the storage period and minimise damage due to pests and fungi (DFAT 2016). Seeds will be stored for a maximum of five years prior to use and regular collections / purchases will be required throughout the duration of the Mine.

Seed application and timing

The seeding application process is outlined in Section 3.6.1.8e. Seeding will take place in rehabilitated areas once the area has been prepared, which will include topsoil placement and ripping. Where possible sowing will take place within one week of ripping and topsoil placement. In most cases, seeds should be sown immediately before the expected onset of rain or after the break of the season (DFAT 2016). Native seeds may require specific cues such as moisture and temperature prior to germination. This need for multiple environmental cues is species specific and may result in seeds being dormant in the seed bank for longer periods prior to germination occurring.

Seeding operations will not be undertaken under the following conditions:

- where the surface is fully saturated;
- when temperatures exceed 37°C;
- when wind speeds exceed 15 km/h; and
- during or immediately after heavy rain.

g Infrastructure

To allow for effective establishment of revegetated areas cattle should be excluded from access to the area in the early stages. This will be achieved by the use of permanent or temporary stock fencing. Existing fence lines will be utilised where possible. Cattle fencing may also discourage some macropods and other animals into the area.

3.6.2 Tailings storage facilities

The rehabilitation methodology for the TSF is provided in Sections 3.6.1.6 and 3.6.6.7.

3.6.3 Voids

The Mine is an underground operation and as such no voids will be present during or following operations.

3.6.4 Underground mining

3.6.4.1 Geotechnical study

Geotechnical stability assessments for the Mine are summarised in Appendix C and have previously been discussed in Section 3.1.4.3. The outcome of these assessments concluded that the risk of post-closure

underground stability and surface subsidence is low. This is largely based on a shallow weathering profile and shallow groundwater meaning groundwater has a minimal influence on underground stability and crown pillar stability.

An initial assessment (Appendix C) of sealing off surface openings to underground concluded that there is minimal risk of a significant build-up of water in the underground workings and further assessment is not currently warranted. This is based on the current mining method and the practice of completely tight filling underground voids. Should mining methodology or practices change further assessment may be required.

Post-closure residual subsidence is also addressed in Appendix CAppendix B. All stopes extracted underground have limited stope strikes and are cable bolted to increase short-term stability. They are all backfilled with either waste rock or cemented backfill to ensure long-term stability and confinement of voids, preventing long-term subsidence.

3.6.4.2 Conceptual model

A review of the existing hydrogeological conceptual model is contained in Appendix B. This review includes:

- an assessment of groundwater interactions and potential lowering of groundwater levels;
- consideration of the potential for AMD generation; and
- consideration of potential groundwater discharges to the surface.

3.6.4.3 Subsidence modelling

The Mine crown pillar and extraction method has been designed to ensure long term stability and prevent surface and underground subsidence. The primary purpose of the crown pillar is to protect surface land users during operations and to maintain stability post-closure. The crown pillar has been designed to prevent surface subsidence by being located in fresh rock and below the level of significant weathering. The top-level stopes beneath the crown are also backfilled, as tight as practically possible, to minimise the change of hangingwall unravelling in the long term. The Mine has also adopted a sub level open stope mine method with backfill to increase the long-term stability of the mine and ensure consolidation of voids.

The surface and underground subsidence risk is reviewed and summarised in Appendix C.

3.6.5 Built infrastructure

3.6.5.1 Retained infrastructure

No formal written agreements have been made regarding retained infrastructure and services. For the purposes of the PRC plan and ERC; it is therefore assumed that all buildings, water structures, powerlines and roads will be decommissioned and rehabilitated. However, opportunities to repurpose these will be investigated with potential post mining land users.

3.6.5.2 Decommissioning and removal

A demolition estimate report was developed in 2016 (Appendix N). The preferred method for the removal of built infrastructure is to progressively cut away sections of the structures using an excavator fitted with a long reach boom which has installed hydraulic shears. Cut sections will fall to the ground and then be collected and transported to a material processing area.

3.6.5.3 Heritage

From a heritage perspective, the Mine contains low levels of local cultural heritage significance. Cultural heritage items will not be damaged during the rehabilitation process.

Plans for the management of indigenous cultural heritage will be addressed through community consultation with the traditional owners.

3.6.5.4 Health and safety

The preparation of tender documents for significant works (ie decommissioning and removal of the administration buildings and infrastructure) will require a review of certain aspects of health, safety and environment. Criteria for each element will be set to appropriately review tender applications. This approach will ensure tender documents provide contractors with appropriate information about potential hazards and clarify MMG's expectations about the management of these hazards during execution of the contract. It also provides contractors with adequate time to plan how to meet MMG's expectations. This will reduce the potential for delays associated with non-compliant personnel, training and inductions. Post-relinquishment Mine safety will be addressed through achieving the rehabilitation requirements described in Table 31.

3.6.5.5 Rehabilitation maintenance

Maintenance of rehabilitated land must take place to ensure and demonstrate:

- stability of landforms and cover systems;
- erosion control measures remain effective;
- stormwater runoff and seepage from rehabilitated land does not negatively affect the environmental values of any waters; and
- vegetation show healthy growth and rehabilitated land are managed regarding declared pest plants.

Maintenance activities on rehabilitated land will be guided by general site inspections and rehabilitation monitoring results. Maintenance activities may include:

- maintenance of new vegetation, (ie addition of fertiliser, re-planting of significant locations of failed vegetation);
- repair of failed drainage or significantly eroded locations;
- modifications to landforms or structures to improve management of surface water runoff;
- upkeep of water management structures;
- removal of temporary drainage structures not required for long-term stability; and
- replacement and probable repairs to fencing and signage.

MMG intend to reduce the need for long-term maintenance to a level consistent with the PMLUs. It is anticipated that maintenance activities will be more substantial in the first few years post-closure, then will gradually diminish as more stable conditions develop.

3.6.6 Methods to rehabilitate land to a stable condition

3.6.6.1 Ancillary infrastructure and services

Demolition and removal of the following mine infrastructure will be undertaken by a third party as per the third-party quote (Appendix N):

- accommodation village and STP;
- Barminco project area;
- communications tower;
- emergency response training (ERT);
- explosives magazine;
- mine support infrastructure;
- office and administration;
- roads; and
- switchyard.

a Rehabilitation goals

On completion of mining, the infrastructure and services will be returned to safe, stable and non-polluting landforms, to allow the intended PMLU.

All mine roads will be removed and rehabilitated to safe and stable landforms to allow for the intended PMLU. Agricultural roads will not be removed as they existed pre-mining.

b Rehabilitation strategy

The closure and rehabilitation strategy associated with infrastructure and services will involve:

- SCA to determine any locations of actual or potential contamination;
- retaining any infrastructure or services (ie road / pipelines) that are required by post-closure land users (under formal agreement);
- removal of any remaining infrastructure, materials or equipment for their salvage and scrap values;
- disposal of any remaining materials in an appropriately licensed landfill or the underground workings;
- removal of any contaminated soils to an appropriate disposal site, followed by a contaminated site clean-up validation assessment to confirm required standards have been met; and
- replacement of soil, ripping and seed / fertiliser application.

It is assumed that only 50% of the accommodation village and STP will require revegetation as much of this area is not covered by infrastructure and will not have been disturbed. Some Mine access roads may be left for site access where appropriate and under formal written agreement with the landholder. Roads that are no longer required will be contoured to the surrounding landscape, ripped and left to naturally revegetate with pasture species in keeping with the surrounding landscape. If natural revegetation is not successful direct seeding will be applied.

Communication will occur with the local landowners during operations, as there is potential for some infrastructure and services to be retained after closure for use by post-closure land users.

Bitumen roads will have the pavement ripped. The surface will then be soiled, ripped and seeded with native species. Unsealed roads will have their surface scraped to remove gravel sheeting. The road surface will then be soiled, ripped and seeded with native species. It is likely that the access road and bridge will be retained post-closure for use by landholders through a formal agreement.

3.6.6.2 Borrow pits and stockpiles

Rehabilitation of the borrow pits and stockpiles will occur once the target material is no longer required, the location is no longer suitable, or the material has been exhausted. There are currently two soil stockpiles at the Mine, totalling approximately 157,203 m^3.

a Rehabilitation goals

Rehabilitated borrow pits will match the surrounding environment with minimal, if any, impact to surface flows, and maintain similar vegetation.

Soil stockpiles will be used throughout the operation and decommissioning phases, as required for rehabilitation, and will be returned to the pre-mining state during the closure phase.

b Rehabilitation strategy

The borrow pits have been previously reprofiled to match the surrounding environment, with slopes battered to be consistent with reference sites. All disturbed land will be soiled and ripped along the contour to minimise erosion. The land will be sown with native seed before the following wet season. Infill seeding may be required

after two years if the first two wet seasons do not produce enough rain to adequately support vegetation germination and growth.

Once stockpiled soil has been removed, the stockpile footprint will be ripped and seeded using the light grazing / native habitat seed mix.

3.6.6.3 Dams and diversion structures

a Rehabilitation goals

Water management structures will be decommissioned and will be safe, stable and non-polluting. Creek crossings and water storage that remain at closure will also be safe, stable and non-polluting.

b Rehabilitation strategy

Before rehabilitation occurs, water storage structures will be tested for any contaminated sediment, which will be removed and disposed of in the TSF. Synthetic liners will be removed and disposed of in accordance with licence conditions. The embankments, or other clean fill, will be dozed back into the dams to natural ground level. All stored water will be removed by solar evaporation. Dam surfaces will be ripped, soiled and seeded using the light grazing / native habitat seed mix.

It is likely that the five creek crossings, the raw water dam and the sediment dams will be retained post-closure for use by landholders through a formal agreement outlining management responsibilities. If creek crossings are to be removed, care will be taken to ensure minimal disruption to creek beds and banks during the rehabilitation process.

3.6.6.4 Exploration

Most of the current disturbance from exploration has been rehabilitated. However, exploration activities will continue during the mining, estimated to result in an additional 4.7 ha of disturbance over the LOM. Exploration areas will be rehabilitated as they become available as per Condition A33 of the EA.

a Rehabilitation goals

Exploration will be returned to safe and stable landforms to allow for the intended PMLU.

b Rehabilitation strategy

All drill holes will have their cases removed to 1 m bgl, backfilled with drill cuttings and sealed with a concrete plug. The disturbed land from exploration will be soiled, ripped and left to naturally revegetate. Should natural revegetation not be successful the areas will be seeded using the light grazing / native habitat seed mix. It is planned that progressive rehabilitation of exploration disturbance will result in no liability at the time of closure.

3.6.6.5 Mineralised waste

a Rehabilitation goals

At the end of mine life, all PAF and high sulfur NAF waste rock within the PAF WRD will have been removed and disposed of underground as part of operational stope-filling.

All other NAF waste rock will eventually be removed and either returned underground or will be used for the construction of the cover on the TSF. NAF waste rock may also be used for rehabilitation of roads, infrastructure, and underground vent shafts.

b Rehabilitation strategy

Once all NAF and PAF waste rock has been removed from the WRDs, rehabilitation of the WRD footprints will start. Soil below the PAF WRD will be excavated down to 0.5 m and disposed of in the TSF (in case the

near ground surface has become contaminated). Soil below the NAF WRD will not require excavation. The WRD footprint will be graded, soiled and deep-ripped to alleviate compaction and encourage natural regeneration. The WRD's will then be seeded using the light grazing seed mix from the revegetation plan.

3.6.6.6 Mining and processing area

The mining and processing area include the following features:

- north and south declines and box cuts;
- ROM pad;
- process plant;
- escape way shafts;
- ventilation shafts (combination of fresh-air intake and exhaust); and
- service holes for communications and services.

a Rehabilitation goals

On completion of mining, the mine facilities will be returned to safe and stable landforms, to allow the intended PMLU. The mining and processing areas have two PMLU's as identified in the EA. Low-intensity grazing and low-intensity grazing / native habitat.

b Rehabilitation strategy

All surface infrastructure (ie vent fans) will be removed. Underground infrastructure such as cabling and ventilation bags will be left underground. The box cut void and underground portal entrances will be backfilled with NAF waste rock. The portals and declines will be sealed with a 5 m long concrete bulkhead, which will be covered with NAF waste rock. Ventilation and egress shafts will be backfilled with NAF waste rock and then capped with concrete to prevent any subsidence.

The ROM pad and the process plant will be cleared of all waste rock and infrastructure. The ROM pad will be removed in full, down to natural ground level and disposed of at a licensed facility. Soil below the process plant will be removed down to 0.5 m and disposed of in a licensed facility in case the near ground surface has become contaminated.

Soil or a substitute growth medium will be applied to the concrete caps and any other disturbance. Low intensity grazing areas and grazing / native habitat will have the appropriate seed mix applied.

3.6.6.7 TSF

a Rehabilitation goals

The TSF will be covered (as per the strategy below) and revegetated. The downstream (western) embankment will be reshaped, and the facility will remain safe, stable and non-polluting.

b Rehabilitation strategy

The expected approach to TSF closure is set out below (noting that the final cover will be confirmed following the completion of cover trials):

- the tailings pipeline will be flushed, dismantled and disposed of at a licensed facility;
- a capillary break may be constructed directly over the tailings to prevent the rise of salts;
- a reduced permeability layer will be constructed above the capillary break to limit water infiltration;
- an infiltration storage layer will be placed over the reduced permeability layer to encourage controlled infiltration and vegetation growth;
- the downstream (western) embankment will be reshaped to a suitable slope, to direct stormwater flows off the TSF in a controlled manner;
- the downstream slope will be reconstructed as a broad, rock-armoured spillway chute;

- soil stripped from within the TSF footprint will placed on top of the cover as per the agreed design; and
- the final TSF surface will be seeded with the native species mix as per the revegetation plan.

The general quantities of materials required to complete the rehabilitation of the TSF have been estimated and are given in Table 52.

Table 52 Estimated quantities of materials required to rehabilitate TSF

Description	Unit	Quantity
Embankment slope modification — general rockfill	m^3	43,000
Capillary break (0.3 m thickness) — select permeable rock	m^3	200,476
Reduced permeability layer (0.5 m thickness) — low permeability weathered waste rock or general earthfill	m^3	167,064
Waste rock cover (ISL) (1 m thickness) — general waste rock	m^3	334,127
Soil layer (0.1 m average thickness)	m^3	66,825
Total	**m^3**	**811,492**

1. Estimated from cover option 2. The use of cover option 1 will require less material (Section 3.6.1.6).

3.6.6.8 How the rehabilitation method supports the rehabilitation milestones

This section presents the connection between the rehabilitation methods and milestones for a PMLU of pasture grazing and / or native habitat (Table 53).

Table 53 Relationship between rehabilitation milestones and rehabilitation methods

Milestone	Relationship to method
Infrastructure decommissioning and removal	All site infrastructure including buildings, dams and roads will be decommissioned and removed: • buildings will be isolated and demolished or removed; • demolition materials will be preferentially recycled; and • raw water and sediment dams will be desilted (if required) and backfilled using their embankments.
Remediation of contaminated land	• contaminated site assessment concentrating on the ROM pad, process pond, MIA, PAF WRDs, workshops and fuel station and storage: – assessment having regard for NEPM, EP Act and *Waste Reduction and Recycling Act 2011*. • contamination clean-up and disposal in accordance with licence conditions; • water management system retained until the threat of potential contamination no longer exists; and • landfill PMLU excluded because of the potential contamination threat to groundwater.
Landform development and reshaping / re-profiling	• modifications to landforms or structures to improve management of surface water runoff; • backfilling underground workings with waste rock;

Milestone	Relationship to method
	• constructing the final layer of the TSF in accordance with design conditions; and • assessment to check that the TSF is geotechnically stable.
Installation of cover	• all waste rock to be used in the cover will be classified as NAF; • the final (TSF) landform will be sheeted with adequate soil and sown with native seed; • the soil assessment has shown that adequate soil resources will be available to rehabilitate the final landform; • the fertility and dispersibility of the soil were assessed as acceptable for rehabilitation without any amelioration being needed; and • if subsoil is needed due to a shortage of topsoil, then gypsum rates have been given to reduce sodicity.
Surface preparation	• an assessment of soil health; • application of ameliorants as per requirements of the soil health assessment; • ripping of surfaces; and • apply appropriate amount of soil cover.
Revegetation (pasture grazing and / or native habitat)	• seeding at the nominated rate appropriate for each PMLU; • application of fertiliser; and • installation of fencing to protect establishing vegetation.
Achievement of surface requirements (pasture grazing and / or native habitat)	• assessment to check that revegetation is comparable to reference sites and consistent with the PMLU; and • assessment to check that weed and pest species are no greater than at reference sites.
Achievement of PMLU to a stable condition (pasture grazing and / or native habitat)	• assessment to check that the land can support the PMLU; • assessment to check that the land is safe and stable; • assessment to check that the erosion rate is <10 t/ha/yr; • assessment of surface water quality to make sure that it is not compromising the nominated PMLU; and • assessment of groundwater quality to make sure that it is not compromising EA conditions.

3.7 Risk assessment

Identifying environmental, community, social and economic impacts and risks associated with closure and rehabilitation is critical for effective closure and rehabilitation planning. The overall objective of the closure and rehabilitation risk assessment (the risk assessment) is to identify risks of a stable condition for land not being achieved and how MMG intends to manage or mitigate the identified risks in accordance with Section 126C(l)(f) of the EP Act. The meaning of a 'stable condition' is given in Section 111A of the EP Act:

111A Meaning of stable condition

Land is in a stable condition if —

a) the land is safe and structurally stable; and

b) there is no environmental harm being caused by anything on or in the land; and

c) the land can sustain a post-mining land use.

The risk assessment given in the following sections is an updated version of the risk assessment developed in 2010 by AARC and presented in the approved EIA. The original risk assessment generally focused on risks to the company or EV's. The updated version is focused on risks that are specific to the achievement of a stable condition for rehabilitated land. These risks have been categorised by their potential impact to the achievement of each rehabilitation milestone.

The risk assessment was developed considering the standard *AS ISO 31000:2018 Risk Management — Guidelines*. Risks and opportunities were identified for all decommissioning, demolition and closure and rehabilitation related activities that are yet to have occurred, or already have occurred at the Mine. The post closure and rehabilitation monitoring periods were also included.

3.7.1 Risk identification

The risk identification step was used to:

- identify and define risks to land being safe and structurally stable;
- identify and define risks which have the potential to adversely affect EV's; and
- identify and define risks to land sustaining the PMLU.

3.7.2 Risk analysis

The risk analysis process considered the maximum probable outcome for each identified risk with the current control measures in place. The likelihood and consequences of each were then analysed and quantified using *MMG's Risk Management Procedure* (Document number: 16254157).

The consequence categories and associated criteria used in the risk assessment process are given in Figure 19 (the consequence table). Given that only the 'environment' category is relevant in this case, the consequence category has been listed according to which aspect of land achieving a stable condition is relevant; that is:

- land being safe and structurally stable (safe and stable);
- potential impact to environmental values (impact to EV's); and
- land able to support the PMLU (PMLU).

Following the identification of the potential consequence, the criteria outlined in the likelihood table were used to identify the likelihood of these events occurring. These criteria are provided in Figure 20. Finally, the risk matrix was used to determine the risk ranking and is given in Figure 21.

Rating	Direct and/or Consequential Financial Loss USD millions	Planned production throughput Days	Fraud or theft USD millions	Safety & People	Environment	Legal Compliance
6	>100	>28	>10	▪ >2 Fatalities ▪ International NGO or National Government intervention in response to multiple community fatalities resulting from mining related activities or disputes	▪ Regional, offsite environmental impact requiring long-term recovery (years) with irreversible residual damage ▪ Species extinction or permanent impairment of ecosystem function or biodiversity value within site ▪ Irreversible loss/damage to site or item of significant cultural heritage value	▪ Regulatory or operating licence non-compliance, or any incident or circumstance with a probable fine of > USD 30 million ▪ Civil claim with damages of >100million ▪ Imprisonment of company executive ▪ Failure to deliver on community agreements or accords with maximum potential compensation cost of > USD 30 million
5	>50 – 100	>14 - 28	>5 - 10	▪ 1 – 2 Fatalities ▪ 1 or more Community Fatalities resulting from mining related activities or disputes	▪ Prolonged or severe, offsite environmental impact requiring long-term clean-up (years). ▪ Extensive unconfined, on lease impact requiring long-term clean-up (months-years) leaving residual damage ▪ Change to ecosystem function or biodiversity value within site ▪ Irreversible damage to site or item of significant cultural heritage value	▪ Regulatory or operating licence non-compliance, or any incident or circumstance with a probable fine of USD 15 -30million or potential trigger for loss of licence. ▪ Civil claim with damages of more than USD 50 -100 million ▪ Failure to deliver on community agreements or accords with maximum potential compensation cost of USD 15-30 million
4	>10 – 50	>7 - 14	>3 – 5	▪ Permanent disabling injury or illness ▪ Multiple Lost Time Injuries ▪ Multiple Community Medical Treatment Injuries resulting from mining related activities or disputes	▪ Major, offsite, environmental impact requiring medium-term clean-up (months). ▪ Onsite confined impact requiring significant clean-up effort (years) ▪ Temporary impairment of an ecosystem function or any kill/loss of a listed or protected species ▪ Repairable damage to site or item of significant cultural heritage value	▪ Regulatory or operating licence non-compliance with a maximum potential fine of USD 10-<15 million ▪ Failure to deliver on community agreements or accords with maximum potential compensation cost of USD 10-<15 million
3	>5 – 10	>3 - 7	>1 – 3	▪ Single Lost Time Injury / Illness ▪ Reversible disability / disabling illness(es) ▪ Single Community Medical Treatment Injury resulting from mining related activities or disputes	▪ Reversible offsite environmental impact, requiring short-term clean-up (weeks) ▪ Onsite, confined, reversible environmental impact, requiring medium term (weeks-months) clean-up	▪ Regulatory or operating licence non-compliance with a maximum potential fine of USD 5 - <10 million ▪ Failure to deliver on community agreements or accords with maximum potential compensation cost of USD 5-<10 million
2	1-5	1 - 3	0.5 - 1	▪ Medical Treatment Injury / Illness(es) ▪ Restricted Work Injury(ies)	▪ Low, confined, reversible environmental impact ▪ Short term (less than a week) clean-up	▪ Regulatory or operating licence non-compliance with a maximum potential fine of less than USD 5 million ▪ Failure to deliver on community agreements or accords with maximum potential compensation cost of < USD 5 million
1	<1	<1	< 0.5	▪ First aid treatment	▪ Very low, reversible environmental impact confined to a small area within operations ▪ Prompt (within a shift) clean-up	▪ Breach of site standard or direction. ▪ Breach of community agreement or accord

Figure 19 Consequence table

Likelihood	Business	Projects	Likelihood Category
	Based on MMG and industry experience and expected conditions, the risk event	Based on MMG and industry experience and expected conditions, with similar studies or projects, the risk event	
Almost Certain	Could be incurred more than once in a year	Could be expected to occur more than once during the study or project delivery	**F**
Likely	Could be incurred over a 1-2 year period	Could easily be incurred and has generally occurred in similar studies or projects	**E**
Possible	Could be incurred within a 5 year period	Has been incurred in a minority of similar studies or projects	**D**
Unlikely	Could be incurred within a 5-20 year period	Has been known to happen, but only rarely	**C**
Rare	Could be incurred within a 20-50 year period	Has not occurred in similar studies or projects but could	**B**
Very Rare	Could be incurred in a period > 50 years	Conceivable, but only in extreme circumstances	**A**

Figure 20 Likelihood table

Likelihood Rating							
	F	Medium	Medium	High	Very High	Very High	Very High
	E	Low	Medium	High	High	Very High	Very High
	D	Low	Medium	Medium	High	Very High	Very High
	C	Low	Low	Medium	High	High	Very High
	B	Low	Low	Medium	Medium	High	Very High
	A	Low	Low	Low	Medium	High	High
		1	2	3	4	5	6
		Consequence Rating					

Figure 21 Risk matrix

3.7.3 Risk evaluation

The risk evaluation results are given in Table 54.

Table 54 Results of risk assessment

Work area or exposure group	Risk / threat (aspect)	Consequence category	Impact	Current control measures	Consequence	Likelihood	Current risk
RM1	1. Water quality in any retained dams does not meet the PMLU.	PMLU	Dams cannot be used for stock watering and are incompatible with the PMLU	Water quality monitoring to establish trends.	3	D	Medium
RM1	2. Inadequate closure and rehabilitation of exploration works.	PMLU	Exploration areas do not support the PMLU	A requirement exists to rehabilitate exploration disturbance within 12 months should they be outside of the mined footprint. Exploration database detailing locations and status of drill holes.	3	D	Medium
RM1	3. Land instability caused by ineffective removal of infrastructure	Safe and stable	Land instability	ERC mapping shows all current infrastructure	1	C	Low
RM1	4. Future land user impacted by ineffective removal of subsurface infrastructure eg. pipelines, cabling etc.	Safe and stable and PMLU	Land unstable and does not support the PMLU	Site services drawings show subsurface infrastructure	1	C	Low
RM2	5. AMD contamination	Impact to EV's	Contaminated soil and / or water. Acidified soil and / or water.	Assumed average depth of contamination of 0.5 m across footprint.	4	D	High

Work area or exposure group	Risk / threat (aspect)	Consequence category	Impact	Current control measures	Consequence	Likelihood	Current risk
	beneath temporary PAF WRD.			Contaminated material will be disposed of either underground or in the TSF.			
RM2	6. Previously unidentified contaminated land and areas mistakenly identified as low risk / not requiring sampling.	Impact to EV's	Hydrocarbon contamination impacts EV's	Record all contamination events in MMG Incident and Event Management (IEM) software module.	3	D	Medium
RM2	7. Ineffective removal/treatment of contaminated material impacts PMLU	Impact to EV's and PMLU	Groundwater or surface water contamination PMLU not supported	Record all contamination events in MMG Incident and Event Management (IEM) software module. AQP to provide assessment and remediation plan at closure AQP validation of previously contaminated areas	3	D	Medium
RM3	8. Dams not properly backfilled	Safe and stable and PMLU	Low lying areas become waterlogged Impact to vegetation Subsidence causing instability Does not support PMLU	Survey control during backfilling Current designs allow for settling of material after backfilling	2	C	Low

Work area or exposure group	Risk / threat (aspect)	Consequence category	Impact	Current control measures	Consequence	Likelihood	Current risk
RM3	9. Inadequate erosion and sediment control leads to excessive erosion / land instability	Impact to EV's	Landform not stable enough for surface preparation Does not support PMLU	ESCP for operational phase of Mine Engineering designs include consideration of drainage and erosion and sediment control	2	C	Low
RM3	10. Constructed landforms not consistent with design	PMLU	Landform does not support PMLU ie. slopes too steep	Current designs consistent with licence conditions Survey control during construction	3	C	Medium
RM3	11. Shafts, portals and adits not properly backfilled	Safe and stable and PMLU	Subsidence causing instability Does not support PMLU Safety risk to people, stock and wildlife	Backfilling during operational phase of Mine Engineering designs for placement of backfill Survey control during backfill placement Subsidence monitoring	3	C	Medium
RM3	12. Drains are removed prematurely leading to landform instability.	Safe and stable	Uncontrolled runoff causes excessive erosion and landform instability	Rehabilitation monitoring to ensure adequate vegetation between contours. Limit disturbance. Rip / create surface roughness to reduce erosion potential.	3	C	Medium
RM4	13. TSF spillway and embankment conversion not	Safe and stable	TSF spillway and embankment not adequate to handle large rain events as per design	Spillway design established	4	C	High

Work area or exposure group	Risk / threat (aspect)	Consequence category	Impact	Current control measures	Consequence	Likelihood	Current risk
	consistent with design			AQP certification of design and construction Survey control during construction			
RM4	14. TSF does not adequately shed water leading to instability	Safe and stable	Damage to rehabilitated surface / vegetation Safety risk to people, stock and wildlife	Required drainage well established and included in design AQP certification of design and construction Survey control during construction	4	C	High
RM4	15. Capillary break not adequate or improperly installed allowing release of solutes	Impact to EV's, safe and stable	Impact to surface and groundwater Landform instability	Field trials to verify proposed cover design prior to closure AQP certification of design and construction Survey control during construction	4	C	High
	16. RPL not adequate or improperly installed allowing release of solutes or water infiltration to the capillary break layer	Impact to EV's, safe and stable	Impact to surface and groundwater Landform instability	Field trials to verify proposed cover design prior to closure AQP certification of design and construction Survey control during construction	4	C	High

Work area or exposure group	Risk / threat (aspect)	Consequence category	Impact	Current control measures	Consequence	Likelihood	Current risk
RM4	17. ISL not properly installed allowing seepage and underlying instability or does not support vegetation growth	Impact to EV's, safe and stable and PMLU	Impact to surface and groundwater Damage to rehabilitated surface / vegetation Safety risk to people, stock and wildlife	Field trials to verify proposed cover design prior to closure AQP certification of design and construction Survey control during construction	4	C	High
RM4	18. Inadequate suitable or unsuitable material used to complete cover layers	Safe and stable	Unsuitable material causes stability issues Potential increased disturbance to recover additional material	Field trials to verify proposed material to be used in cover layers prior to closure Projected to be adequate material in waste rock dump Survey updates of stockpile size	2	C	Low
RM5	19. Inadequate stockpiles of soil / growth media.	PMLU	Inability or delay to rehabilitate some landforms. Thin growth media application may impact closure and rehabilitation success and require additional growth media.	Survey checks and monitoring. Soil management procedures. Soil inventory updated in register.	3	E	High
RM5	20. Soil / growth media not applied as per required specifications	PMLU	Vegetation does not adequately establish Loss of topsoil / growth medium resource	Supervision during rehabilitation works Survey control of surface prior to and following soil placement	2	D	Medium

Work area or exposure group	Risk / threat (aspect)	Consequence category	Impact	Current control measures	Consequence	Likelihood	Current risk
RM5	21. Subsidence or erosion not effectively remediated leading to instability	Safe and stable	Landform instability Loss of topsoil / growth medium resource	Reshaped / resurfaced areas inspected prior to surface preparation ESCP for operational phase of Mine	2	C	Low
RM5	22. Inadequate amelioration does not prepare soil for target vegetation impacting PMLU	PMLU	Loss of topsoil / growth medium resource due to erosion Does not support PMLU	Soil health and suitability assessment completed by AQP Rehabilitation trials during operational phase	2	C	Low
RM6	23. Natural revegetation not sufficient for surface stabilisation	PMLU	Vegetation does not adequately establish Loss of topsoil / growth medium resource	Inspection one year post completion to evaluate establishment by natural revegetation Rehabilitation trials during operations Natural revegetation not completed on slopes / high risk areas	2	D	Medium
RM6	24. Direct seeding not sufficient for vegetation establishment	PMLU	Vegetation does not adequately establish Loss of topsoil / growth medium resource	Seeding rate chosen based on AQP input Rehabilitation trials during operations	2	D	Medium

Work area or exposure group	Risk / threat (aspect)	Consequence category	Impact	Current control measures	Consequence	Likelihood	Current risk
RM6	25. Inadequate fertiliser application	PMLU	Vegetation does not adequately establish	Fertiliser application based on soil health and suitability assessment	2	C	Low
RM6	26. Stock fencing not effective in protecting rehabilitated areas prior to stabilisation	PMLU	Vegetation does not adequately establish	Some stock fencing already established on site Communication with neighbouring landholders	2	C	Low
RM7	27. Areas nominated for establishment of native habitat are dominated by pasture species and don't achieve desired native species composition or density.	PMLU	Does not support PMLU	Presence of unwanted species will be noted during rehabilitation monitoring Seed mixes for native habitat areas exclude pasture grasses	3	D	Medium
RM7	28. Vegetation cover on the rehabilitated landform is dominated by weeds and is not	PMLU	Does not support PMLU	Presence of weeds will be reported to SHEC personnel. Inspection of all mobile and stationary plants for seed. Manage according with DRM Weed Control Program.	3	D	Medium

Work area or exposure group	Risk / threat (aspect)	Consequence category	Impact	Current control measures	Consequence	Likelihood	Current risk
	compatible with the PMLU						
RM7	29. Groundcover not sufficient for surface stabilisation	PMLU and safe and stable	Vegetation does not adequately establish Loss of topsoil / growth medium resource Landform instability Does not support PMLU	Seeding rate and seed variety chosen based on AQP input Rehabilitation trials during operations	2	D	Medium
RM7	30. Vegetation species not consistent with PMLU	PMLU	Does not support PMLU	Seed varieties chosen by AQP and consistent with PMLU	2	B	Low
RM7	31. Surface erosion exceeds criteria leading to surface instability	PMLU and safe and stable	Loss of topsoil / growth medium resource Landform instability Does not support PMLU	Effective establishment of groundcover for stabilisation	2	C	Low
RM8	32. Surface water runoff not compatible with PMLU / causes environmental harm	Impact to EV's and PMLU	PMLU not achieved Environmental harm from contaminated runoff	Rehabilitation planning Conceptual closure plan Surface water monitoring	4	C	High
RM8	33. Introduction of grazing onto steeper slopes triggers erosion	PMLU and safe and stable	Impact on revegetation success. Erosion causes landform instability	No current controls (currently no grazing of rehabilitation)	3	E	High

Work area or exposure group	Risk / threat (aspect)	Consequence category	Impact	Current control measures	Consequence	Likelihood	Current risk
	where carrying capacity is exceeded.						
RM8	34. Lack of closure and rehabilitation maintenance ie repair of significant erosion.	Safe and stable and PMLU	Heavily eroded landforms become unstable Does not support PMLU	No current controls (no significant rehabilitation completed)	3	D	Medium
RM8	35. Groundwater contamination from rehabilitated area	Impact to EV's	Contamination of groundwater	Groundwater monitoring Hydrogeological conditions not favourable to surface and groundwater interaction Groundwater generally of poor quality and not used for productive purposes	3	C	Medium
RM8	36. Inappropriate PMLU – PMLU criteria cannot be met	PMLU	Does not support the nominated PMLU	PMLU is low intensity grazing, native habitat or mixed use based on the EA. PMLU's are compatible with current and previous land uses Engagement with potential landholders ongoing.	4	D	High
RM8	37. PMLU does not meet expectations	PMLU	Does not support the PMLU	CHMP commitments.	3	D	Medium

Work area or exposure group	Risk / threat (aspect)	Consequence category	Impact	Current control measures	Consequence	Likelihood	Current risk
	of Traditional Owners.			Quarterly meeting with Kalkadoon, Mitakoodi and Mayi Traditional Owners through the CCC.			
RM8	38. Stakeholders want different PMLU's to what is currently agreed.	PMLU	Does not support the PMLU	Continuing community consultation. Current PMLU's are consistent with community views PMLU is compliant with EA.	3	D	Medium
RM8	39. Rehabilitated landforms are not maintained by future landowners.	PMLU	Moderate impacts and levels of remediation required.	Post-closure management plan in place. Legal agreement.	3	D	Medium
RM8	40. In the future local weather patterns may change (ie rainfall and ambient temperature) resulting in weather patterns that are not compatible with a PMLU.	PMLU	Does not support the PMLU	PRC plan that includes landforms and vegetation that is compatible to a PMLU of grazing and is compatible with current weather patterns.	I	C	Low

3.7.4 Risk treatment

Risk treatment involves evaluating options for the management or mitigation of identified risks. The most appropriate risk treatment options (proposed actions) have been selected based on multiple criteria including cost benefit, regulatory obligations, community responsibility and protection of EVs. Actions to apply these options have been allocated to the appropriate work parties, scheduled and performance measures and constraints identified. The risk treatment plan is given in Table 55.

3.7.4.1 Residual risk

The nominated treatment options have been assessed as adequate in reducing the original risk ranking to an acceptable level. The risk treatments and the remaining risk should be monitored and reviewed regularly with any significant changes or emerging issues communicated with relevant parties. Treatments may be modified, replaced, or complemented with additional treatments as needed to make sure an acceptable level of risk is maintained.

Table 55 Risk treatment plan

Risk	Treatment	Justification for risk treatment	Responsibility	Resource requirements	Performance measures and constraints	Reporting and monitoring	Timing and scheduling	Residual risk (C+L)
1. Water quality in any retained dams does not meet the PMLU	Include dam removal in ERC Incorporate actions in response to monitoring results in annual report. Investigate treatment and disposal options for water as required.	Inclusion in ERC allows budget for 'worst case scenario' of full removal. Intervention based on monitoring may be able to improve water quality outcomes. If dams cannot be retained options for	SHEC	Data from water quality monitoring	Water quality data	Internal reporting only	Ongoing	2 + C = Low

Risk	Treatment	Justification for risk treatment	Responsibility	Resource requirements	Performance measures and constraints	Reporting and monitoring	Timing and scheduling	Residual risk (C+L)
		treatment and disposal will be required						
2. Inadequate closure and rehabilitation of exploration works.	Review and validate audit of all historic and current drill holes to determine how many remain unrehabilitated Develop program to progressively rehabilitate drill holes and pads Add additional drillholes to database as they are constructed	Validation audit provides accurate data for rehabilitation works scope.	SHEC Technical services	Exploration drill data Equipment for rehabilitation	Rehabilitation monitoring to include exploration areas	Rehabilitation monitoring reports	As per exploration code of practice or as dictated in EA	2 + C = Low
3. Land instability caused by ineffective removal of infrastructure	Ensure infrastructure mapping is kept updated	Current infrastructure well known	SHEC Technical Services	ERC tool Survey support	ERC auditing	ERC reportable to regulator	Ongoing	1 + B = Low

Risk	Treatment	Justification for risk treatment	Responsibility	Resource requirements	Performance measures and constraints	Reporting and monitoring	Timing and scheduling	Residual risk (C+L)
4. Future land user impacted by ineffective removal of subsurface infrastructure eg. pipelines, cabling etc.	Ensure infrastructure mapping is kept updated	Current infrastructure well known	SHEC Technical Services	ERC tool Survey support	ERC auditing	ERC reportable to regulator	Ongoing	1 + B = Low
5. AMD contamination beneath temporary PAF WRD	Allow for contaminated soil disposal in closure costs Monitor groundwater adjacent to dump	High probability of contamination below dump so remediation will most likely be required Inclusion in ERC provides budget and time allocation for completion Groundwater monitoring may provide early evidence of issues to rectify	SHEC	ERC estimate Groundwater monitoring data	Groundwater data Update ERC as required	Groundwater reporting as per EA requirements	Data review as per EA conditions	3 + D = Medium

Risk	Treatment	Justification for risk treatment	Responsibility	Resource requirements	Performance measures and constraints	Reporting and monitoring	Timing and scheduling	Residual risk (C+L)
6. Previously unidentified contaminated land mistakenly identified as low risk / not requiring sampling.	Record incidents and events with potential to cause contamination. Develop a plan to identify which domains require a phase 1 contaminated land assessment Complete a phase 1 contaminated land assessment for identified areas	Properly kept records allow for potential contamination to be identified during contaminated land assessments. Validation from a SQP required	SHEC	MMG Incident and Event management (IEM) software module. ERC tool	Performance may be measured by inspections, auditing and land assessment.	Regular review of event and incident system. Contaminated land report part of relinquishment documentation	Ongoing audits, inspections and review of register Contaminated land assessment following treatment	2 + D = Medium
7. Ineffective removal/treatment of contaminated material impacts PMLU	Ensure contamination removal / treatment program is certified by an AQP	AQP best placed to design and oversee treatment programs	SHEC	MMG Incident and Event management (IEM) software module. ERC tool	Performance may be measured by contaminated land assessment and validation testing	Contaminated land report part of relinquishment documentation	Phase 1 contaminated land assessment during decommissioning Validation testing prior to earthworks	2 + C = Low

Risk	Treatment	Justification for risk treatment	Responsibility	Resource requirements	Performance measures and constraints	Reporting and monitoring	Timing and scheduling	Residual risk (C+L)
8. Dams not properly backfilled impacting PMLU	Ensure adequate supervision of field works	Supervision ensures backfilling is completed to design	Technical services SHEC	Design plans Survey support	Inspections and survey during construction Final survey at completion	Internal reporting only	Ongoing during works	1 + C = Low
9. Inadequate erosion and sediment control leads to excessive erosion / land instability	Ensure adequate supervision and inspection of field works	Supervision and inspection ensure controls are installed as per design	SHEC	Design plans ESCP	Regular inspections during construction Rehabilitation monitoring	Internal reporting only	Regularly during construction and upon completion	1 + C = Low
10. Constructed landforms not consistent with design	Ensure adequate supervision of field works	Supervision ensures landform is constructed to design	Technical services SHEC	Design plans Survey support	Inspections and survey during construction Final survey at completion	Internal reporting only	Ongoing during works Final survey	2 + C = Low
11. Shafts, portals and adits not properly backfilled	Ensure adequate supervision of field works	Supervision ensures backfilling is completed to design	Technical services SHEC	Design plans Survey support Geotechnical support	Inspections and survey during construction Subsidence monitoring	Internal reporting Communication to landholders if safety risk remains	Regularly during construction and upon completion	2 + C = Low

Risk	Treatment	Justification for risk treatment	Responsibility	Resource requirements	Performance measures and constraints	Reporting and monitoring	Timing and scheduling	Residual risk (C+L)
12. Drains are removed prematurely leading to landform instability	Implement rehabilitation monitoring program Develop suitable criteria for drain removal	Consistent criteria will allow for removal at appropriate time	SHEC	Data from rehabilitation monitoring.	Rehabilitation monitoring	Internal reporting only	Prior to removal of any drainage systems	2 + C = Low
13. TSF spillway and embankment conversion not consistent with design	Ensure AQP supervision and inspection of field works	AQP certification ensures conversion is constructed as per design	Technical services SHEC	Certified design plans Survey support	Inspections and survey during construction AQP construction certification	AQP reporting to site team	Inspection by AQP set by certified design requirements	2 + C = Low
14. TSF does not adequately shed water leading to instability	AQP certified design and construction supervision	Effective water shedding is a critical element of design and has been addressed	Technical services SHEC	Certified design plans Survey support	Inspections and survey during construction AQP construction certification	AQP reporting to site team	Inspection by AQP set by certified design requirements	3 + C = Medium
15. Capillary break not adequate or improperly installed allowing	AQP certified design and construction supervision	Proper design and construction of the capillary break layer	Technical services SHEC	Certified design plans Survey support Cover trial results	Inspections and survey during construction	AQP reporting to site team	Inspection by AQP set by certified design requirements	3 + C = Medium

Risk	Treatment	Justification for risk treatment	Responsibility	Resource requirements	Performance measures and constraints	Reporting and monitoring	Timing and scheduling	Residual risk (C+L)
release of solutes		will mitigate the risk of solute release			AQP construction certification			
16. RPL not adequate or improperly installed allowing release of solutes or water infiltration to the capillary break layer	AQP certified design and construction supervision	RPL designed as a barrier between capillary break and ISL layer	Technical services SHEC	Certified design plans Survey support Cover trial results	Inspections and survey during construction AQP construction certification	AQP reporting to site team	Inspection by AQP set by certified design requirements	3 + C = Medium
17. ISL not properly installed allowing seepage and underlying instability or does not support vegetation growth	AQP certified design and construction supervision	ISL designed to prevent seepage	Technical services SHEC	Certified design plans Survey support Cover trial results	Inspections and survey during construction AQP construction certification	AQP reporting to site team	Inspection by AQP set by certified design requirements	3 + C = Medium
18. Inadequate suitable or unsuitable material used to complete cover layers	Update waste rock volumes regularly	Projected waste rock is adequate for ISL construction	Technical services SHEC	Certified design plans Survey support ERC tool	Assess waste rock inventory against rehabilitation requirements regularly.	Waste rock inventory included in ERC supporting information.	Regularly and during ERC reporting	1 + C = Low

Risk	Treatment	Justification for risk treatment	Responsibility	Resource requirements	Performance measures and constraints	Reporting and monitoring	Timing and scheduling	Residual risk (C+L)
19. Inadequate stockpiles of soil / growth media.	Assess soil inventory ahead of rehabilitation. Maintain record of soil inventory. Undertake growth media trials Develop management plan for deficient areas	Quantifying and monitoring of soil inventory aids in planning of rehabilitation. Suitable alternate growth mediums may supplement supply	Technical services SHEC	Survey support. Soil inventory tool.	Assess soil inventory against rehabilitation requirements regularly.	Soil inventory included in ERC supporting information.	Prior to any site clearing.	2 + E = Medium
20. Soil / growth media not applied as per required specifications	Ensure adequate supervision and inspection of field works	Supervision ensures soil / growth medium placement is completed to specifications	SHEC	Survey support Soil inventory tool	Test pitting of placed material	Internal reporting only	Regularly during material placement	1 + D = Low
21. Subsidence or erosion not effectively remediated leading to instability	Inspection and remediation of surface prior to material placement	Subsidence or erosion issues must be addressed prior to further works	SHEC	Survey support	Field inspection	Internal reporting only	Prior to placement of topsoil / growth medium	1 + C = Low

Risk	Treatment	Justification for risk treatment	Responsibility	Resource requirements	Performance measures and constraints	Reporting and monitoring	Timing and scheduling	Residual risk (C+L)
22. Inadequate amelioration does not prepare soil for target vegetation impacting PMLU	Review rehabilitation trial data and rehabilitation monitoring data	Review of data from trials and monitoring provides evidence of treatment success	SHEC	Data from rehabilitation monitoring Rehabilitation trial data	Rehabilitation monitoring Rehabilitation trials	Internal reporting only	Following establishment of rehab trials or completed rehabilitation	1 + C = Low
23. Natural revegetation not sufficient for surface stabilisation	Implement follow up seeding for areas not sufficiently established	Reseeding will enhance vegetation establishment	SHEC	Data from rehabilitation monitoring Rehabilitation trial data	Rehabilitation monitoring Rehabilitation trials	Internal reporting only	Following establishment of rehab trials or completed rehabilitation	2 + C = Low
24. Direct seeding not sufficient for vegetation establishment	Review seeding methodology and seed mix and implement follow up seeding for areas not sufficiently established	Review to determine root cause of lack of establishment Reseeding will enhance vegetation establishment	SHEC	Data from rehabilitation monitoring Rehabilitation trial data	Rehabilitation monitoring Rehabilitation trials	Internal reporting only	Following establishment of rehab trials or completed rehabilitation	2 + C = Low
25. Inadequate fertiliser application	Review application rate following rehabilitation trials and monitoring	Review of data from trials and monitoring used to evaluate	SHEC	Data from rehabilitation monitoring Rehabilitation trial data	Rehabilitation monitoring Rehabilitation trials	Internal reporting only	Following establishment of rehab trials or completed rehabilitation	1 + C = Low

Risk	Treatment	Justification for risk treatment	Responsibility	Resource requirements	Performance measures and constraints	Reporting and monitoring	Timing and scheduling	Residual risk (C+L)
		application rate						
26. Stock fencing not effective in protecting rehabilitated areas prior to stabilisation	Inspect rehabilitation areas for stock presence	Ensure stock are not allowed access to rehabilitation areas prior to stabilisation	SHEC	Budget provision for fencing Landholder co-operation	Inspections Rehabilitation monitoring	Internal reporting Communication with landholders	Immediately following rehabilitation and ongoing	1 + C = Low
27. Areas nominated for establishment of native habitat are dominated by pasture species and don't achieve desired native species composition or density.	Implement rehabilitation monitoring program	Monitoring will confirm presence of pasture species	SHEC	Data from rehabilitation monitoring	Rehabilitation monitoring	Rehabilitation monitoring reports	Ongoing	2 + C = Low
28. Vegetation cover on the rehabilitated landform is dominated by weeds and is not compatible with the PMLU	Consider including weed declarations during seed procurement Implement rehabilitation monitoring	Source weed free seed where feasible to remove a source of weed seed. Monitoring will confirm	Commercial and procurement SHEC Site maintenance	Seed testing and validation results Data from rehabilitation monitoring	Rehabilitation monitoring	Rehabilitation monitoring reports	Following first site rehabilitation / ongoing	2 + C = Low

Risk	Treatment	Justification for risk treatment	Responsibility	Resource requirements	Performance measures and constraints	Reporting and monitoring	Timing and scheduling	Residual risk (C+L)
	program including weed survey Implement inspection of all mobile and stationary plant for seeds.	early outbreaks can be treated. Inspection of equipment will help to manage another source of weed seed.		Equipment inspection standard				
29. Groundcover not sufficient for surface stabilisation	Review rehabilitation monitoring data and implement remediation where required	Data will provide targets for remediation	SHEC	Data from rehabilitation monitoring	Rehabilitation monitoring	Internal reporting only	Following first site rehabilitation / ongoing	2 + C = Low
30. Vegetation species not consistent with PMLU	Review rehabilitation monitoring data	Data to confirm species present	SHEC	Data from rehabilitation monitoring	Rehabilitation monitoring	Internal reporting only	Following first site rehabilitation / ongoing	1 + B = Low
31. Surface erosion exceeds criteria leading to surface instability	Review rehabilitation monitoring data	Monitoring to check outcome against criteria	SHEC	Data from rehabilitation monitoring	Rehabilitation monitoring	Internal reporting only	Following first site rehabilitation / ongoing	1 + C = Low

Risk	Treatment	Justification for risk treatment	Responsibility	Resource requirements	Performance measures and constraints	Reporting and monitoring	Timing and scheduling	Residual risk (C+L)
32. Surface water runoff not compatible with PMLU / causes environmental harm	Ensure appropriate rehabilitation of contaminated areas Ensure ongoing monitoring of surface water runoff	The most likely source of surface water contamination is contaminated land. Ensuring contaminated land is identified and treated effectively will reduce the risk of poor runoff	SHEC	Data from rehabilitation monitoring reports Data from water monitoring Data from materials characterisation	Assessed against completion criteria.	Internal reporting	Ongoing	3 + C = Medium
33. Introduction of grazing onto steeper slopes triggers erosion where carrying capacity is exceeded	Implement rehabilitation monitoring program. Undertake grazing trials Fencing of unsuitable pasture grazing land (if required) Continue ESC monitoring and	Monitoring is the best methodology for identifying erosion issues. Fencing of unsuitable land is an effective physical control if needed.	SHEC	Data from rehabilitation monitoring. Data from grazing trials Data from ESC monitoring.	Assessed against completion criteria. Rehabilitation monitoring. Grazing trials ESC monitoring.	Performance against completion criteria communicated to SHEC team	Following start of pasture grazing on rehabilitated land.	3 + D = Medium

Risk	Treatment	Justification for risk treatment	Responsibility	Resource requirements	Performance measures and constraints	Reporting and monitoring	Timing and scheduling	Residual risk (C+L)
	management program.							
34. Lack of closure and rehabilitation maintenance ie repair of significant erosion.	Implement rehabilitation monitoring program. Budget for closure and rehabilitation maintenance works. Develop closure and rehabilitation maintenance plan and schedule based on monitoring. Develop and start ESC monitoring and management program.	Monitoring allows for detection of rehabilitation maintenance needs. Budget allocation is essential for works to be carried out. Planning for the method and scheduling of works confirms their effectiveness.	SHEC Dugald River – GM	Survey control Data from rehabilitation monitoring Equipment for remediation	Follow up monitoring and inspection of remediated areas	Rehabilitation and ESC monitoring results and maintenance needs will be communicated internally	Ongoing	2 + D = Medium
35. Groundwater contamination from rehabilitated area	Ongoing monitoring of groundwater	Monitoring will confirm modelling prediction of	SHEC	Data from groundwater monitoring	Groundwater quality data	Internal reporting Compliance reporting	Ongoing	2 + C = Low

Risk	Treatment	Justification for risk treatment	Responsibility	Resource requirements	Performance measures and constraints	Reporting and monitoring	Timing and scheduling	Residual risk (C+L)
		low risk to groundwater Monitoring will provide early indication of potential issues						
36. Inappropriate PMLU – PMLU criteria cannot be met	Develop closure and rehabilitation vision. Develop final landform designs. Include closure vision and final landform design in CCP. Implement rehabilitation monitoring program.	PMLU has been determined based on available information (vision and design). Field testing of rehabilitation approach and PMLU (rehabilitation monitoring). CCP feedback on performance / suitability of PMLU (consultation).	SHEC Technical services	Data from materials characterisation. Data from rehabilitation monitoring. CCP feedback.	Assessed against completion criteria.	Performance against completion criteria communicated to environment team and community.	At start of rehabilitation monitoring / ongoing.	3 + C = Medium

Risk	Treatment	Justification for risk treatment	Responsibility	Resource requirements	Performance measures and constraints	Reporting and monitoring	Timing and scheduling	Residual risk (C+L)
37. PMLU does not meet expectations of Traditional Owners	Continue regular engagement with Traditional owners	Traditional owner feedback to guide decision making	SHEC	Traditional Owner contact list CHMP	Traditional Owner feedback	Internal reporting only	Currently meetings are held quarterly	2 + C = Low
38. Stakeholders want different PMLU's to what is currently agreed.	Continue community consultation Ongoing monitoring of underlying landholder sale of property	Consultation will bring up potential issues with adequate time to address them	SHEC	Community contact list Tenement and land holder records	Community feedback	Internal reporting only	Ongoing	2 + B = Low
39. Rehabilitated landforms are not maintained by future landowners.	Develop post-closure management plan. Ensure community consultation in rehabilitation process.	Post closure management plan to give appropriate management strategies. Ensures future landholders input into plan.	SHEC	Data from rehabilitation monitoring.	Ongoing landholder consultation and feedback. Mine operator may have minimal involvement beyond relinquishment of leases (constraint).	Monitoring will be the responsibility of future landholder following relinquishment.	To be prepared prior to lease relinquishment.	2 + D = Medium

Risk	Treatment	Justification for risk treatment	Responsibility	Resource requirements	Performance measures and constraints	Reporting and monitoring	Timing and scheduling	Residual risk (C+L)
40. In the future local weather patterns may change (ie rainfall and ambient temperature) resulting in weather patterns that are not compatible with a PMLU	Develop a land management plan for future landowner. Assess reference sites against revegetated areas of the Mine as part of the rehabilitation monitoring program to identify areas of concern	Effective management of rehabilitated land may help offset climate changes	SHEC	Data from rehabilitation monitoring.	Revegetation monitoring	Internal reporting only	Ongoing	I + B = Low

3.7.5 Rehabilitation trials

Two field scale trials are planned for the Mine as part of ongoing closure planning. These are the TSF cover design trial and a subsoil amelioration trial as described in the following sections. The location for both of these trials is shown in Figure 22.

3.7.5.1 Objectives

a TSF cover trial

The TSF cover trial will be used to field test the proposed cover systems for effectiveness. The current designs are based on modelling and column trials and will need to be field tested on a larger scale. The cover system design may be updated based on the results of the field trials.

b Subsoil amelioration trials

Subsoil amelioration trials will determine if subsoil or waste rock can be ameliorated and used as a topsoil substitute. The trials will also inform the amelioration regime required.

3.7.5.2 Design

a TSF cover trial

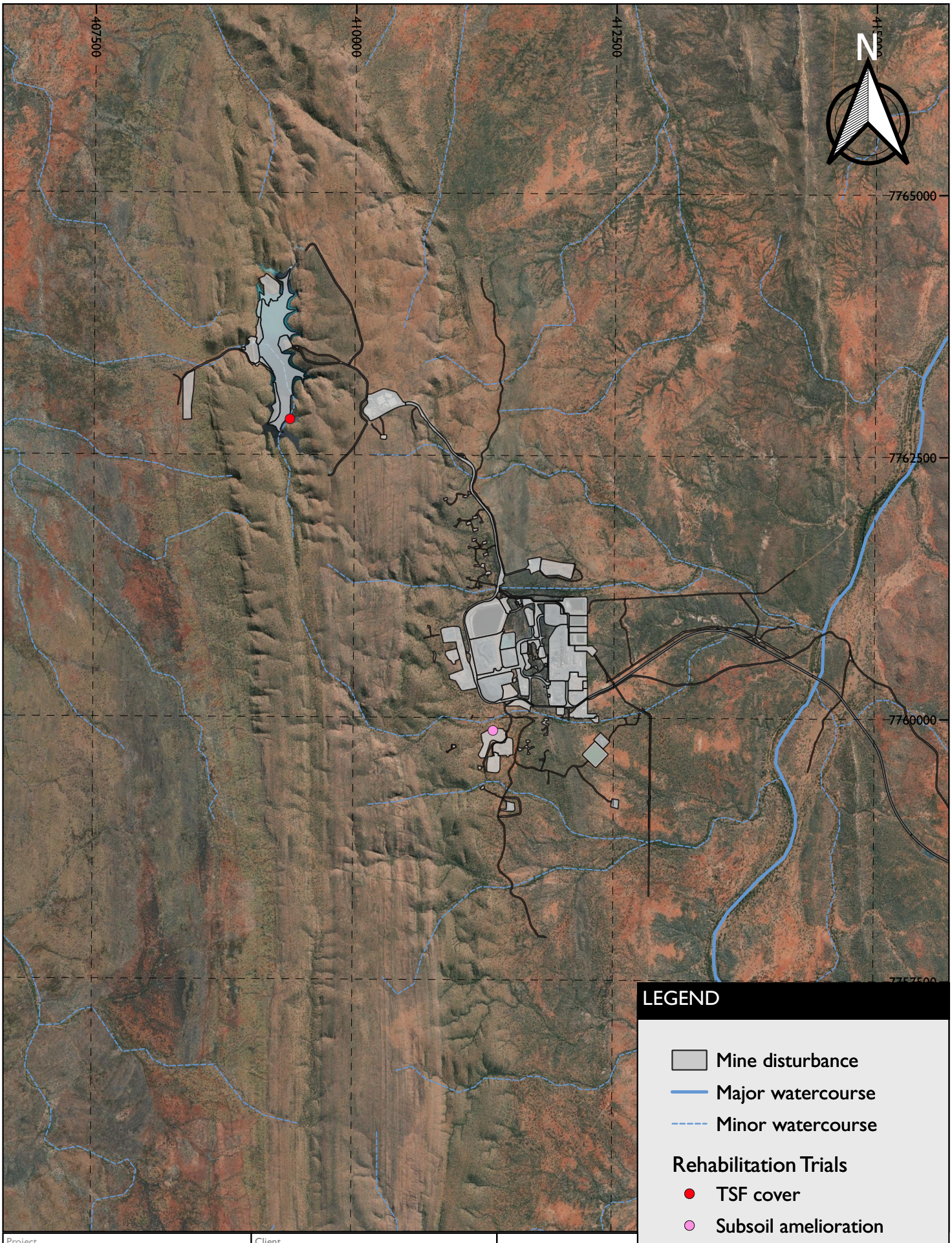
As outlined in Section 3.6.1.6 there are currently two options for the TSF cover design. Both of these options will be installed, on a small scale, as designed on a suitable area of the TSF. It is likely at least two other variations on these cover designs will also be installed to provide additional data. In the same way as column trials, sensors will be installed at discrete intervals through the cover system and linked to a data logger.

b Subsoil amelioration trials

Amelioration trials will involve the establishment of adjacent plots with a nominated treatment regime applied to each plot. Control plots will also be established. These plots will then be sown with a seed mix appropriate to the PMLU being investigated and monitored for vegetation establishment. Treatment agents and application rates will be determined based on the material analysis completed in Section 3.6.1.3 and the nominated PMLU. The exact methodology of each plot is not yet determined but it is likely variations of the following parameters will be examined:

- treatment agent and rates eg gypsum, organic matter, fertiliser etc;
- subsoil or waste rock thickness;
- seeding species and rate; and
- landform angle ie. flat ground or batter angle.

The control plots established during these trials will double as field verification trials for the current proposed rehabilitation methodology. Control plots will be topsoiled to 200 mm, ripped and seeded with a seed mix appropriate for the PMLU. This will provide data for an evaluation of the proposed methodology.



Project: Progressive Rehabilitation and Closure Plan		Client: MMG Limited	
Figure: 22	Title: Rehabilitation Trial Locations	Design: SGM Environmental Pty Ltd 27.09.2021 Scale: 1 : 50,000 CRS: GDA94 / MGA zone 54	

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3.7.5.3 Timing and duration

a TSF cover trial

Cover trials will commence when a suitable and accessible location is available in the TSF area. That is, an area that has reached the final deposition level and has sufficiently drained / dried to safely allow vehicle and personnel access. The trial period will likely be a minimum 18-24 months to ensure seasonal variation is adequately accounted for.

b Subsoil amelioration trials

Amelioration trials will be established within 2-3 years and may run for a minimum period of 18-24 months to ensure seasonal variation is adequately accounted for. The trial may be continued after this period to better understand the long-term effectiveness of this approach.

3.7.5.4 Monitoring and evaluation

a TSF cover trial

Data gathered from the trial will be used to verify the modelled results and further refine the cover system design. This data along with previous column results and laboratory analysis will provide sufficient information to develop a final cover design system for installation.

b Subsoil amelioration trials

Amelioration plots will be monitored as per other rehabilitation analogue sites with the addition of increased soil sampling and laboratory analysis. Data gathered from the monitoring will inform the suitability of subsoil / waste rock for use as a topsoil substitute.

3.8 Monitoring and maintenance

3.8.1 Reference sites

In accordance with the EA, several reference / analogue sites that are representative of the pre-mining landform have been chosen for monitoring. The reference sites will be monitored as per the rehabilitation monitoring schedule and will assist in revising rehabilitation milestone monitoring and completion criteria. The nominated reference sites are shown in Figure 18

3.8.2 Milestone monitoring

This section of the PRC plan describes monitoring and maintenance activities that will be done post-rehabilitation. Information collected during monitoring will demonstrate achievement of the rehabilitation criteria and contribute to satisfying DES's decision to progress surrender of the EA.

The post-rehabilitation phase will start when all the activities specified in this plan are done. During post-rehabilitation, monitoring will be conducted to assess whether the closure objectives and rehabilitation criteria are being met, while maintenance will be done to address those areas where the objectives and rehabilitation criteria remain incomplete or unsatisfactory. At this stage, the identified monitoring and maintenance activities are conceptual and will need to be refined as the strategy develops in the future. Current operational monitoring will continue up until closure and data collected during this time will enhance monitoring data captured during the post-closure monitoring period.

3.8.3 Biodiversity offset

The Lawn Hill biodiversity offset site is being monitored for the following attributes using BioCondition and photo-monitoring techniques as stated in the *Offset Management Area Management Plan* (DNRM 2014):

- ecological condition;
- grazing;
- fire;
- weeds; and
- pest animals.

The first monitoring event was performed in 2017 (the third year following the start of the *Offset Management Area Management Plan*) and will be continued every fifth year for a period of 15 years until the last monitoring event in 2029. Corresponding reports will be submitted to DNRM at these times also.

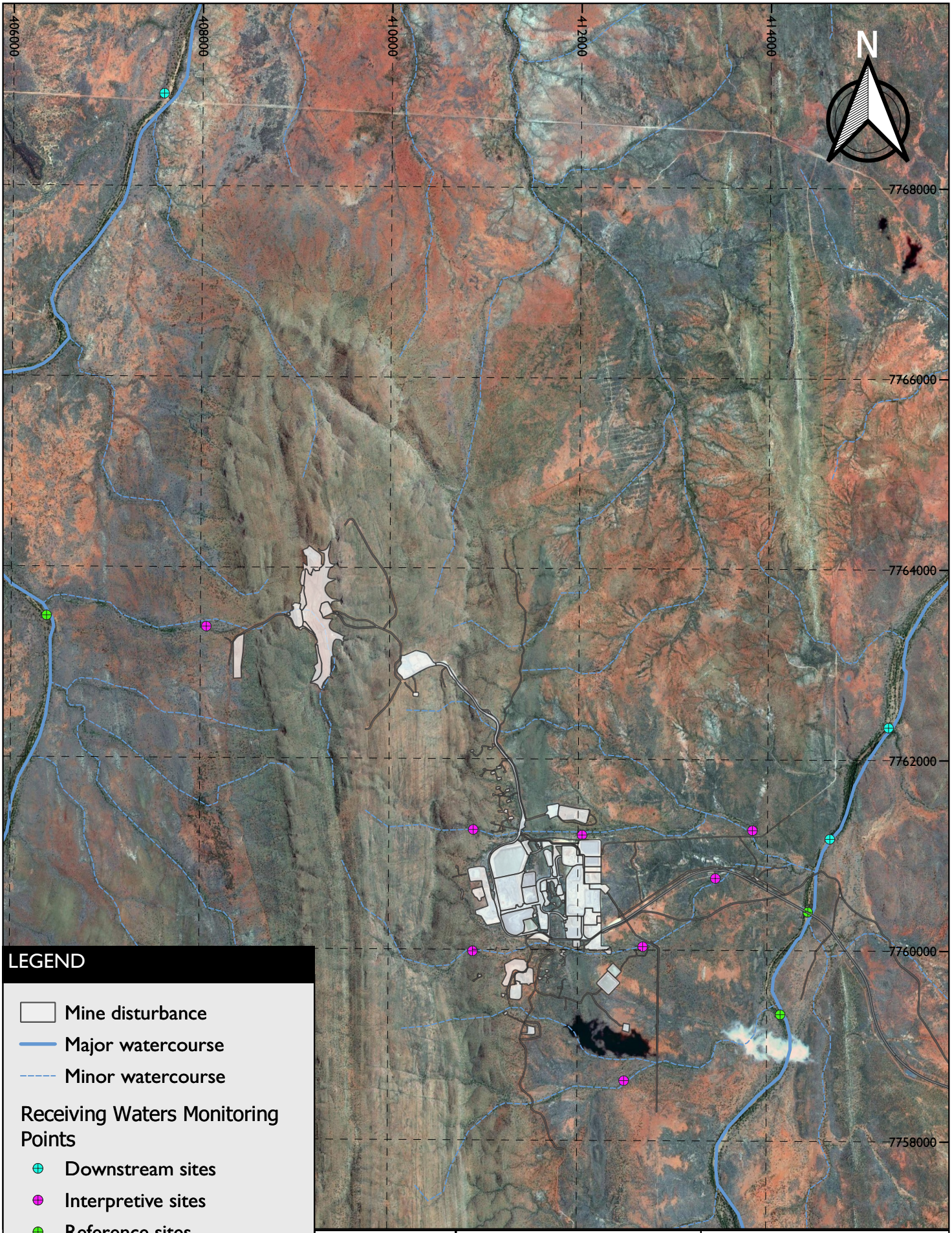
Photo-monitoring events occur annually from 2014 through to 2029 at the locations specified in the (DNRM 2014).

Management, monitoring and reporting will stop at the offset site when the administering authority acknowledges to MMG in writing that the vegetation in the offset management area has achieved the offset objectives and outcomes contained in the Offset Management Area Management Plan (DNRM 2014). Therefore, it is anticipated that before the end of the planned Mine life (2044), the Lawn Hill offset site will no longer require management.

3.8.4 Surface water

3.8.4.1 Receiving waters monitoring

A REMP has been developed to monitor, identify and describe any adverse impacts to surface water environmental values, quality and flows due to mining activity. The REMP encompasses any sensitive receiving waters or environmental values downstream of the Mine that could potentially be directly affected by an authorised release of mine-affected water. Ongoing investigation into the existing health and water quality of the surrounding creeks will continue through the initial rehabilitation phases. The REMP will be adapted post-closure to suit the requirements of monitoring for rehabilitation success criteria.



LEGEND

- Mine disturbance
- Major watercourse
- Minor watercourse

Receiving Waters Monitoring Points

- Downstream sites
- Interpretive sites
- Reference sites

Scale 1 : 55 000

0 1 2 km

SGM environmental	Client: MMG Limited	Project: Progressive Rehabilitation and Closure Plan	
	Design: SGM Environmental 24.02.2021 Scale: 1 :55,000 CRS: GDA94 / MGA zone 54	Title: Receiving Waters Monitoring Points	FIGURE 23

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Table 56 Proposed monitoring points and receiving waters

Monitoring point	Description	Easting	Northing
Interpretive sites			
SC-08 (MSS Ref)	Silvermine Creek — upstream of processing plant	410892	7759982
SN-05 (MS8 Ref)	North Creek — upstream of processing plant	410893	7761256
CT3-08 (MS2)	Un-named tributary of Cabbage Tree Creek — West of Knapdale Ranges on the northwest boundary, downstream of the TSF	408063	7763376
MSS (SC-29)	Un-named tributary of Silvermine Creek — South of processing plant, east of the Knapdale Ranges, downstream of the processing plant	412689	7760035
UTI-06 (MS6 Ref)	Un-named tributary of Dugald River — East of the Knapdale Ranges on the south eastern boundary	412495	7758628
SN-15 (MS8)	North Creek — Downstream of processing plant on the boundary of the mining lease	412043	7761203
SN-23 (MS9)	North Creek — Downstream of processing plant, and upstream of confluence with Silvermine Creek	413842	7761258
SC-38 (MSlO)	Un-named tributary of Silvermine Creek — East of processing plant, downstream of the Process Plant Run off Dam overflows and within access road easement	413453	7760754
Reference sites			
DR-10	Dugald River upstream of unnamed tributary (REMP waterway designation UT1)	414144	7759328
DR-14	Dugald River mine site access bridge, downstream of UT1 and upstream of Silvermine Creek confluence	414431	7760405
CC-05	Cabbage Tree Creek, upstream of the tributary which drains the TSF (REMP waterway designation CT3)	406375	7763485
Downstream monitoring sites			
DR-18 (Downstream compliance for DR-10 / DR14)	Dugald River downstream of Silvermine Creek (the upstream end of Longamundi Waterhole, possibly within the mixing zone associated with Silvermine Creek)	414660	7761171
DR-22 (Downstream compliance for DR-10 / DR14)	Dugald River downstream of Silvermine Creek (the downstream end of Longamundi waterhole, and likely downstream of the Silvermine Creek mixing zone)	415275	7762341
CC-15 (Downstream compliance for CC-05)	Cabbage Tree Creek downstream of the TSF (the closest waterhole to the TSF that retains water long enough to sustain seasonal aquatic communities, and the only accessible point on the creek during wet weather)	407593	7768969

Notes: Coordinate reference system GDA 94 / MGA Zone 54

a Discharge contaminant trigger levels

The receiving waters trigger levels and contaminant limits, as per the EA, are given in Table 57.

Table 57 Receiving waters trigger levels and contaminant limits

Quality characteristic	Unit	Trigger level	Contaminant limit
Physicochemical			
Hardness ($CaCO_3$)	mg/L	For interpretation purposes	For interpretation purposes
pH	pH units	6.0 (minimum) 7.5 (maximum)	5.5 (minimum) 8.5 (maximum)
EC	µS/cm	435	1,000
TSS	mg/L	For interpretation purposes	For interpretation purposes
Sulfate	mg/L	771	400
Fluoride	mg/L	80th percentile of reference	22
Total metals and metalloids			
Al	mg/L	-	0.2
As	mg/L	-	0.5
Cd	mg/L	-	0.005
Cu	mg/L	-	1
Pb	mg/L	-	0.05
Mn	mg/L	For interpretation purposes	For interpretation purposes
Ni	mg/L	-	1
Zn	mg/L	-	20
Dissolved metals and metalloids			
Al	mg/L	0.0551	95th percentile of reference
As	mg/L	0.0131	95th percentile of reference
Cd	mg/L	0.00021	95th percentile of reference
Cu	mg/L	0.00141	95th percentile of reference
Pb	mg/L	0.00341	95th percentile of reference
Mn	mg/L	1.91	95th percentile of reference
Ni	mg/L	0.0111	95th percentile of reference
Zn	mg/L	0.0081	95th percentile of reference

1. or 80th percentile of reference, whichever is higher
2. or 95th percentile of reference, whichever is lower

3.8.5 Groundwater

Regular monitoring of groundwater levels and quality at bores will continue throughout LOM and closure in order to identify any potential impacts. The groundwater monitoring strategy is described in the *Dugald River Mine Groundwater Monitoring Program* (BDH 2014) and is consistent with the requirements of the EA.

3.8.6 Soil and erosion

3.8.6.1 Soil

The objectives of soil monitoring are to:

- ensure maximum value to the rehabilitation process;
- measure the performance of stockpile storage and soil reuse; and
- improve the management and reuse of stockpiled soils.

Soil has been previously stripped from the disturbance footprint in line with the processes set out in Section 3.6.1.3. Stockpiles will be inspected at regular intervals for stability and the presence of weeds. Stockpile volumes will be updated as they are used for rehabilitation activities.

3.8.6.2 Erosion

Erosion monitoring at the Mine will be conducted at a number of locations, focusing on constructed landforms with steep batter slopes, which provide the greatest erosion risk. Permanent photographic points will be set up to monitor slopes on the following landforms annually:

- WRDs;
- ROM Pads and ore stockpiles;
- the TSF embankment walls; and
- selected reference sites.

Photographs will be taken following each wet season in order to capture the potential erosion caused by runoff. These will be compared to the previous years to determine any locations of erosion that may require remedial works.

Physical examination of erosion will be conducted together with the photographic monitoring. Examination will be done by traversing the landforms on foot at mid-slope, and recording any erosion or rill lines deeper than 10 cm. The data to be collected at each rill line will include the following:

- GPS reading of location;
- general description of type of erosion (gully, rill, tunnel etc) and possible cause;
- depth, width and length of erosion;
- location of sediment deposition; and
- suggested remedial works.

Remedial works will generally be required for any erosion that is increasing in size, or if the depth or width of erosion is >1 m.

All drainage, erosion and sediment control measures will be maintained until their function is no longer required and adequate surface stabilisation is achieved.

3.8.7 Vegetation

Vegetation monitoring will be done on all re-contoured surfaces. The sampling density will be determined by MMG closer to closure, based on what is practical to achieve and what DES will accept. To ensure consistency and repeatability of the vegetation monitoring, permanent sites need to be established. Vegetation monitoring methods will be refined closer to closure, but should involve:

- photographing;
- recording general site notes;
- measuring soil loss;
- measuring ground cover and species diversity; and
- measuring biomass.

The recommended method is similar to the BioCondition monitoring methodology described by the Queensland Herbarium (DEHP 2011).

3.8.8 TSF cover performance

Monitoring requirements for the TSF will be relatively straight-forward due to the configuration of the storage:

- tailings will be beached from both ends of the valley, forming a low permeability barrier over the valley floor, limiting seepage flux into the underlying rock mass;
- seepage will not be able to flow out of the valley elsewhere along the western valley profile, due to the height of the western valley ridge line;
- given that the main embankment will be constructed of free-draining rockfill fitted with a geomembrane sealing system (GSS), a phreatic surface will not develop, even if a concentrated leak in the GSS were to occur;
- standpipe piezometers will hence not be required in the main embankment, as any seepage would flow along the foundation, and accumulate in the collection pond downstream of the embankment; and
- the collection pond will be regularly inspected; however, it is expected to remain dry (ie. not register any seepage) under design conditions.

The landform stability will be assessed through the monitoring of erosion and the overall success will be assessed through vegetation monitoring. A system of groundwater monitoring bores is installed downstream of the main embankment to the west of the TSF. These will be assessed as part of the Mine-wide groundwater monitoring strategy.

3.8.9 Schedule

In accordance with the EA and the revised closure rehabilitation strategy, rehabilitation monitoring will be done on the following proposed schedule, given in Table 58.

Table 58 Proposed monitoring schedule

Name	Frequency	Duration (post-closure)
Reference sites	Every five years	Five years
Rehabilitation trials	Annually	Five years
Surface water / receiving environment	Twice yearly	10 years (then every five years for the following 20 years)

Name	Frequency	Duration (post-closure)
Ground water and seepage	Annually	10 years (then every five years for the following 20 years)
Soil / growth media	Every two years	10 years (then every five years for the following 20 years)
Erosion / landform stability	Every two years	10 years (then every five years for the following 20 years)
Vegetation	Every two years	10 years (then every five years for the following 20 years)

The duration of monitoring post-closure may be refined through gathered data and consultation with DES.

3.8.10 Schedule of monitoring, reporting and review of each milestone

An annual report will be done and will present a review of all rehabilitation monitoring done to the end of each annual period. The purpose of the report will be to provide an assessment of whether rehabilitation is trending towards the PMLU. If the data trend indicates a deviation from the completion criteria, then corrective actions will be recommended in the report. Corrective actions will be carried out and their success examined in the next annual report.

A schedule of monitoring, reporting and review for each milestone is given in Table 59-Table 66. Contingency strategies if rehabilitation monitoring indicates milestone criteria are not being met is given in Table 67. The rehabilitation monitoring program will help identify and quantify problems, risks and opportunities for corrective actions and adaptive management.

Table 59 RM1 (infrastructure decommissioning and removal) milestone monitoring

Milestone criteria	Periodic monitoring	Monitoring methodology	Frequency	Reporting	Contingency strategy	Review timing	Review methodology	Contingency strategy
All site services decommissioned.	Review infrastructure mapping for currency Review legal agreements for retention of infrastructure	Document review	Annually	Internal	Update mapping and records as required	At completion of works	Visual inspection and review of termination documentation	Organise disconnection
All road materials (bitumen and gravel) removed.	Review infrastructure mapping for currency Review legal agreements for retention of infrastructure	Document review and site inspection	Annually	Internal	Update mapping as required	At completion of works	Visual inspection	Organise removal
All pipelines drained and removed.	Review infrastructure mapping for currency Review legal agreements for retention of infrastructure	Document review and site inspection	Annually	Internal	Update mapping as required	At completion of works	Visual inspection	Organise removal
All fencing is removed.	Review infrastructure mapping for currency Review legal agreements for retention of infrastructure	Document review and site inspection	Annually	Internal	Update mapping as required	At completion of works	Visual inspection	Organise removal
All buildings removed.	Review infrastructure mapping for currency Review legal agreements for retention of infrastructure	Document review and site inspection	Annually	Internal	Update mapping as required	At completion of works	Visual inspection	Organise removal
All drill holes, sumps, exploration tracks and gridlines decommissioned.	Review infrastructure mapping for currency Review legal agreements for retention of infrastructure	Document review and site inspection	Annually	Internal	Update documentation as required	At completion of works	Site inspection Rehabilitation monitoring BioCondition monitoring	Review rehabilitation processes if criteria not being met
Legal agreements with landholders developed	Review legal agreements for retention of infrastructure	Document review	Annually	Internal	Revise or draft agreements as necessary	At completion of works	Comparison of agreed infrastructure vs residual infrastructure	Organise removal of infrastructure not under agreement

Table 60 RM2 (remediation of contaminated land) milestone monitoring

Milestone criteria	Periodic monitoring	Monitoring methodology	Frequency	Reporting	Contingency strategy	Review timing	Review methodology	Contingency strategy
Carry out preliminary and intrusive contaminated land investigations with a site	Review infrastructure mapping for inclusion of potentially contaminated land sites	Document review and site inspection	Annually	Internal	Update mapping as required Consider training on spill procedure as required	Following removal of contaminated material	Investigation as per NEPM legislation and sampling and analysis verification (SAP) standards	Prepare remediation plan for any remaining areas of contamination

Milestone criteria	Periodic monitoring	Monitoring methodology	Frequency	Reporting	Contingency strategy	Review timing	Review methodology	Contingency strategy
investigation report prepared by an AQP	Review incident reports for hydrocarbon and other spills Review adequacy of incident report actions and location details Identify high risk / regularly affected areas and proximity to sensitive receptors				Consider training on incident reporting (environment) as required Consider containment or mitigation strategies for identified areas			
Removal or on-site treatment of contaminated water	Surface and groundwater monitoring as per EA requirements	Sampling and laboratory analysis	As per EA	As per EA	Investigate non-compliant results as required	Annually	Sampling and laboratory analysis	Investigate cause of non-compliant results
Removal and appropriate disposal of contaminated materials	Review register of potentially contaminated land and disposal records	Register and disposal record review	Annually	Internal	Update register and records as required	At completion of mining	Sampling and laboratory analysis	Investigate cause of non-compliant results
Conduct validation testing to confirm that contaminated materials have been removed or remediated	Validation testing following remediation / removal	Sampling and laboratory analysis as directed by the AQP	Once at completion of remediation / removal works	To be included in the final contaminated land report	Investigate cause of failed test areas if required	Immediately following removal / remediation works	Sampling and laboratory analysis as directed by the AQP	Remediate or remove contamination from failed areas
Certification from an AQP that all contaminated land has been either remediated or removed	Review records / register / map files of contaminated material Ensure appropriate locations for contaminated material disposal is available in accordance with licence conditions	Document review and site inspection	Annually	Internal	Update register / records / mapping as required Investigate and nominate suitable locations as required	Following removal of contaminated material	Investigation as per NEPM legislation and SAP standards	Start remediation of failed areas

Table 61 RM3 (landform development and reshaping / reprofiling) milestone monitoring

Milestone criteria	Periodic monitoring	Monitoring methodology	Frequency	Reporting	Contingency strategy	Review timing	Review methodology	Contingency strategy
Finalise engineering and design plans	Review final landform designs against mine plan	Design review	Annually	Internal	Update designs as required	Prior to earthworks starting	Design review	Update designs as required
Bulk earthworks to achieve landform and slopes as per the agreed design	Monitor against PRCP schedule and milestones	Ground survey and LiDAR	Annually	Internal	Update schedule if required	Following completion of works	Ground survey and LiDAR	Remediate areas as required
General reshaping and trimming to achieve final landform as per agreed design	Monitor against PRCP schedule and milestones	Ground survey, LiDAR and visual inspection	Annually	Internal	Update schedule if required	Following completion of works	Ground survey, LiDAR and visual inspection	Remediate areas as required

Milestone criteria	Periodic monitoring	Monitoring methodology	Frequency	Reporting	Contingency strategy	Review timing	Review methodology	Contingency strategy
Fill dams	Ensure dams are present in the PRC schedule or under a legal agreement with future landholders	Desktop review	Annually	Internal	Update schedule if required	Following completion of works	Visual inspection and survey	Remediate areas as required
Backfill and seal shafts, portals / adits	Ensure shafts, portals and adits are in the PRC schedule	Desktop review	Annually	Internal	Update schedule if required	Following completion of works	Visual inspection and survey	Remediate areas as required
Install erosion and sediment control systems	Review final landforms designs for inclusion of erosion and sediment control systems	Desktop review	Annually	Internal	Update designs as required	Following completion of works	Visual inspection	Install or remediate systems as required
Verification from an AQP that the final constructed landform is consistent with reference sites and as per the agreed design	Review landform designs to make sure slopes are planned to be consistent with reference sites and design. Review survey / LiDAR data for compliance with maximum slope angle	Document / design review Ground survey and LiDAR	Annually Monthly during reshaping works	Internal Internal	Update designs if required Remediate areas as required	Following completion of works	Ground survey and LiDAR	Remediate areas as required

Table 62 RM4 (installation of cover) milestone monitoring

Milestone criteria	Periodic monitoring	Monitoring methodology	Frequency	Reporting	Contingency strategy	Review timing	Review methodology	Contingency strategy
Conversion of operational TSF spillway and embankment wall to the final closure rock lined spillway as per the agreed design	Ensure approved design is included in the PRC schedule and required materials are available	Document / design review	Annually	Internal	Update designs if required	Following completion of works	Visual inspection and survey	Remediate or assess altered design as required
Installation of capillary break layer over the TSF surface	Ensure approved design is included in the PRC schedule and required materials are available	Document / design review	Annually	Internal	Update designs if required	Following install of the capillary break layer	Visual inspection and survey	Remediate or assess altered design as required
Installation of reduced permeability layer (RPL) over the capillary break layer	Ensure approved design is included in the PRC schedule and required materials are available	Document / design review	Annually	Internal	Update designs if required	Following install of the RPL	Visual inspection and survey	Remediate or assess altered design as required
Installation of infiltration storage layer (ISL) over the RPL layer	Ensure approved design is included in the PRC schedule and required materials are available	Document / design review	Annually	Internal	Update designs if required	Following install of the ISL	Visual inspection and survey	Remediate or assess altered design as required
Certification by an AQP that the TSF cover layers and spillway have been installed in	Inspection of tailings cover by an AQP for compliance with the cover design.	Visual inspections, ground survey	During construction	Internal	Review design or remediate works	At completion	AQP review	Review design or remediate works

Milestone criteria	Periodic monitoring	Monitoring methodology	Frequency	Reporting	Contingency strategy	Review timing	Review methodology	Contingency strategy
accordance with the approved design								

Table 63 RM5 (surface preparation) milestone monitoring

Milestone criteria	Periodic monitoring	Monitoring methodology	Frequency	Reporting	Contingency strategy	Review timing	Review methodology	Contingency strategy
Remediate any erosion or subsidence	As per subsidence and rehabilitation monitoring	Subsidence and rehabilitation monitoring	As per subsidence and rehabilitation monitoring requirements	Internal	Remediate erosion or subsidence when identified	Prior to placement of soil	Visual inspection	Remediate erosion or subsidence as required
An assessment of soil health and suitability has been completed by an AQP to confirm soil is suitable for target vegetation establishment.	Not applicable (N/A) — assessment completed prior to works starting	N/A	N/A	N/A	N/A	Prior to placement of soil	Soil sampling, laboratory analysis and results interpretation	Treat soil as required
Placement of 200mm of soil / growth medium.	Inspect areas of topsoil / growth medium placement during works	Visual inspection Test pitting	Ongoing during works	Internal	Review methodology if topsoil / growth medium is too shallow in multiple areas Remediate isolated areas as required ie. especially on slopes or in high-risk areas	Prior to seeding	Visual inspection Test pitting	Remediate areas as required
Application of ameliorants as per requirements of the soil health and suitability assessment.	Review rehabilitation records for evidence of amelioration application Review effectiveness of amelioration on rehabilitation	Visual inspection and document review Rehabilitation monitoring	Annually (document review) Ongoing during application works Annually (rehabilitation monitoring)	Internal Internal Internal	Update rehabilitation records as required Review rehabilitation methodology if amelioration not appearing to be effective	Prior to seeding	Visual inspection Test pitting, sampling and laboratory analysis if required	Complete amelioration
Ripping completed as per the required specification	Review rehabilitation records for evidence of ripping	Visual inspection	Annually	Internal	Update rehabilitation records as required	Prior to seeding	Visual inspection	Remediate areas not adequately ripped

Table 64 RM6 (revegetation — pasture grazing and / or native habitat) milestone monitoring

Milestone criteria	Periodic monitoring	Monitoring methodology	Frequency	Reporting	Contingency strategy	Review timing	Review methodology	Contingency strategy
Completed seeding of target species at a rate consistent with the revegetation plan in the PRC plan	Review rehabilitation records for evidence of seed application rates Visual inspection during seeding works	Visual inspection and document review	Annually Ongoing during works	Internal Internal	Update records as required	Annually	Rehabilitation monitoring BioCondition monitoring	Reseed as required Review seeding methodology, seeding rate, seed species, seed viability etc
Application of fertiliser as per soil and health suitability assessment	Review rehabilitation records for evidence of fertiliser application	Visual inspection and document review	Annually Ongoing during works	Internal Internal	Update records as required	Annually	Rehabilitation monitoring BioCondition monitoring	Fertilise as required Fertilise as required

Milestone criteria	Periodic monitoring	Monitoring methodology	Frequency	Reporting	Contingency strategy	Review timing	Review methodology	Contingency strategy
	Visual inspection during works							
Install stock fencing to protect rehabilitated area	Inspect rehabilitated areas	Visual inspection	At completion of each rehabilitation area	Internal	Install fencing as required	At completion of each rehabilitation area	Visual inspection	Install fencing as required

Table 65 RM7 (achieve surface requirements — pasture grazing and / or native vegetation) milestone monitoring

Milestone criteria	Periodic monitoring	Monitoring methodology	Frequency	Reporting	Contingency strategy	Review timing	Review methodology	Contingency strategy
Average total ground cover (all ground cover categories aggregated) is no less than the 15th percentile of equivalent control site	Inspection of rehabilitation areas	Rehabilitation monitoring	Annually following first rehabilitation	Internal	Remediate areas where minimal cover may pose a risk ie. erosion, stability, sediment runoff etc	Annually	Rehabilitation monitoring BioCondition monitoring	Plan and execute remediation program
Average soft spinifex cover estimates are no less that the 15th percentile of equivalent control sites	Inspection of rehabilitation areas	Rehabilitation monitoring	Annually following first rehabilitation	Internal	Adjust seed mix as appropriate	Annually	Rehabilitation monitoring BioCondition monitoring	Review seed mix as required
Buffel grass cover estimates exceed no more than the 70th percentile of equivalent control sites (native habitat)	Inspection of rehabilitation areas	Rehabilitation monitoring	Annually following first rehabilitation	Internal	Adjust seed mix as appropriate	Annually	Rehabilitation monitoring BioCondition monitoring	Review seed mix as required
Kapok bush cover estimates exceed no more than the 70th percentile of equivalent control site	Inspection of rehabilitation areas	Rehabilitation monitoring	Annually following first rehabilitation	Internal and neighbouring landholders as required	Targeted treatment of weed outbreaks	Annually	Rehabilitation monitoring	Plan and execute weed treatment program
A minimum of 70% of target species as per the revegetation plan have been established	Inspection of rehabilitation areas	Rehabilitation monitoring	Annually following first rehabilitation	Internal	Adjust seed mix as appropriate	Annually	Rehabilitation monitoring BioCondition monitoring	Review seed mix as required
Erosion gullies are ≤1 m deep.	Inspect areas of active erosion	Visual inspection LiDAR	Annually	Internal	Identify root cause of erosion Remediate where necessary	Annually	Rehabilitation monitoring	Investigate underlying cause of drainage issues eg design, construction, material types, ineffective maintenance etc Develop maintenance program for remediation Carry out remediation program

Milestone criteria	Periodic monitoring	Monitoring methodology	Frequency	Reporting	Contingency strategy	Review timing	Review methodology	Contingency strategy
Certification by an AQP that revegetation is comparable to reference sites, erosion and drainage is acceptable and weeds and pest species are in densities no greater than at reference sites.	Inspection of rehabilitated areas	Rehabilitation monitoring Visual inspection	Annually	Internal and neighbouring landholders as required	Targeted treatment of weed outbreaks	Annually	Rehabilitation monitoring	Plan and execute weed treatment program

Table 66 RM8 (achievement of PMLU to a stable condition — pasture grazing and / or native vegetation) milestone monitoring

Milestone criteria	Periodic monitoring	Monitoring methodology	Frequency	Reporting	Contingency strategy	Review timing	Review methodology	Contingency strategy
The rehabilitated landforms can sustain the agreed PMLU as certified by an AQP	Inspection of rehabilitation areas	Rehabilitation monitoring	Annually	Internal	Remediate areas not meeting criteria	Annually	Investigate failed criteria and assess underlying causes	Develop remediation program to address deficiencies
The rehabilitated landforms have achieved a suitable factor of safety as certified by an AQP	Monitoring of landform stability by geotechnical engineer Analysis of survey data by geotechnical engineer	Geotechnical inspections Ground survey / LiDAR	Annually Annually	Internal Internal	Remediate areas of instability Review and update design plans if required	Following completion of works	Geotechnical assessment	Remediate as advised or start redesign process
The rehabilitated landforms have a maximum erosion rate of <10 t/ha/yr as certified by an AQP	Inspect areas of active erosion	Visual inspection LiDAR	Annually	Internal	Identify root cause of erosion Remediate where necessary	Annually	Rehabilitation monitoring	Develop maintenance program for remediation Carry out remediation program
Develop a post closure land management plan for future landholders in consultation with them	Review stakeholder feedback and land management requirements for inclusion in post closure management plan	Desktop review	As information becomes available	Internal and to future landholders	Include feedback and requirements where feasible	At completion of rehabilitation	Desktop review	Finalise plan
Surface water quality at downstream compliance sites DR-18 and DR-22 complies with nominated criteria	Monitoring as per EA requirements	Sampling and laboratory analysis	As per EA	As per EA	Investigate non-compliant results as required	Annually	Sampling and laboratory analysis	Investigate cause of non-compliant results
Groundwater quality at MB2 and MB4 complies with nominated criteria	Monitoring as per EA requirements	Sampling and laboratory analysis	As per EA	As per EA	Investigate non-compliant results as required	Annually	Sampling and laboratory analysis	Investigate cause of non-compliant results

Table 67 Milestone review and contingency planning

Milestone reference	Description	Milestone criteria	Monitoring methodology	Reported to:	Intervention trigger	Action	Response	Review schedule
RM1	Infrastructure decommissioning and removal	1. All site services decommissioned.	1. Visual inspection and review of termination documentation	1. SHEC and service providers	1. Services still connected	1. Investigate why services remain connected	1. Organise disconnection 2. Organise removal	1. Following infrastructure removal

Milestone reference	Description	Milestone criteria	Monitoring methodology	Reported to:	Intervention trigger	Action	Response	Review schedule
		2. All road materials (bitumen and gravel) removed. 3. All pipelines drained and removed. 4. All fencing is removed. 5. All buildings removed. 6. All drill holes, sumps, exploration tracks and gridlines decommissioned. 7. Consultation with stakeholders and legal agreements developed with landholders for any infrastructure retained	2. Visual inspection 3. Visual inspection 4. Visual inspection 5. Visual inspection 6. Visual inspection, rehabilitation monitoring 7. Comparison of agreed infrastructure vs residual infrastructure	2. SHEC 3. SHEC 4. SHEC 5. SHEC 6. SHEC 7. SHEC	2. Road materials not removed 3. Pipelines not removed 4. Fence lines not removed 5. Buildings not removed 6. Works not completed 7. Inconsistency with agreed retention infrastructure and actual	2. Organise removal 3. Organise removal 4. Engage with landholder 5. Engage with landholder 6. Audit completed and outstanding works 7. Investigate if infrastructure is suitable for retention	3. Organise removal 4. Organise removal or add to retention agreement 5. Organise removal or add to retention agreement 6. Start remediation works 7. Remove infrastructure and rehabilitate or obtain legal agreement for retention	2. Following infrastructure removal 3. Following infrastructure removal 4. Following infrastructure removal 5. Following infrastructure removal 6. Following infrastructure removal 7. Following infrastructure removal
RM2	Remediation of contaminated land	1. Carry out preliminary and intrusive contaminated land investigations with a site investigation report prepared by an AQP 2. Removal or on-site treatment of contaminated water 3. Removal and appropriate disposal of contaminated materials 4. Conduct validation testing to confirm that contaminated materials have been removed or remediated 5. Certification from an AQP that all contaminated land has been removed or remediated	1. Investigation as per NEPM legislation and sampling and analysis verification (SAP) standards 2. Sampling and laboratory analysis 3. Sampling and laboratory analysis 4. Sampling and laboratory analysis as directed by an AQP 5. Certification of assessment report by an AQP	1. SHEC 2. SHEC 3. SHEC 4. SHEC	1. Assessment identifies additional areas of contamination 2. Monitoring shows potential contamination source 3. Analysis shows source of contamination 4. Validation testing shows contamination still present 5. Certification not received	1. Identify all contamination areas 2. Investigate source of contamination 3. Investigate source of contamination 4. Investigate source of contamination 5. Identify failed areas	1. Prepare remediation plan for additional areas of contamination 2. Remove source or confine contamination 3. Remove or remediate contamination 4. Remove or remediate contamination 5. Start remediation of failed areas	1. Following removal of contaminated material 2. Following removal of contaminated material / source 3. Following removal / remediation of contaminated material 4. Following remedial action 5. Following removal of contaminated material
RM3	Landform development and reshaping / reprofiling	1. Finalise engineering and design plans 2.Bulk earthworks to achieve landform and slopes as per the agreed design 3. General reshaping and trimming to achieve final landform as per agreed design 4. Fill dams 5. Backfill and seal shafts, portals and adits	1. Design review 2. Ground survey and LiDAR 3. Visual inspection and survey 4. Visual inspection and survey 5. Visual inspection and survey 6. Visual inspection 7. Ground survey and LiDAR	1. SHEC 2. Works supervisor / SHEC 3. Works supervisor / SHEC 4. Works supervisor / SHEC 5. Works supervisor / SHEC 6. Works supervisor / SHEC 7. Works supervisor / SHEC	1.Design has substantially changed or is not suitable 2. Earthworks not completed 3. Reshaping and trimming not completed 4. Dams not backfilled 5. Shafts, portals or adits not sealed 6. Systems not installed or ineffective	1. Identify issue with design 2. Investigate schedule delay 3. Investigate schedule delay 4. Investigate reason for dams not backfilled 5. Identify all areas not backfilled 6.Review design if failed or rehabilitation process if not installed	1. Update design as required 2.. Update schedule or accelerate works 3. Update schedule or accelerate works 4. Remediate if required 5. Backfill all affected areas 6. Update design if failed or install as per original design if not installed 7. Analyse impact of areas outside specification on	1. Prior to earthworks 2. Periodically during reprofiling 3. Periodically during works 4. Periodically during works 5. Periodically during works 6. At completion of bulk earthworks 7. Upon completion of earthworks

Milestone reference	Description	Milestone criteria	Monitoring methodology	Reported to:	Intervention trigger	Action	Response	Review schedule
		6. Install erosion and sediment control systems 7. Verification from an AQP that the final constructed landform is consistent with reference sites and as per the agreed design			7. Constructed landform is not consistent with reference sites or as per design	7. Assess the scale of the issue ie. how many areas outside of specification	overall stability and start remediation if required	
RM4	Installation of cover	1. Conversion of operational TSF spillway and embankment wall to the final closure rock lined spillway as per the agreed design 2.Installation of capillary break layer over the TSF surface 3. Installation of reduced permeability layer (RPL) over the capillary break layer 4. Installation of the infiltration storage layer (ISL) over the RPL 5. Certification by an AQP that the TSF cover layers and spillway have been installed in accordance with the approved design	1. Ground survey, LiDAR and visual inspection 2. Ground survey, QA/QC testing and visual inspection 3. Ground survey, QA/QC testing and visual inspection 4. Ground survey, QA/QC testing and visual inspection 5. Visual inspections, ground survey, test pitting and lab analysis	1. Works supervisor / SHEC 2. Works supervisor / SHEC 3. Works supervisor / SHEC 4. Works supervisor / SHEC 5. Works supervisor / SHEC	1. Spillway and embankment conversion works not to design 2.Cover layer not to design or outside of specifications 3. Cover layer not to design or outside of specifications 4. Cover layer not to design or outside of specifications 5. Works not consistent with design	1. Investigate deviation and engage AQP for assessment 2. Investigate deviation and engage AQP for assessment 3. Investigate deviation and engage AQP for assessment 4. Investigate deviation and engage AQP for assessment 5. Investigate deviation and engage AQP for assessment	1. Halt works until update of design and / or rectify works 2. Halt works until update of design and / or rectify works 3. Halt works until update of design and / or rectify works 4. Halt works until update of design and / or rectify works 5. Update design or remediate where required	1. Periodically during works 2. Periodically during works 3. Periodically during works 4. Periodically during works 5. At completion of works
RM5	Surface preparation	1. Remediate any erosion or subsidence 2. An assessment of soil health and suitability has been completed by an AQP to confirm soil is suitable for target vegetation establishment 3. Placement of 200mm of soil / growth medium 4. Application of ameliorants as per requirements of the soil health and suitability assessment. 5. Ripping completed as per the required specification	1. Visual inspection 2. Sampling, lab testing and results analysis of soil 3. Visual inspection. Test pitting of selected areas 4. Visual inspection and application record keeping 5. Visual inspection 4	1. SHEC 2. SHEC 3. SHEC 4. SHEC 5. SHEC	1. Excessive erosion or subsidence present 2. Soil not suitable for target vegetation 3. Soil / growth medium not to adequate depth 4. Amelioration not completed 5. Ripping not completed or not to adequate depth 4.	1. Investigate cause ie. drainage issues etc. 2. Determine treatment options 3 Complete additional test holes to determine extent of issue. 4. Complete amelioration 5. Determine extent of areas not adequately ripped 4.	1. Remediate impacted areas 2. Treat soil as required 3. Consider placement of additional soil / growth medium in high-risk areas or areas of concern 4. Complete amelioration 5. Rip areas not adequately treated 4.	1. Prior to placement of soil 2. Prior to placement of soil 2. Prior to seeding works 3. Prior to seeding works 4. Prior to seeding works 5. Prior to seeding works
RM6	Revegetation	1. Completed seeding of target species at a rate	1. Visual inspection, review records	1. SHEC 2. SHEC	1. Seeding not completed or inadequate	1. Determine extent of inadequacy	1. Start reseeding works 2. Fertilise areas if required	1. Immediately following seeding

Milestone reference	Description	Milestone criteria	Monitoring methodology	Reported to:	Intervention trigger	Action	Response	Review schedule
		consistent with the revegetation plan 2. Application of fertiliser as per soil and health suitability assessment 3. Install stock fencing to protect rehabilitated areas	2. Visual inspection, review records 3. Visual inspection	3. SHEC	2. Fertiliser not applied or inadequate 3. Fencing not installed	2. Determine need for fertiliser treatment 3. Determine impact to rehabilitation if any	3. Install fencing if required	2. Immediately following seeding / first expectation of vegetation strike / ongoing 3. Immediately following completion of seeding
RM7	Achieve surface requirements	1. Average total ground cover (all ground cover categories aggregated) is no less than the 15th percentile of equivalent control sites 2. Average soft spinifex cover estimates are no less than the 15th percentile of equivalent control sites 3. Buffel grass cover estimates exceed no more than the 70th percentile of equivalent control sites (native habitat) 4. Kapok Bush cover estimates exceed no more than the 70th percentile of equivalent control sites 5. A minimum of 70% of target species as per the revegetation plan have been established 6. Erosion gullies are ≤1m deep. 7. Certification by AQP that revegetation is comparable to reference sites, erosion and drainage is acceptable and weed and pest species are in densities no greater than at reference sites	1. Rehabilitation monitoring, BioCondition monitoring 2. Rehabilitation monitoring and Biocondition monitoring 3. Rehabilitation monitoring and BioCondition monitoring 4. Rehabilitation monitoring and BioCondition monitoring 5. Rehabilitation monitoring and BioCondition monitoring 6. Rehabilitation monitoring, visual inspection, LiDAR and ground survey 7. Rehabilitation monitoring, visual inspection, LiDAR and ground survey	1. SHEC 2. SHEC 3. SHEC 4. SHEC 5. SHEC 6. SHEC 7. SHEC	1. Groundcover not comparable to reference sites 2. Soft spinifex less than the 15th percentile of reference sites 3. Buffel grass greater than the 70th percentile of reference sites in native habitat areas 4. Kapok Bush greater than the 70th percentile of reference sites 5. Less than 70% of target species established 6. Identification of gullies >0.5m 7. Active erosion present and / or evidence of ineffective drainage, weeds identified in densities greater than reference sites	1. Investigate cause of inadequate cover (soil quality, seed quality, seed variety, weather patterns etc) 2. Investigate cause of inadequate spinifex cover (soil quality, seed quality, seed variety, weather patterns etc) 3. Investigate cause of over representation of Buffel grass 4. Investigate cause of over representation of Kapok Bush 5. Determine cause of target species being underrepresented 6. Determine underlying cause of drainage issues (design, construction, material types, ineffective maintenance etc) and /or source erosion scour 7. Investigate gully formation, potential weed source and impact on proposed PMLU	1. Plan remediation program based on investigation ie. soil treatment, reseeding etc 2. Plan remediation program based on investigation ie. soil treatment, reseeding etc 3. Plan remediation program ie. reseeding, Buffel grass control etc. 4. Plan remediation program ie. reseeding, Kapok Bush control etc. Plan and execute weed treatment program 5. Plan remediation program or revise species composition 6. Start remediation works potentially including drainage alterations 7. Plan remediation works including weed and pest management if required	1. Immediately following first round of monitoring 2. Immediately following first round of monitoring 3. Immediately following first monitoring 4. Immediately following first monitoring 5. Immediately following first monitoring 6. Immediately following first monitoring 7. After a least three years of monitoring data
RM8	Achievement of PMLU to a stable condition	1. The rehabilitated landforms can sustain the agreed PMLU as certified by an AQP 2. The rehabilitated landforms have achieved a suitable factor of safety (FOS) as certified by an AQP	1. Certification assessment by an AQP based on achievement of safe, stable, non-polluting and self-sustaining 2. Geotechnical assessment by qualified geotechnical engineer	1. SHEC 2. SHEC and technical services 3. SHEC 4. SHEC and impacted landholders 5. SHEC 6. SHEC	1. Area does not meet requirements of the PMLU 2. FOS not acceptable 3. Erosion rate exceeds 10 t/ha/yr (calculated) 4. Plan not completed or landholders do not agree with content	1. Investigate failed criteria and assess underlying causes 2. Complete geotechnical assessment 3. Identify potential sources of erosion 4. Identify and discuss points of disagreement	1. Develop remediation program to address deficiencies 2. Implement recommendations from geotechnical assessment 3. Start remediation / soil stabilisation 4. Update plan as required	1. Immediately following last rehabilitation in the area 2. Immediately following last rehabilitation in the area

Milestone reference	Description	Milestone criteria	Monitoring methodology	Reported to:	Intervention trigger	Action	Response	Review schedule
		3. The rehabilitated landforms have a maximum erosion rate of <10 t/ha/yr as certified by an AQP 4. Develop a post closure land management plan for future landholders in consultation with them 5. Surface water quality from compliance sites DR-18 and DR-22 is compatible with PMLU 6. Groundwater quality at MB2 and MB4 complies with proposed limits	3. Survey, LiDAR monitoring and rehabilitation monitoring 4. Review developed plan 5. Surface water sampling and laboratory analysis 6. Groundwater sampling and laboratory analysis		5. Surface water quality exceeds limits 6. Groundwater quality exceeds EA limits	5. Investigate cause of surface water quality exceedances 6. Investigate cause of Groundwater quality exceedances	5. Response based on investigation results 6. Response based on investigation results	3. Immediately following first monitoring 4. 3-yearly / ongoing 5. Following first round of surface water sampling from rehabilitated area 6. Start following first groundwater sampling

3.8.11 Quality assurance

Monitoring, data assessment and reporting will be done by a suitably qualified person. This could be Mine staff (eg. environment officer) or external consultant(s). All monitoring data files will be stored at the Mine. The Mine will be responsible for reviewing monitoring data, analysis, reports and managing consultants.

Aspects to consider when reviewing the data, analysis and reports include quality assurance / quality control of data, methodologies used, fluctuating trends in data from previous years, accuracy of figures and graphs and general conclusions made about rehabilitation progress.

3.8.12 Review

This document will be reviewed by an appropriately qualified person once every five years or earlier in response to any of the following:

- changes required, or improvements / deficiencies identified as part of a review of the PRC plan;
- evidence that demonstrates rehabilitation criteria are not practicable;
- changes identified as part of the closure monitoring program;
- changes in community/stakeholder expectations;
- improved technology;
- changes to legislation;
- changes to the closure risk register;
- changes to rehabilitation methodology;
- as part of the PRC plan schedule audit; and / or
- modification to EA EPML00731213.

Any major amendments to the PRC plan (ie variations to completion criteria, changes to PMLU or changed date of milestone completion) will be done in accordance with the PRC plan guideline. Accordingly, major amendments will be done in consultation with the DES and community members. During revisions for the PRC plan any changes that will significantly alter environmental values, or that are likely to result in increased levels of significant environmental harm, will require an amendment to the EA and / or PRC plan which may require public notification.

3.8.13 EA surrender

DES must be satisfied with the rehabilitation before it can certify progressive rehabilitation for part of the Mine or accept the surrender of the EA for the whole or part of the Mine. DES's decision is based on an assessment of either a progressive rehabilitation report for part of the Mine (refer to Section 318Z of the EP Act) or a final rehabilitation report (refer to Section 264 of the EP Act) for the whole Mine or a part being surrendered.

MMG is required to prepare a progressive / final rehabilitation report, including a compliance statement and submit it to DES for assessment. DES will consider the relevant rehabilitation requirements (refer to Section 318ZI or Section 268 of the EP Act) when deciding whether to certify progressive rehabilitation or whether to approve a surrender application. MMG is also required to develop a post-surrender management plan to assist ongoing land management beyond surrender of the MLs.

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Appendix A
PRC plan Schedule



PRC plan schedule

The PRC plan schedule contains milestones and conditions that relate to the completion of progressive rehabilitation and closure. The PRC plan schedule has been prepared in accordance with Section 126D of the EP Act and includes the final site design, rehabilitation areas, a schedule of land availability, rehabilitation milestones and milestone criteria. The PRC plan schedule applies to the entire life of the Mine.

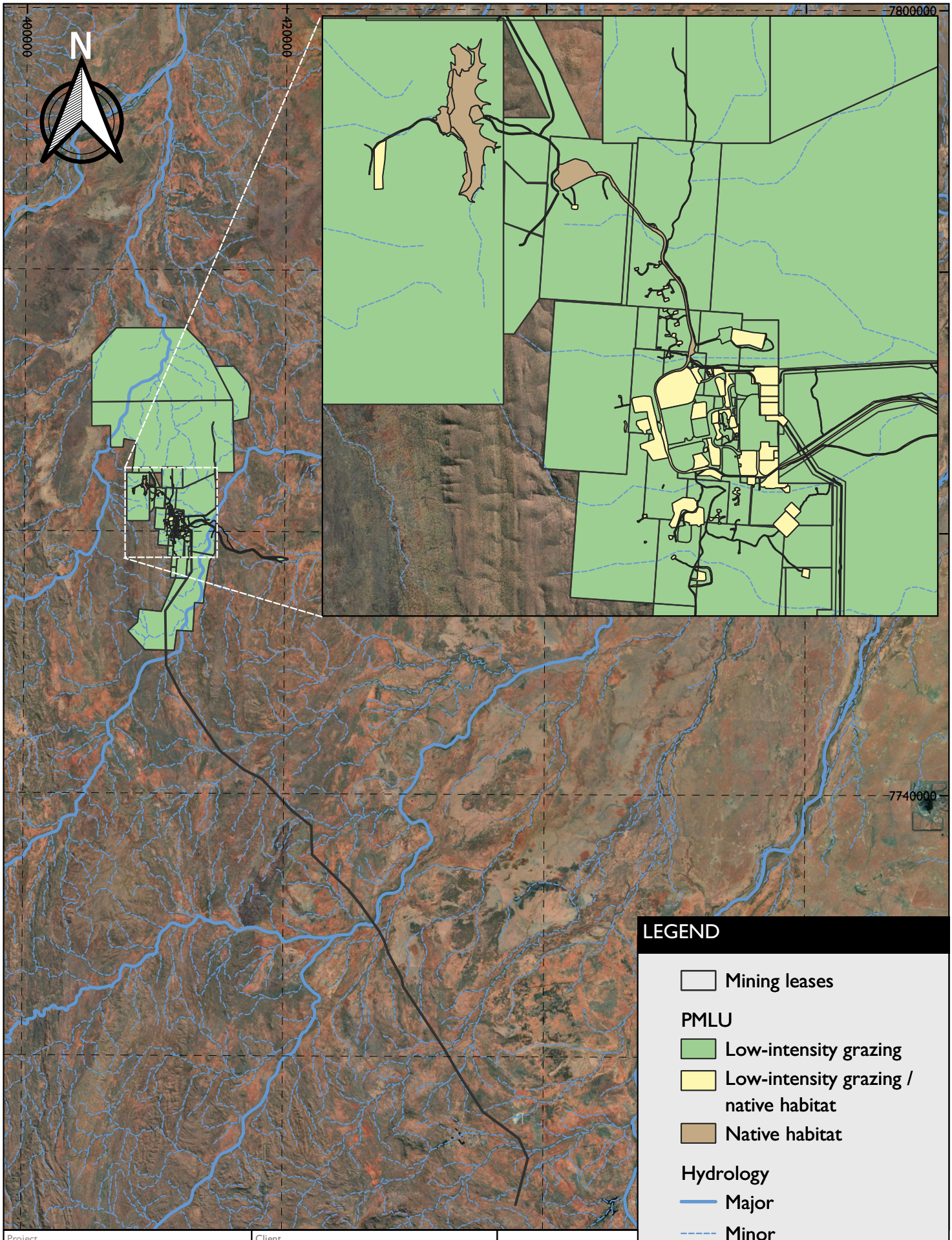
A.1 Final site design

The final site design (Figure 24) delineates the total area of the PRC plan as planned for surrender and includes the maximum disturbance footprint, MLA area as well as proposed PMLUs.

A.1.1 Rehabilitation areas

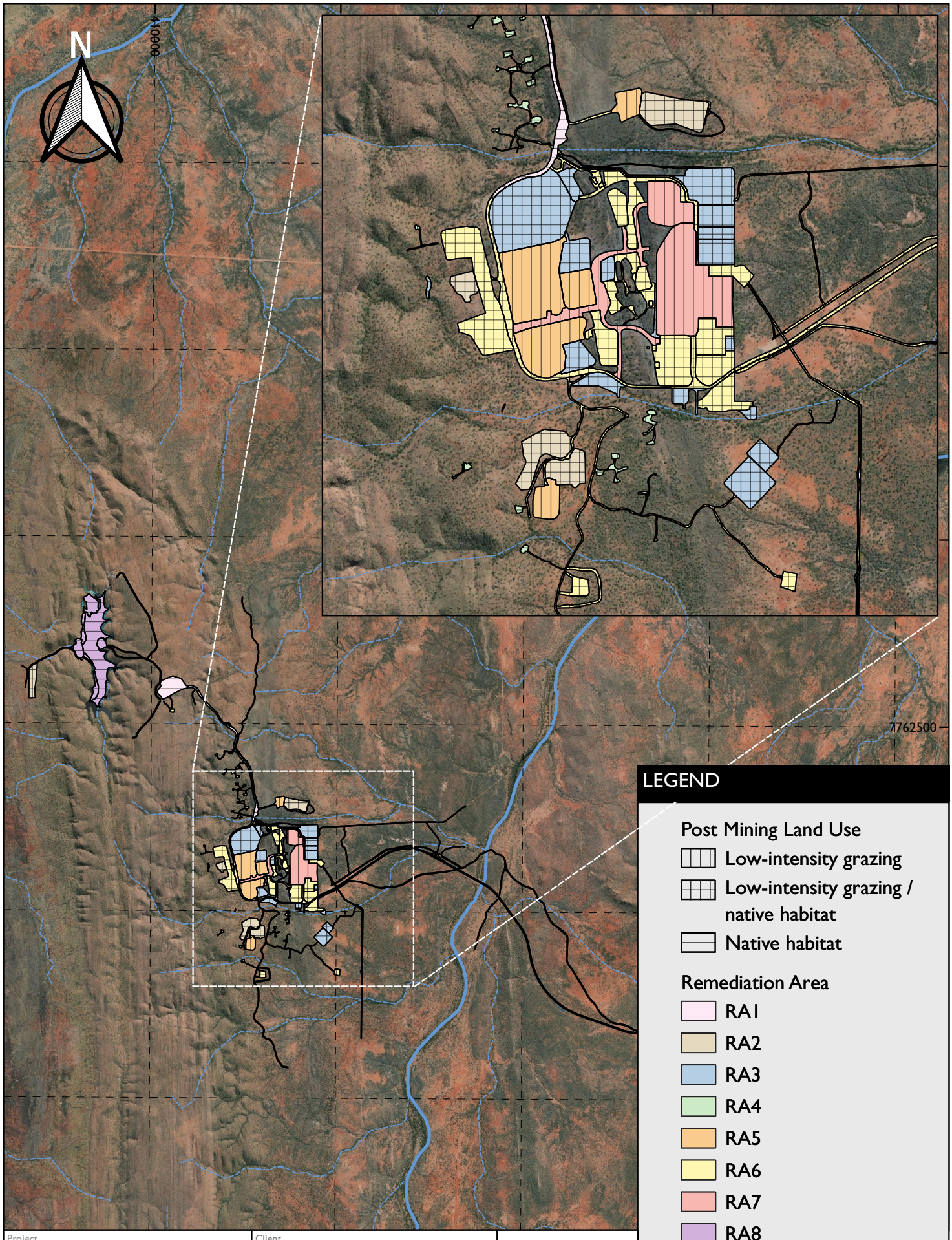
The disturbance areas identified in the final site design have been divided into the following rehabilitation areas, which have a common PMLU and rehabilitation methodology (Figure 25):

- RA1 — ancillary infrastructure and services;
- RA2 — borrow pits and stockpiles;
- RA3 — dams and diversion structures;
- RA4 — exploration;
- RA5 — mineralised waste;
- RA6 — mining and processing area (native habitat / grazing PMLU);
- RA7 — mining and processing area (grazing PMLU); and
- RA8 — TSF.



Project: Progressive Rehabilitation and Closure Plan		Client: MMG Limited	
Figure: 24	Title: Final Site Design	Design: SGM Environmental Pty Ltd 09.09.2021 Scale: 1 : 400,000 CRS: GDA94 / MGA zone 54	SGM environmental

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Project: Progressive Rehabilitation and Closure Plan		Client: MMG Limited	
Figure: 25	Title: Reference Map	Design: SGM Environmental Pty Ltd 27.09.2021 Scale: 1 : 70,000 CRS: GDA94 / MGA zone 54	SGM environmental

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A.2 Schedule of land availability

Land will become progressively available for rehabilitation throughout the life of the Mine. Land is considered available for rehabilitation when:

- the land is no longer being mined;
- the land is no longer being used for operating infrastructure or machinery for mining including dam or water storage;
- the land is not needed for mining of a probable or proved ore reserve; or
- the land contains permanent infrastructure that will remain on the land for a PMLU.

The schedule of land availability for rehabilitation at each feature is given in Table 68.

Table 68 Schedule of land availability for rehabilitation (non — cumulative)

		Land available for rehabilitation in each RA (ha)								
Feature		2022	2038	2039	2040	2041	2042	2043	2044	2045
RA1	Ancillary infrastructure and services		13.2							
RA2	Borrow pits and stockpiles		7.8							8.1
RA3	Dams and diversion structures				15.7				18.3	
RA4	Exploration	4.7								
RA5	Mineralised waste		22							
RA6	Mining and processing area (Grazing / Native habitat PMLU)		78.9							
RA7	Mining and processing area (Grazing PMLU)		23.3							
RA8	TSF and associated infrastructure		0.3	1.2	42.6					
Total (ha)		**4.7**	**145.5**	**1.2**	**58.3**	**0**	**0**	**0**	**18.3**	**8.1**

A.3 Rehabilitation milestones / criteria

Rehabilitation milestones are needed for each PMLU identified in accordance with Section 126D of the EP Act. The purpose is to identify each significant event or step necessary to rehabilitate the land to a stable condition.

Land is in a stable condition if the land is safe and structurally stable, there is no environmental harm being caused by anything on or in the land and the land can sustain a PMLU (Section 11A of the EP Act).

Rehabilitation milestones and milestone criteria relevant to each rehabilitation area are listed in Table 69.

Table 69 Rehabilitation milestones and milestone criteria

Milestone reference	Rehabilitation milestone	Milestone criteria	Rehabilitation area
RM1	Infrastructure decommissioning and removal	a) All site services decommissioned. b) All road materials (bitumen and gravel) removed. c) All pipelines drained and removed. d) All fencing is removed. e) All buildings removed. f) All drill holes, sumps, exploration tracks and gridlines decommissioned. g) Consultation with stakeholders and legal agreements developed with landholders for any infrastructure to be retained.	RA1, RA3, RA4, RA6, RA7 and RA8
RM2	Remediation of contaminated land	a) Carry out preliminary and intrusive contaminated land investigations with a site investigation report prepared by an appropriately qualified person (AQP). b) Removal or on-site treatment of contaminated water. c) Removal and appropriate disposal of contaminated materials. d) Conduct validation testing to confirm that contaminated materials have been removed or remediated. e) Certification from an AQP that all contaminated land has been either remediated or removed.	RA1, RA3, RA5, RA6 and RA7
RM3	Landform development and reshaping / re-profiling	a) Finalise engineering and design plans. b) Bulk earthworks to achieve landform and slopes as per the agreed design. c) General reshaping and trimming to achieve final landform as per agreed design. d) Fill dams. e) Backfill and seal shafts, portals / adits. f) Install erosion and sediment control systems.	RA1, RA2, RA3, RA5, RA6, RA7, RA8

Milestone reference	Rehabilitation milestone	Milestone criteria	Rehabilitation area
		g) Verification from an AQP that the final constructed landform is consistent with reference sites and as per agreed design.	
RM4	Installation of cover	a) Conversion of operational TSF spillway and embankment to the final closure rock lined spillway as per the agreed design b) Installation of capillary break layer over the TSF surface c) Installation of reduced permeability layer (RPL) over the capillary break layer d) Installation of infiltration storage layer (ISL) over the RPL layer e) Certification by an AQP that the TSF cover layers and spillway have been installed in accordance with the approved design	RA8
RM5	Surface preparation	a) Remediate any erosion or subsidence b) An assessment of soil health and suitability has been completed by an AQP to confirm soil is suitable for target vegetation establishment. c) Application of ameliorants as per requirements of the soil health and suitability assessment. d) Placement of 200mm of soil / growth medium e) Ripping completed as per the agreed specification	RA1, RA2, RA3, RA4, RA5, RA6, RA7, RA8
RM6	Revegetation (pasture grazing or native habitat)	a) Completed seeding at a rate consistent with the revegetation plan in the PRC plan. b) Application of fertiliser as per soil and health suitability assessment. c) Install stock fencing to protect rehabilitated area.	RA1, RA2, RA3, RA4, RA5, RA6, RA7, RA8

Milestone reference	Rehabilitation milestone	Milestone criteria	Rehabilitation area
RM7	Achievement of surface requirements (pasture grazing or native habitat)	a) Average total ground cover (all ground cover categories aggregated) is no less than the 15th percentile of equivalent control site. b) Average soft spinifex cover estimates are no less that the 15th percentile of equivalent control sites. c) Buffel grass cover estimates exceed no more than the 70th percentile of equivalent control sites for native habitat areas (native habitat). d) Kapok bush cover estimates exceed no more than the 70th percentile of equivalent control sites. e) A minimum of 70% of target species as per the revegetation plan have been established f) Erosion gullies are less than or equal to 1m deep. g) Certification by an AQP that revegetation is comparable to reference sites, erosion and drainage is acceptable and weeds and pest species are in densities no greater than at reference sites.	RA1, RA2, RA3, RA4, RA5, RA6, RA7, RA8
RM8	Achievement of PMLU to a stable condition (pasture grazing or native habitat)	a) The rehabilitated landforms can sustain the agreed PMLU as certified by an AQP. b) The rehabilitated landforms have achieved a suitable factor if safety as certified by an AQP. c) The rehabilitated landforms have a maximum erosion rate of <10 t/ha/yr as certified by an AQP. d) Develop a post closure land management plan for future landholder in consultation with them. e) Surface water quality at downstream compliance sites DR-18 and DR-22 complies with the following: • pH is between 6.0 and 9.0 or 95th percentile of reference, whichever is higher;	RA1, RA2, RA3, RA4, RA5, RA6, RA7, RA8

Milestone reference	Rehabilitation milestone	Milestone criteria	Rehabilitation area
		• electrical conductivity (EC) is ≤5970 microsiemens/centimetre (µS/cm) or 95th percentile of reference, whichever is higher; • sulphate is ≤1000 milligrams/litre (mg/L) or 95th percentile of reference, whichever is higher; • fluoride is ≤2 mg/L or 95th percentile of reference, whichever is higher; • aluminium is ≤5 mg/L or 95th percentile of reference, whichever is higher; • arsenic is ≤0.5 mg/L or 95th percentile of reference, whichever is higher; • cadmium is ≤0.01 mg/L or 95th percentile of reference, whichever is higher; • copper is ≤1 mg/L or 95th percentile of reference, whichever is higher; • lead is ≤0.1 mg/L or 95th percentile of reference, whichever is higher; • nickel is ≤1 mg/L or 95th percentile of reference, whichever is higher; • zinc is ≤20 mg/L or 95th percentile of reference, whichever is higher. *1. All metals and metalloids measured as total (unfiltered)* f) Groundwater quality at MB2 and MB4 complies with the following; • pH is between 6 and 9 or 95th percentile of reference, whichever is higher; • electrical conductivity is ≤2000 µS/cm or 95th percentile of reference, whichever is higher; • sulphate is ≤1000 mg/L or 95th percentile of reference, whichever is higher;	

Milestone reference	Rehabilitation milestone	Milestone criteria	Rehabilitation area
		• fluoride is ≤2 mg/L or 95th percentile of reference, whichever is higher; • aluminium is ≤5 mg/L or 95th percentile of reference, whichever is higher; • arsenic is ≤0.5 mg/L or 95th percentile of reference, whichever is higher; • cadmium is ≤0.01 mg/L or 95th percentile of reference, whichever is higher; • copper is ≤1 mg/L or 95th percentile of reference, whichever is higher; • lead is ≤0.1 mg/L or 95th percentile of reference, whichever is higher; • manganese is ≤1.9 mg/L or 95th percentile of reference, whichever is higher; • nickel is ≤1 mg/L or 95th percentile of reference, whichever is higher; and • zinc is ≤20 mg/L or 95th percentile of reference, whichever is higher. *1. All metals and metalloids measured as total (unfiltered)*	

A.4 Proposed PRC plan schedule

The *Progressive Rehabilitation and Closure Plan Schedule template* is given on the following page.

A.4.1 Timing considerations

The Mine and its rehabilitation are strongly dependent on updates to the Mine plan. Revegetation (RM6) is strongly season-dependent as well as vegetation establishment (RM7).

All predictions of land availability within the calendar year are based on the current forecast projection date of the Project. This date is subject to change and government approval. Milestones (ie annual report of rehabilitation works) have a completion date of the 10 December of the calendar year.

Progressive Rehabilitation and Closure Plan Schedule template

Instructions

General Instructions:

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

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

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

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

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

Further Instructions when inputting PMLUs

Headings under Rehabilitation Area (RA) sheets

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

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

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

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

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

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

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

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

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

Headings under Rehabilitation Area Milestones sheet

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

Further Instructions when inputting NUMAs

Headings under Improvement Area (IA) sheets

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

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

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

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

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

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

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

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

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

Headings under Improvement Area Milestones sheet

Post-mining land uses (PMLU)										
Rehabilitation area	RA1									
Relevant activities	Ancillary infrastructure and services									
Total rehabilitation area size (ha)	13.2									
Commencement of first milestone: RM1	1 Jan 2038									
PMLU	Native habitat									
Date area is available	1/01/2038									
Cumulative area available (ha)	13.2									
Milestone completed by	10/12/2039	10/12/2041	10/12/2042	10/12/2043	10/12/2046					
Milestone Reference	**Cumulative area achieved (ha)**									
RM1	13.2									
RM2		13.2								
RM3			13.2							
RM5				13.2						
RM6				13.2						
RM7					13.2					
RM8					13.2					

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

Post-mining land uses (PMLU)										
Rehabilitation area	RA2									
Relevant activities	Borrow pits and stockpiles									
Total rehabilitation area size (ha)	15.9									
Commencement of first milestone: RM3	1 Jan 2038									
PMLU	Grazing / Native habitat									
Date area is available	1/01/2038	1/01/2039	1/01/2040	1/01/2045	1/01/2046					
Cumulative area available (ha)	7.8			15.9						
Milestone completed by	10/12/2038	10/12/2039	10/12/2042	10/12/2045	10/12/2048					
Milestone Reference	**Cumulative area achieved (ha)**									
RM3	7.8			15.9						
RM5		7.8		15.9						
RM6		7.8		15.9						
RM7			7.8		15.9					
RM8			7.8		15.9					

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

Post-mining land uses (PMLU)										
Rehabilitation area	RA3									
Relevant activities	Dams and diversion structures									
Total rehabilitation area size (ha)	34									
Commencement of first milestone: RM1	1 Jan 2040									
PMLU	Grazing / Native habitat									
Date area is available	1/01/2040	10/12/2044								
Cumulative area available (ha)	15.7	34								
Milestone completed by	10/12/2040	10/12/2045	10/12/2046	10/12/2049						
Milestone Reference	**Cumulative area achieved (ha)**									
RM1	15.7	34								
RM2	15.7	34								
RM3		15.7	34							
RM5		15.7	34							
RM6		15.7	34							
RM7				34						
RM8				34						

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

Post-mining land uses (PMLU)										
Rehabilitation area	RA4									
Relevant activities	Exploration									
Total rehabilitation area size (ha)	4.7									
Commencement of first milestone: RM1	1 Jan 2022									
PMLU	Grazing / Native habitat									
Date area is available	1/01/2022									
Cumulative area available (ha)	4.7									
Milestone completed by	10/12/2030	10/12/2031	10/12/2034							
Milestone Reference	**Cumulative area achieved (ha)**									
RM1	4.7									
RM5		4.7								
RM6		4.7								
RM7			4.7							
RM8			4.7							

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

Post-mining land uses (PMLU)										
Rehabilitation area	RA5									
Relevant activities	Mineralised waste									
Total rehabilitation area size (ha)	22									
Commencement of first milestone: RM2	1 Jan 2038									
PMLU	Grazing									
Date area is available	1/01/2038									
Cumulative area available (ha)	22									
Milestone completed by	10/12/2040	10/12/2043	10/12/2044	10/12/2047						
Milestone Reference	**Cumulative area achieved (ha)**									
RM2	22									
RM3		22								
RM5			22							
RM6			22							
RM7				22						
RM8				22						

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

Post-mining land uses (PMLU)										
Rehabilitation area	RA6									
Relevant activities	Mining and processing area									
Total rehabilitation area size (ha)	78.9									
Commencement of first milestone: RM1	1 Jan 2038									
PMLU	Grazing / Native habitat									
Date area is available	1/01/2038									
Cumulative area available (ha)	78.9									
Milestone completed by	10/12/2040	10/12/2041	10/12/2042	10/12/2045						
Milestone Reference	**Cumulative area achieved (ha)**									
RM1	78.9									
RM2	78.9									
RM3		78.9								
RM5			78.9							
RM6			78.9							
RM7				78.9						
RM8				78.9						

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

Post-mining land uses (PMLU)										
Rehabilitation area	RA7									
Relevant activities	Mining and processing area									
Total rehabilitation area size (ha)	23.3									
Commencement of first milestone: RM1	1 Jan 2038									
PMLU	Grazing									
Date area is available	1/01/2038									
Cumulative area available (ha)	23.3									
Milestone completed by	10/12/2040	10/12/2041	10/12/2042	10/12/2045						
Milestone Reference	**Cumulative area achieved (ha)**									
RM1	23.3									
RM2	23.3									
RM3		23.3								
RM5			23.3							
RM6			23.3							
RM7				23.3						
RM8				23.3						

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

Post-mining land uses (PMLU)										
Rehabilitation area	RA8									
Relevant activities	TSF									
Total rehabilitation area size (ha)	44									
Commencement of first milestone: RM1	1 Jan 2038									
PMLU	Native habitat									
Date area is available	1/01/2038	1/01/2039	1/01/2040							
Cumulative area available (ha)	0.3	1.5	44							
Milestone completed by	10/12/2038	10/12/2039	10/12/2042	10/12/2043	10/12/2046					
Milestone Reference	**Cumulative area achieved (ha)**									
RM1	0.3	1.5	44							
RM3		1.5	44							
RM4			44							
RM5				44						
RM6				44						
RM7					44					
RM8					44					

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

Milestone referenc	Rehabilitation milestone	Milestone criteria
RM1	Infrastructure decommissioning and removal	a) All site services decommissioned. b) All road materials (bitumen and gravel) removed. c) All pipelines drained and removed. d) All fencing is removed. e) All buildings removed. f) All drill holes, sumps, exploration tracks and gridlines decommissioned. g) Consultation with stakeholders and legal agreements developed with landholders for any infrastructure to be retained
RM2	Remediation of contaminated land	a) Carry out preliminary and intrusive contaminated land investigations with a site investigation report prepared by an appropriately qualified person (AQP) b) Removal or on-site treatment of contaminated water c) Removal and appropriate disposal of contaminated materials d) Conduct validation testing to confirm that contaminated materials have been removed or remediated e) Certification from an AQP that all contaminated land has been either remediated or removed
RM3	Landform development and reshaping / re-profiling	a) Finalise engineering and design plans b) Bulk earthworks to achieve landform and slopes as per the agreed design c) General reshaping and trimming to achieve final landform as per agreed design d) Fill dams e) Backfill and seal shafts, portals / adits f) Install erosion and sediment control systems g) Verification from an AQP that the final constructed landform is consistent with reference sites and as per agreed design
RM4	Installation of cover	a) Conversion of operational TSF spillway and embankment to the final closure rock lined spillway as per the agreed design b) Installation of capillary break layer over the TSF surface c) Installation of reduced permeability layer (RPL) over the capillary break layer d) Installation of infiltration storage layer (ISL) over the RPL e) Certification by an AQP that the TSF cover layers and spillway have been installed in accordance with the approved design
RM5	Surface preparation	a) Remediate any erosion or subsidence b) An assessment of soil health and suitability has been completed by an AQP to confirm soil is suitable for target vegetation establishment. c) Placement of 200mm of soil / growth medium d) Application of ameliorants as per requirements of the soil health and suitability assessment. e) Ripping completed as per the agreed specification
RM6	Revegetation (pasture grazing, native habitat or grazing / native habitat)	a) Completed seeding of target species at a rate consistent with the revegetation plan in the PRC plan b) Application of fertiliser as per soil and health suitability assessment c) Install stock fencing to protect rehabilitated area
RM7	Achievement of surface requirements (pasture grazing, native habitat or grazing / native habitat)	a) Average total ground cover (all ground cover categories aggregated) is no less than the 15th percentile of equivalent control site b) Average soft spinifex cover estimates are no less that the 15th percentile of equivalent control sites c) Buffel grass cover estimates exceed no more than the 70th percentile of equivalent control sites (native habitat) d) Kapok bush cover estimates exceed no more than the 70th percentile of equivalent control site e) A minimum of 70% of target species as per the revegetation plan have been established f) Erosion gullies are less than or equal to 1m deep. g) Certification by an AQP that revegetation is comparable to reference sites, erosion and drainage is acceptable and weeds and pest species are in densities no greater than at reference sites.
RM8	Achievement of PMLU to a stable condition (pasture grazing, native habitat or grazing / native habitat)	a) The rehabilitated landforms can sustain the agreed PMLU as certified by an AQP b) The rehabilitated landforms have achieved a suitable factor of safety as certified by an AQP c) The rehabilitated landforms have a maximum erosion rate of <10 t/ha/yr as certified by an AQP d) Develop a post closure land management plan for future landholder in consultation with them
RM8	Continued	e) Surface water quality at downstream compliance sites DR-18 and DR-22 complies with the following: • pH is between 6.0 and 9.0 or 95th percentile of reference, whichever is higher; • electrical conductivity (EC) is ≤ 5970 microsiemens/centimetre (µS/cm) or 95th percentile of reference, whichever is higher; • sulphate is ≤1000 milligrams/litre (mg/L) or 95th percentile of reference, whichever is higher; • fluoride is ≤2 mg/L or 95th percentile of reference, whichever is higher; • aluminium is ≤ 5 mg/L or 95th percentile of reference, whichever is higher; • arsenic is ≤ 0.5 mg/L or 95th percentile of reference, whichever is higher; • cadmium is ≤ 0.01 mg/L or 95th percentile of reference, whichever is higher; • copper is ≤ 1 mg/L or 95th percentile of reference, whichever is higher; • lead is ≤ 0.1 mg/L or 95th percentile of reference, whichever is higher; • nickel is ≤ 1 mg/L or 95th percentile of reference, whichever is higher; • zinc is ≤ 20 mg/L or 95th percentile of reference, whichever is higher. *1. All metals and metalloids measured as total (unfiltered)*
RM8	Continued	f) Groundwater quality at MB2 and MB4 complies with the following; • pH is between 6 and 9 or 95th percentile of reference, whichever is higher; • electrical conductivity is ≤2000 µS/cm or 95th percentile of reference, whichever is higher; • sulphate is ≤1000 mg/L or 95th percentile of reference, whichever is higher; • fluoride is ≤2 mg/L or 95th percentile of reference, whichever is higher; • aluminium is ≤5 mg/L or 95th percentile of reference, whichever is higher; • arsenic is ≤0.5 mg/L or 95th percentile of reference, whichever is higher; • cadmium is ≤0.01 mg/L or 95th percentile of reference, whichever is higher; • copper is ≤1 mg/L or 95th percentile of reference, whichever is higher; • lead is ≤0.1 mg/L or 95th percentile of reference, whichever is higher; • manganese is ≤1.9 mg/L or 95th percentile of reference, whichever is higher; • nickel is ≤1 mg/L or 95th percentile of reference, whichever is higher; and • zinc is ≤20 mg/L or 95th percentile of reference, whichever is higher. *1. All metals and metalloids measured as total (unfiltered)*

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

Appendix B
Dugald River Mine Biennial Groundwater Review



MMG Limited

Dugald River Mine Biennial Groundwater Review

6 September 2019

CDM Smith

listen. think. deliver.

Executive Summary

CDM Smith Australia Pty Ltd (CDM Smith) was engaged by MMG Australia Limited (MMG) to undertake a biennial groundwater review at MMG's Dugald River Mine (the Site) to meet compliance requirements associated with the mine's condition of approval outlined in the Environmental Authority Permit (No. EPML00731213) (EA). This biennial groundwater review focuses on groundwater quality data collected in 2017 and 2018.

Data collected over the review period was imported into a database and assessed against standard data quality objectives. Overall, groundwater chemistry and groundwater level data are considered reliable for the interpretation of groundwater conditions at the Site. A number of non-compliances of condition C36 (which relates to monitoring frequency and analysis) occurred during the monitoring period, however, these omissions are not thought to affect the overall interpretation of groundwater conditions at the site. Some recommendations have been made to improve data quality and collection to comply with the EA.

The groundwater level data indicates similar trends to those identified in the past:

- The Mount Roseby Schist bores show seasonal variations (1 to 3 m) in groundwater levels consistent with rainfall trends, with lowest groundwater levels at the end of the dry season and levels rising during the wet season.
- Monitoring bore MB9D is screened within the deep portion Knapdale Quartzite (18 to 30 m) and shows minimal seasonal variations. MB9S monitors a shallower portion of the Knapdale Quartzite and is observed to be dry most of the time.
- MB10 and MB11 (Dugald River Slate – ore body host) have been compromised due to interactions with underground mining operations and are unlikely to reflect true groundwater levels within the Dugald River Slate.

The validated data was assessed against trigger levels and contaminant limits defined in the EA:

- Condition C36 (trigger levels): Most analytes were below trigger levels or below background levels. Zinc at MB6 requires further investigation and copper at MB2 should be assessed using control charting.
- Condition C37 (contaminant limits): Most analytes were below contaminant limits; however, the following non-compliances are noted:
    - Non-compliance for fluoride at MB2 in Q1, Q2 and Q3 2017 and Q2 2018 – these concentrations are within natural variations across the site.
    - Non-compliance for total lead at MB9D in Q3 2018 – may be related to high suspended solids in the bore. It is recommended that this bore is redeveloped prior to the next sampling round.

This report represents compliance with Condition C40 to produce a report detailing the monitoring undertaken over the two-year period from the beginning of 2017 to the end of 2018. Changes to the GMP and/or EA that are recommended as a result of this review include:

- Update the GMP to include clear objectives, sampling procedures and data analysis and reporting requirements;
- Inclusion of the Cabbage Creek catchment bores in the GMP (MB5, MB6, MB9S and MB9D);
- Investigation of the fluoride contaminant limit in the EA to take into account background and historical concentrations and bring this in line with natural variations; and
- Inclusion of the use of control charting to assess copper concentrations at MB2 in the EA

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Section 1 Introduction

1.1 Background

CDM Smith Australia Pty Ltd (CDM Smith) was engaged by MMG Australia Limited (MMG) to undertake a biennial review of groundwater monitoring and monitoring results for MMG's Dugald River Mine (the Site) to meet the compliance requirements of Condition C40 in the site's Environmental Authority (EA) EPML00731213.

Condition C40 of EA EPML00731213 requires a report on groundwater monitoring, including monitoring results and interpretations, and must include:

a) An assessment of groundwater monitoring results against the objectives of the MMG Dugald River Mine Groundwater Monitoring Program (GMP);

b) A review of groundwater compliance against requirements specified in the EA; and

c) Any proposed refinement or update to the GMP or EA, with respect to monitoring locations, frequency, parameters, specified trigger values and/or specified contaminant limits, that may be applicable on review of the collected data or other relevant information.

The previous biennial groundwater review was conducted by Big Dog Hydrogeology Pty Ltd (BDH) in April 2017.

The MMG Dugald River Mine GMP was developed by BDH in 2014. The groundwater monitoring requirements included in the GMP were endorsed by the Department of Environment and Science (DES) and included in EA EPML00731213.

1.2 Site description

The 1.7 Million tonnes per annum (Mtpa) Dugald River operation is located approximately 65 km northwest of Cloncurry and 100 km northeast of Mount Isa, Queensland (Figure 1), and involves the mining and on-site processing of a high-grade zinc deposit (MMG 2017). Underground mining is conducted by utilising a stoping and backfill method, with access to the orebody provided by two declines, which may eventually reach 1,000 m in depth (BDH 2017 and Golder 2017). Waste rock is temporarily stored on the surface while stoping operations are completed, with waste rock returned underground at the completion of stoping activities.

1.3 Scope of works

This biennial groundwater review focuses on groundwater quality data collected in 2017 and 2018. The tasks completed as part of this review are described below.

- Data analysis including:
  - data validation and cleansing of the 2017-2018 groundwater monitoring data in line with the DES guidelines (DSITI, 2017) and general good practice;
  - assessment of the validated groundwater quality data collected from compliance bores in Table 2-1 against trigger and contaminant values outlined in Schedule C – Table 8 of the EA (Groundwater Levels and Contaminant Limits);
  - assessment of the validated data against objectives outlined in the GMP;
  - identification of further actions required based on the outcome of the groundwater quality comparisons; and
  - interpretation of outputs generated from the data analysis related to compliance.

- Preparation of this biennial groundwater report, including:
  - a summary of mine site activities that could impact groundwater at the site over the monitoring period (2017-2018 - provided by MMG, see Section 1.4);
  - a summary of the hydrogeological setting of Dugald River Mine (see Section 2);
  - a summary of the data analysis undertaken for the groundwater quality results from bores shown in Table 2-1 (see Section 3);
  - a summary of results compared against the EA and the GMP for Dugald River Mine (see Section 3); and
  - conclusions and recommendations regarding any proposed changes to the GMP, if any (see Section 4).

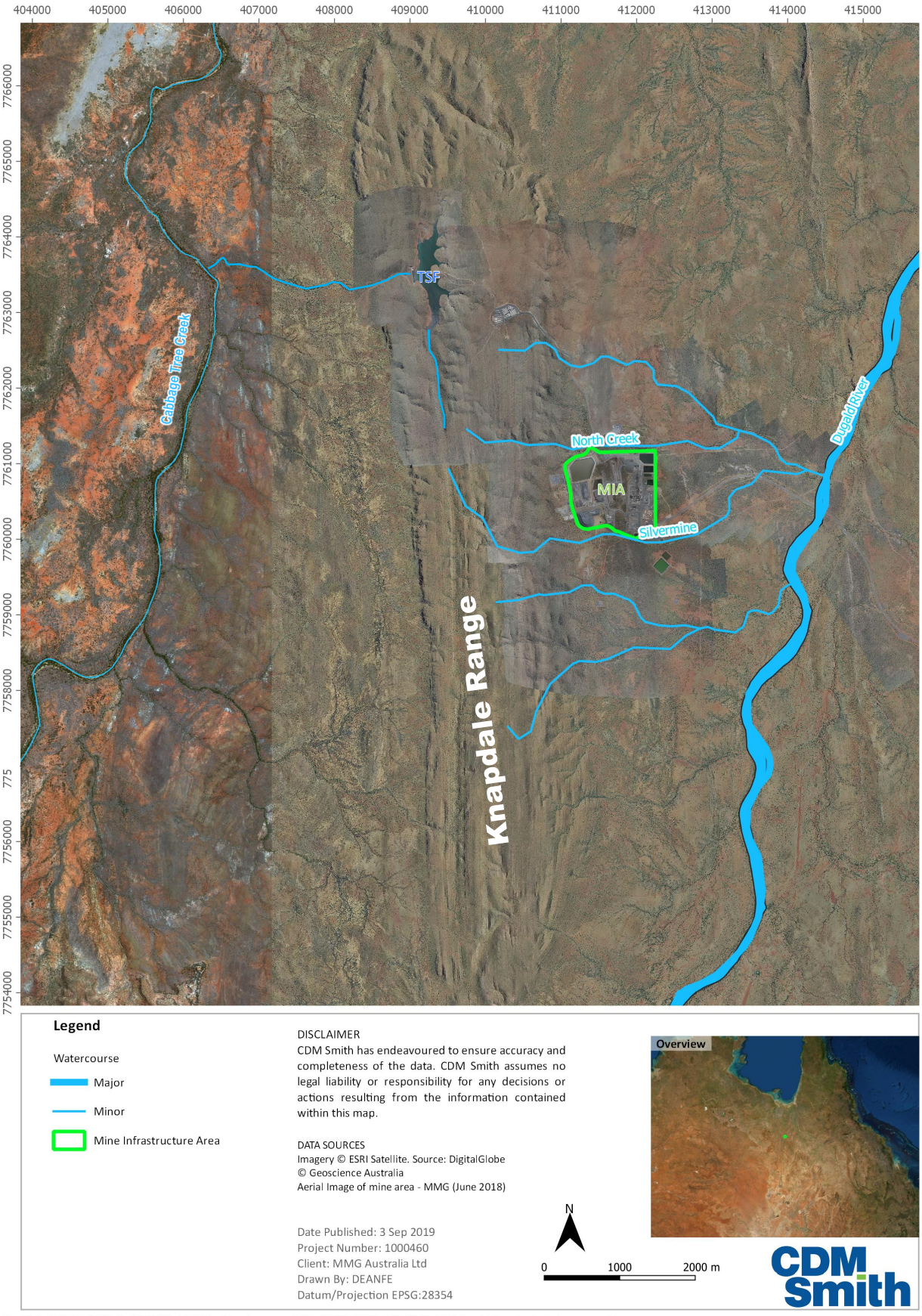


Figure 1-1 Project locality plan

1.4 Site facilities

Table 1-1 summarises the facilities located at the Site which are utilised for ore processing and other associated mining activities (based on previous reporting by BDH (2017) and Golder (2017)). Most activities undertaken at the Site are within the Mine Infrastructure Area (MIA), except for the Tailings Storage Facility (TSF). A detailed map outlining the location of relevant mine facilities and monitoring bores has been provided in Figure 1-2.

Table 1-1 Mine facility description

Facility	Description
Tailings Storage Facility (TSF) and TSF seepage collection pond	Receives and stores mineralised process tailings and supernatant, HDPE lined TSF seepage collection pond.
Run of Mine (ROM) Pad and ROM Run Off-Dam	Ore storage area prior to crushing. ROM run-off is captured and stored in a HDPE lined Dam.
Mineral Processing Area and Processing Area Run-Off Dam	Includes crusher, coarse or stockpile, mills, concentrator, concentrate storage shed, paste plant, maintenance and warehousing infrastructure, fuel storage and processing area run-off dam (unlined).
Raw Water Dam	Lined dam receives raw (clean) water from Lake Julius.
Sediment Dam A	Unlined dam receives stormwater runoff from mining areas.
PAF Waste Rock storage pads, batching plant area, run off ponds and Sediment Dam G	Temporary storage area for potential acid forming waste rock (Stages 1 and 2), two HDPE lined run off collection ponds which discharge to Sediment Dam G. Sediment Dam G also receives stormwater runoff from laydown areas.
NAF Waste Rock storage pad, run off pond and Sediment Dam F	Temporary storage of non-acid forming waste rock, unlined run off pond discharging to Sediment Dam F.
Mining infrastructure area	North and south portals and declines, haul roads, fuel storage, ventilation shafts, laydown areas and mine water dam facility (3 unlined sediment dams) .
Mine maintenance workshop and sediment dam.	Mechanical, electrical and mobile equipment maintenance workshops, fuel storage, work shop runoff sediment dam.
Core shed	Core processing shed, core storage, unlined sediment dam (D)
Administration area and sediment dam C.	Administration buildings, fly camp, STP and sediment dam C.

Information provided by MMG regarding mining activities conducted during the reporting period that have the potential to impact groundwater (2017 and 2018) is summarised below:

- The Dugald River Mine concentrator commenced operation in September 2017;
- The TSF began receiving tailings and tailing supernatant in September 2017;
- All site sediment dams have received and held stormwater since the last biennial groundwater review (BDH, 2017), water is received during the wet season and evaporated during the dry season;
- All containment dams (NAF, PAF1, PAF2, ROM run off, Process Plant run off and STP dams) filled during the wet seasons and evaporated during the dry seasons; and
- The Process Plant Run Off Storages have held water since the 2017/2018 wet season.

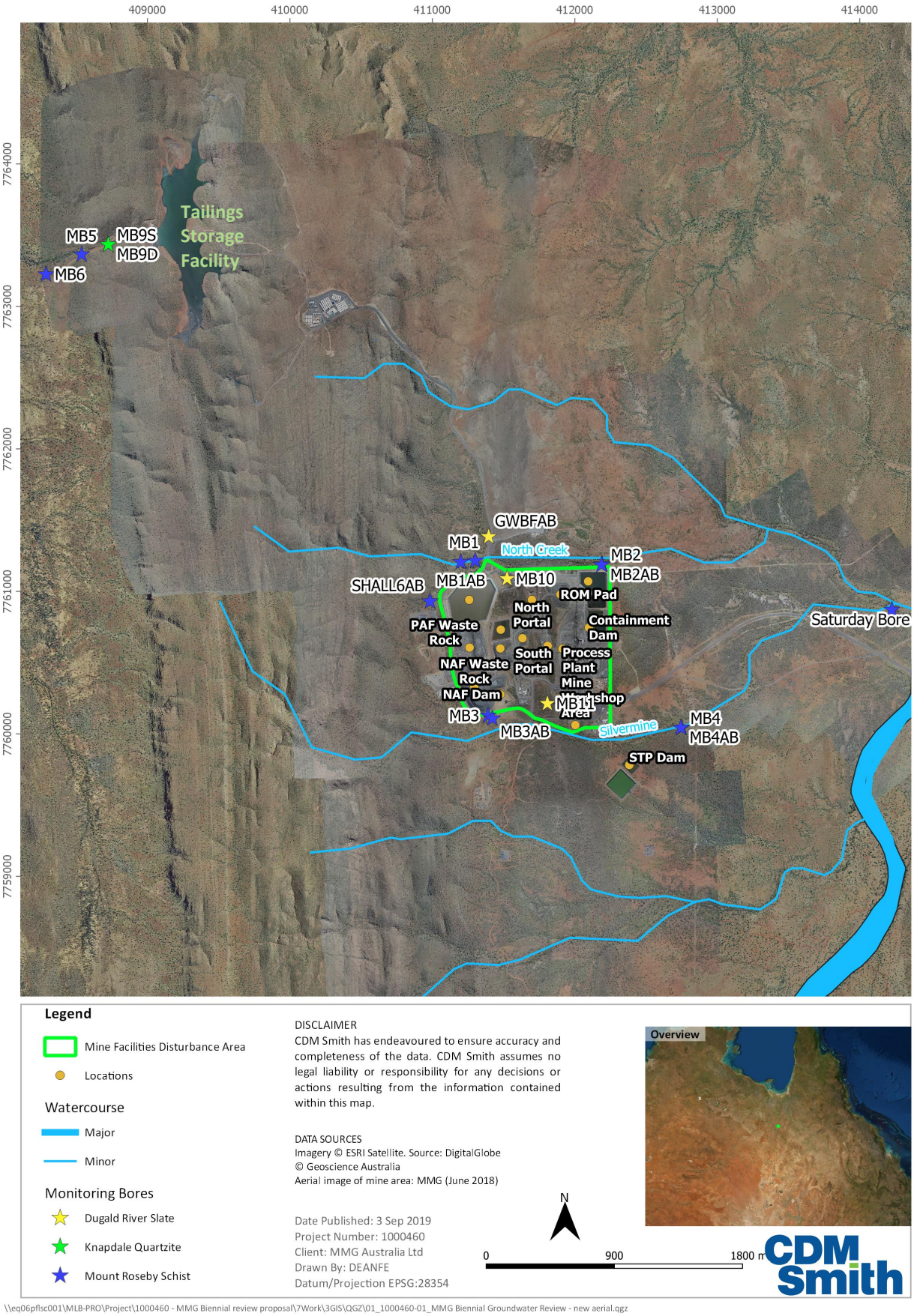


Figure 1-2 Mine facilities locality plan

1.5 Environmental Authority conditions (EPML00731213)

The Site currently operates under a Queensland Department of Environment and Science (DES) EA (No. EPML00731213), with specific conditions relating to groundwater monitoring and reporting outlined in Condition 36 to Condition 40, inclusive (Table 1-2).

Table 1-2 Relevant Conditions of Approvals

Condition Number	Relevance	Condition
C36	Groundwater	*Groundwater quality and level must be monitored at the locations and frequency defined in Schedule C – Table 7 (Groundwater Monitoring Location and Frequency) and Schedule K - Figure 5 (Groundwater Bore Monitoring Locations) for quality characteristics identified in Schedule C – Table 8 (Groundwater Trigger Levels and Contaminant Limits).*
C37	Groundwater	*If quality characteristics of groundwater from compliance bores identified in Schedule C – Table 7 (Groundwater Monitoring Locations and Frequency) exceed any of the trigger levels stated in Schedule C – Table 8 (Groundwater Trigger Levels and Contaminant Limits), the holder of this environmental authority must compare the compliance monitoring bore results to the reference bore results and:* *a) If the level of contaminants at the compliance monitoring bore does not exceed the reference bore results, then no action is to be taken; and* *b) If the level of contaminants at the compliance monitoring bore is greater than the reference bore results, complete an investigation in accordance with the ANZECC and ARMCNZ 2000, into the potential for environmental harm an provide a written report to the administering authority within three (3) months outlining:* *(i) Details of the investigation carried out;* *(ii) Details of environmental impacts observed; and* *(iii) Actions taken to prevent environmental harm.*
C38	Groundwater	*Results of monitoring of groundwater from compliance bores identified in Schedule C – Table 7 (Groundwater Monitoring Locations and Frequency), must not exceed any of the contaminant limits defined in Schedule C – Table 8 (Groundwater Trigger Levels and Contaminant Limits).*
C39	Bore Construction	*The construction, maintenance and management of groundwater bores (including groundwater monitoring bores) must be undertaken in a manner that prevents or minimises impacts to the environment and ensures the integrity of the bores to obtain accurate monitoring.*
C40	Reporting	*A report on groundwater monitoring, including monitoring results and interpretations, must be prepared by a relevantly qualified and suitable person on a biennial (two yearly) basis and be made available to the administering authority on request. The report must include.* *a) An assessment of groundwater monitoring results against the objectives of the MMG Dugald River Mine Groundwater Monitoring Program.* *b) A review of groundwater compliance against requirements specified in the environmental authority.* c) *Any proposed refinement or update to the groundwater monitoring program or environmental authority, with respect to monitoring locations, frequencies, parameters, specified trigger values and/or specified contaminant limits, that may be applicable on review of the collected data or other relevant information.*

1.6 Groundwater monitoring program objectives

EA condition C40 requires an assessment of groundwater monitoring results against the objectives of the MMG Dugald River Mine Groundwater Monitoring Program (GMP). The current GMP for the Dugald River Mine was developed by BDH in 2014 to replace the 2012 GMP. The objectives in the GMP are not clear, although the general aim of the GMP can be inferred from the document as to comply with the EA and to protect environmental values in the area from impacts of mining activities, including risk of impacts from mine dewatering, risk associated with stock watering and potable use, and risk of hydrochemical impacts to aquatic ecosystems.

The requirements of the GMP generally align with the EA. Where the GMP and EA differ is as follows:

- Four of the bores specified for gauging (MB7S, MB7D, MB8S and MB8D) in the GMP have been decommissioned since the preparation of this document; and
- The GMP focusses on the MIA and does not include sampling of the bores in the Cabbage Tree Creek catchment (related to the TSF)

The GMP requires updating to include these differences. As the GMP does not include clear objectives of the monitoring, it is not possible to state whether the objectives of the GMP have been met through the current monitoring.

Section 2 Hydrogeological Conceptual Model

The hydrogeological conceptual model is described below and is based on the recent CDM Smith groundwater quality review (CDM Smith, 2018). This review was based on the previous reports by BDH (2014 and 2017) and Golder (2017) and summarises the previous descriptions of the groundwater conditions at the site. The most recent data has been used to update this conceptual model, which does not differ significantly from previous interpretations.

2.1 Topography and drainage

On a regional scale, the Knapdale Range is a north south trending ridge located approximately one kilometre to the west of MIA and to the east of the TSF. The general area is characterised by several north-south trending ridges, with the Knapdale Ridge being the highest regionally (323 m AHD) and forming the drainage divide between the Flinders River catchment to the east and the Leichardt River catchment to the west.

On a local scale, the topography around the MIA ranges in elevation between around 195 and 210 m AHD according to elevation data recorded on composite well logs MB1 to MB11 (see Appendix A) and digital elevation model (DEM) data. The topography around the MIA slopes towards Saturday Bore and Dugald River (182 m AHD) whereas near the TSF the elevation drops to the west, as it is on the western side of the Knapdale Range.

To the north and south of the MIA, watercourses flow in an easterly direction from the Knapdale Range towards Dugald River. North Creek is located north of the MIA and Silvermine Creek is located to the south. The TSF is located in the Leichardt River Catchment and is constructed in the headwaters of a Cabbage Tree Creek tributary. All of these drainage features are ephemeral, and flows are described as being brief and episodic (BDH, 2017).

2.2 Geology

The geology in the area of the Dugald River Mine comprises of Proterozoic metasedimentary rocks of the Mt Isa Inlier (BDH, 2017). The geological units in the study area dip steeply to the west and comprise (from oldest to youngest):

- Knapdale Quartzite – pink, massive recrystallised dolomite, locally micaceous (Geoscience Australia, 2018). The Knapdale Quartzite unit underlies all of the TSF (BDH, 2017);
- Mount Roseby Schist – calcareous silicate metasediments;
- Dugald River Slate – black calcareous slates and black graphite slate, hosts the Dugald River orebody which outcrops at the eastern edge of the unit; and
- Lady Clayre Formation – dark brown to black dolomite and dolomitic siltstone with minor quartz sandstone, siltstone and micaceous sandstone (Blake, 1987).

Although the geological units identified above are differentiated by age and the proportions of individual lithologies, they may generally be characterised as mineralised calcareous metasediments (BDH, 2017).

2.3 Monitoring bores

Schedule C – Table 7 in the EA identifies 17 bores which are to be used in the quarterly monitoring and biennial reporting, of which:

- Seven bores are designated Background Bores;
- Two bores are designated Compliances Bores; and
- Eight bores are designated Interpretation bores.

The classification of the bores in the EA was based on the hydrogeological conceptual model described in the GMP (BDH, 2014). The bores are shown in Table 2-1 and the classifications are described as (BDH, 2017):

- **Compliance Bores:** MB2 and MB4 are screened in the main groundwater transmitting formation (unweathered and fractured metasediments of the Mt Roseby Schist) and are located in areas which have been demonstrated to be hydraulically down gradient of the mine facilities. Monitoring bores in these locations aim to assist in identifying potential changes in groundwater conditions due to mining activities. MB5, MB6, MB9S and MB9D became compliance bores when the TSF began receiving tailings and tailing supernatant in September 2017. Before then they were background bores.
- **Background Bores:** Screened within the same groundwater transmitting formation as the compliance bores, the background bores are strategically located in areas which were considered unlikely to be influenced by mining activities. Some bores are located up hydraulic gradient of the mining facilities and Saturday Bore is located down hydraulic gradient but is distant to the mine facilities. The background bores are used to monitor natural background changes (i.e. seasonal change) and long-term influences.

  MB5, MB6, MB9S and MB9D were background bores until September 2017 when the TSF began receiving tailings and tailing supernatant..
- **Interpretation Bores:** Screened in groundwater flow zones which are not equivalent to the Mt Roseby Schist (i.e. intercepting groundwater not monitored by the compliance bores). The majority of the interpretation bores are screened in the weathered zone above the main groundwater flow zone. MB10 and MB11 were not used for interpretation purposes as they are screened within the Dugald River Slate and have been intercepted by mine workings (Carl Rieck, Senior Advisor SHEC, personal communication, 7 August 2019). Interpretation bores within the Mt Roseby Schist are used to monitor changes in background conditions.

2.3.1 Changes to the monitoring network

MB10 and MB11

MB10 and MB11 were installed to monitor groundwater levels near the mine workings in the Dugald River Slate. In Quarter 3 of 2012 these bores were intercepted by the mine workings. Figure 2-1 shows isometric and top down views of the mine workings, with the bore positions marked in red. MB10 has been intercepted by the North 100 Access and MB11 has been intercepted by the South 100 Access.

Mining through these bores makes them unsuitable for use as groundwater monitoring bores. Although samples were collected from these bores in April 2018, these samples do not represent groundwater in the Dugald River Slate and have therefore not been considered further in this report. For the purpose of this report, MB10 and MB11 are considered inactive and awaiting decommissioning.

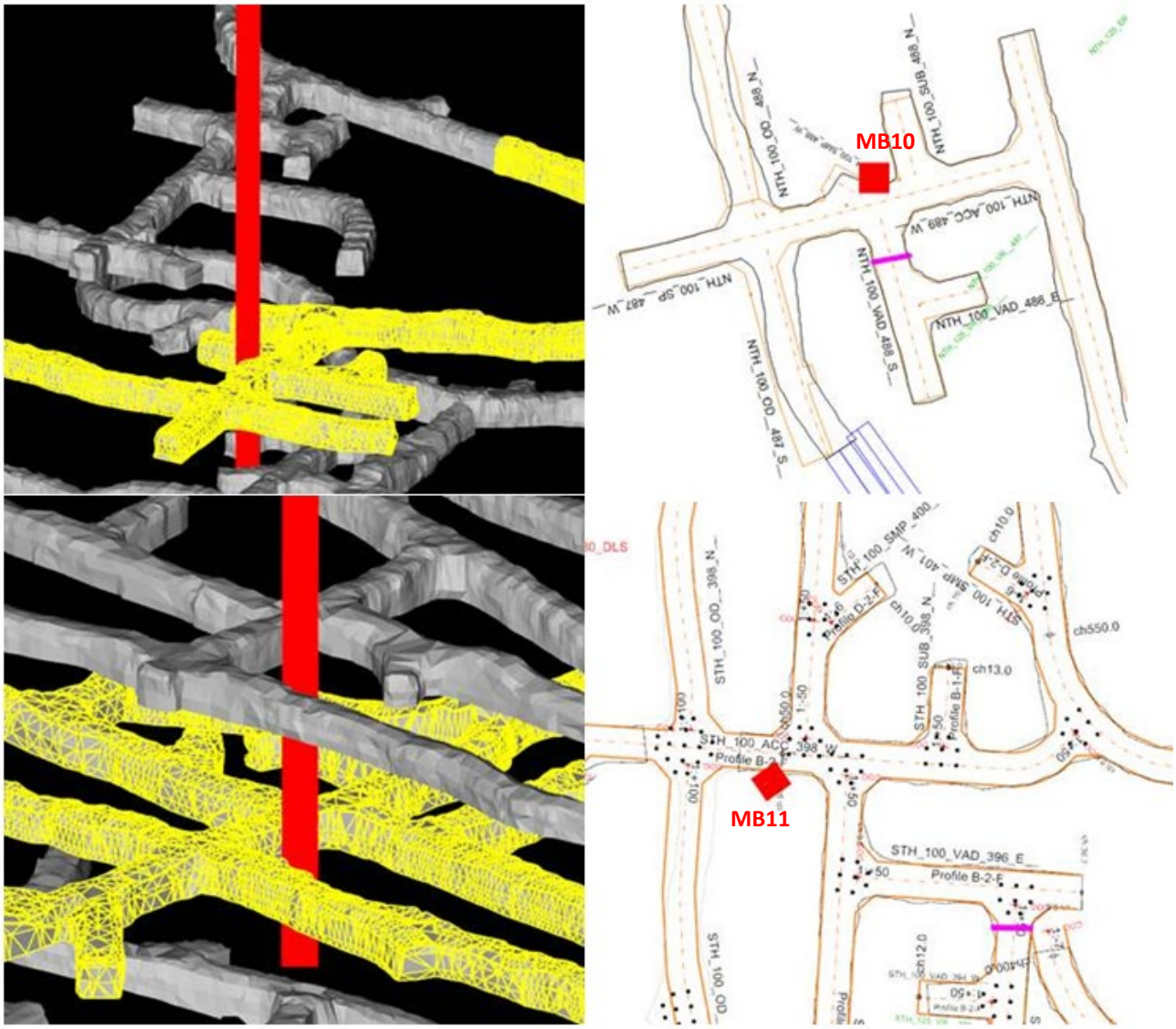


Figure 2-1 **Isometric (left) and top down (right) views of mine workings intercepting MB10 (top) and MB11 (bottom)**

MB9S

MB9S was installed to monitor the shallow Knapdale Quartzite near the TSF. This bore is installed in the unsaturated zone with the intended purpose of identifying rising watertable elevations as a result of TSF leakage. This bore was observed to be dry for the majority of monitoring events during the 2017-2018 reporting period. Water was recorded in the bore in Q1 of 2017 and Q2 of 2018 and samples were collected at these times. In the Q2 2018 monitoring period, over 6 m of water was recorded to be standing in the bore (Figure 2-2).

The data from samples collected from this bore are not considered representative of groundwater or TSF seepage for the following reasons:

- The water levels measured in MB9D (screened in the deeper Knapdale Quartzite and located 3 m from MB9S) do not indicate any rising trend that could be associated with TSF leakage and are consistently more than 5 m below the base of MB9S.
- Water is only observed in MB9S during and after the wet season and is dry throughout the rest of the year, indicating that water in the bore is related to rainfall and/or surface water flows.

- The water sampled from the bore exhibits chemistry suggestive of surface water rather than groundwater, with low total dissolved solids and low hardness.

Given the above, MB9S is more likely to be filling with water from the surface, via the anulus, during the wet season than with groundwater from a rising watertable. Data obtained from this bore during the monitoring period has therefore been omitted from the analysis in this report.

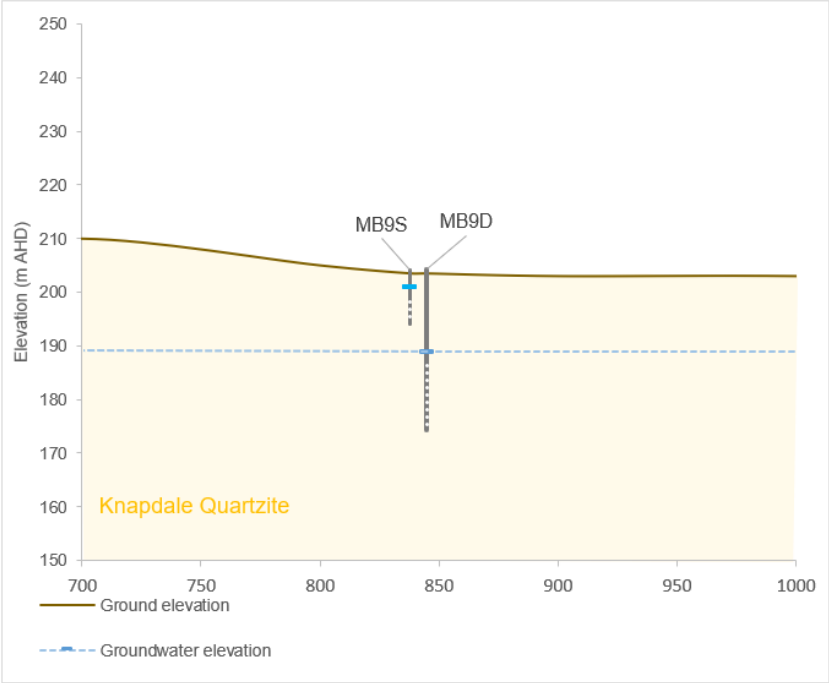


Figure 2-2 Relative screen elevations and groundwater elevations of MB9S and MB9D during April 2018

2.4 Groundwater recharge and flow

The primary groundwater recharge mechanism is via diffuse rainfall infiltration across the general area and possibly enhanced along the watercourses when they flow. The highest rates of rainfall are considered to occur across the Knapdale Range (BDH, 2017), causing a groundwater divide, with groundwater west of the divide flowing west and groundwater east of the divide flowing east.

In the vicinity of the MIA, groundwater generally flows from west to east, consistent with topographic fall. The 2017-2018 data supports this and gradients across the site have remained consistent throughout the monitoring period. Previous reporting (BDH, 2017) has suggested that in the Cabbage Tree Catchment (near the TSF) groundwater flows from east to west. However, there is very limited available data to confirm this, as monitoring bores MB7S, MB7D, MB8 and MB8D had been permanently decommissioned once groundwater gradient to the west was confirmed (BHD, 2014)). Based on MB5 and MB6, the hydraulic gradient appears to be opposite that suggested by BDH (2017), with a slight west to east flow inferred. However, these levels are lower than those seen in the western portion of the MIA, suggesting that these bores are on the western side of the groundwater divide where flow is expected to be to the west.

Monitoring bores in the vicinity of the MIA monitor both the Mount Roseby Schist and the Dugald River Slate. MB1AB, MB2AB, MB3AB, MB4AB and SHALL6AB monitor the shallow Mount Roseby Schist (approximately 10 to 15 m depth). MB1, MB2, MB3 and MB4 monitor the deeper section of the Mount Roseby Schist (from 10 to 99 m depth). The paired bores show a very slight downward gradient or no gradient (Appendix B).

Table 2-1 Groundwater monitoring bores and monitoring requirements located at the Site

Bore ID	Screened interval	Screened Formation	Location (GDA MGA zone 54)		Collar Elevation (mAHD)	EA Classification	Monitoring	Quality Characteristic	Monitoring Frequency
			Easting	Northing					
MB1	11 to 99	Mount Roseby Schist	411301	7761214	205.506	Background	Level and quality	pH, EC, Hardness as $CaCO_3$, TDS Major ions: Na, Ca, K, Mg, Cl, HCO3, total alkalinity, SO_4, F Metals: Al, As, Cd, Cu, Pb, Mn, Ni, Zn Cyanide (if introduced to mining process)	Quarterly
MB3	11 to 99	Mount Roseby Schist	411391	7760127	209.757	Background	Level and quality		
Saturday Bore	Unknown	Mount Roseby Schist	414226	7760870	182.375	Background	Level and quality		
MB5	18 to 99	Mount Roseby Schist	408537	7763364	202.474	Background/ compliance	Level and quality		
MB6	46 to 99	Mount Roseby Schist	408287	7763224	200.617	Background/ compliance	Level and quality		
MB9D	18 to 30	Knapdale Quartzite	408723	7763433	204.299	Background/ compliance	Level and quality		
MB9S	6 to 10	Knapdale Quartzite	408724	7763433	204.182	Background/ compliance	Level and quality		
MB2	21 to 99	Mount Roseby Schist	412191	7761189	196.89	Compliance	Level and quality		
MB4	46 to 99	Mount Roseby Schist	412749	7760041	195.525	Compliance	Level and quality		
GWBFAB	6.3 to 12.3	Dugald River Slate	411395	7761383	209.842	Interpretation	Level	-	
MB10	36 to 54 and 90 to 108	Dugald River Slate	411524	7761088	212.485	Interpretation	Level	-	
MB11	18 to 36 and 90 to 108	Dugald River Slate	411807	7760212	220.443	Interpretation	Level	-	
MB1AB	9.7 to 15.7	Mount Roseby Schist	411199	7761205	208.278	Interpretation	Level	-	
MB2AB	9.2 to 15.2	Mount Roseby Schist	412187	7761185	197.46	Interpretation	Level	-	
MB3AB	9.3 to 15.3	Mount Roseby Schist	411421	7760107	209.13	Interpretation	Level	-	
MB4AB	9 to 15	Mount Roseby Schist	412744	7760042	196.02	Interpretation	Level	-	
SHALL6AB	9.3 to 15.3	Mount Roseby Schist	410983	7760929	217.028	Interpretation	Level	-	

*Level refers to depth to water, converted to elevation head using surveyed bore elevations.

*MB10 and MB11 are inactive and awaiting decommissioning

The bores monitoring the Mount Roseby Schist across the Site show seasonal variations in groundwater levels consistent with general rainfall (and expected recharge) trends, with lowest groundwater levels at the end of the dry season and levels rising during the wet season (Figure 2-3). The seasonal variation is of a similar magnitude (1 to 3 m) in both the shallow and deep bores. MB4 and MB4AB show the smallest variations (less than 1 m) and MB3 and MB3AB show the highest variations (3 m).

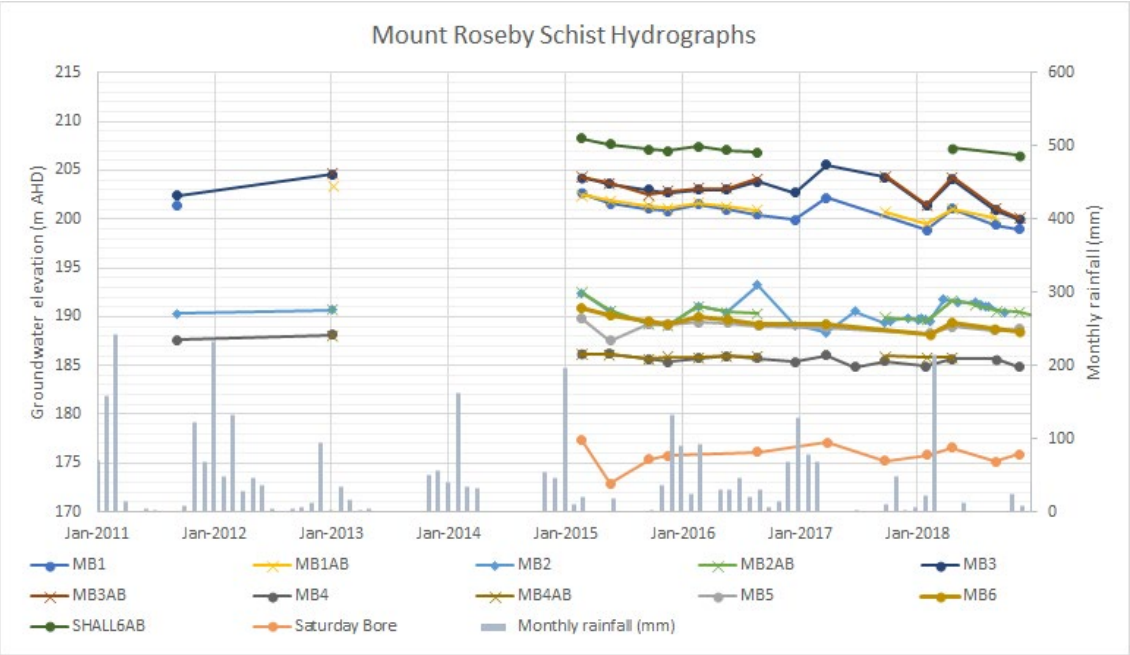


Figure 2-3 Groundwater elevations for bores in Mount Roseby Schist across the Site

Monitoring bore MB9D is screened within the lower Knapdale Quartzite (18 to 30 m) and shows minimal seasonal variations. MB9S monitors the shallow Knapdale Quartzite, although this bore is found to be dry most of the time (as discussed previously, water measured in this bore after wet seasons is not thought to represent groundwater).

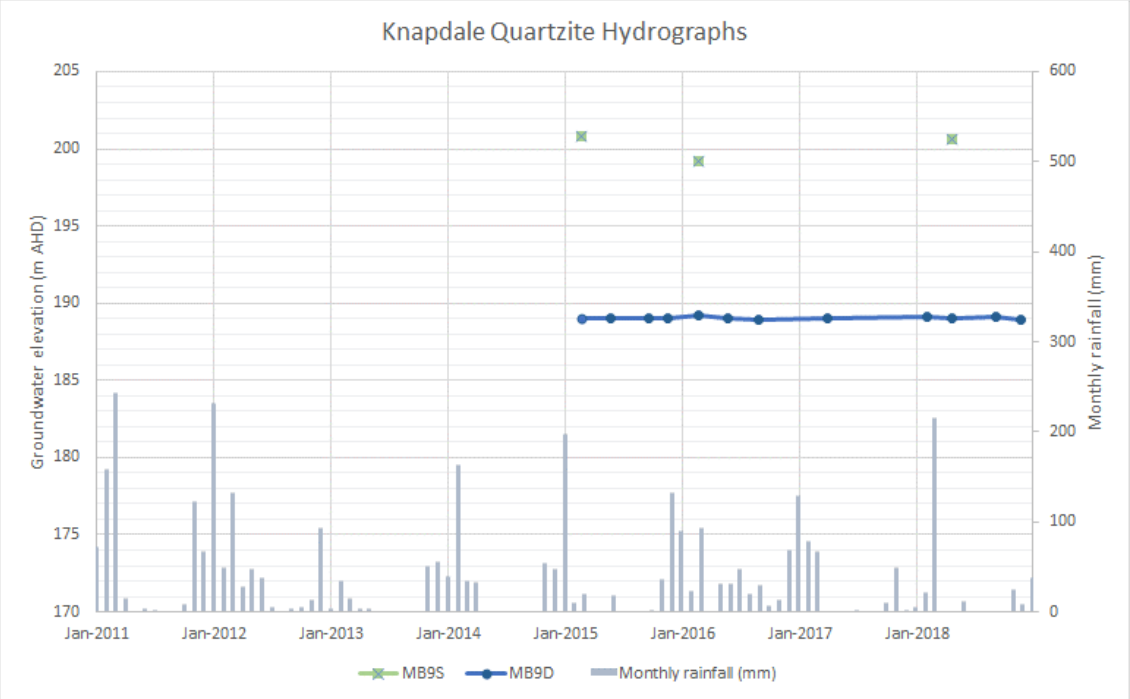


Figure 2-4 Groundwater elevations for bores in Knapdale Quartzite across the Site

BHD (2017) suggests groundwater movement generally occurs within the unweathered fractured zones of the metasediments. Shallow portions of these units are more weathered and less transmissive. BDH (2017) concludes North Creek and Silvermine Creek may reflect the presence of east-west orientated structural features, which may act as preferential groundwater flow zones.

Depth to groundwater across the site is generally greater than 4 m, with most monitoring bores located in close proximity to ephemeral surface water and drainage features (i.e. North Creek, Silvermine Creek and Cabbage Tree Creek). It is unlikely that groundwater contributes baseflow to surface water features in the vicinity of the mine based on the depth to groundwater compared to creek bed levels, and the ephemeral nature of the streams.

Bore hydrographs do not appear to intersect ground surface (refer Figure 2-3 and Section 2.1) and it is unlikely groundwater – surface water interaction occurs in the area of the MIA. This observation is supported by interpretations presented in the EIS for the Project (Ref: *Environmental Impact Statement (EIS) Report under the Environmental Protection Act 1994 – Dugald River Project,* November 2011), which concluded that localised natural groundwater discharge does not occur in the project area.

The GDE Atlas (BoM) shows the Dugald River as a low potential GDE based on national assessment. North Creek, Silverman Creek and Cabbage Creek were not identified as potential GDEs in the Atlas.

2.5 Groundwater Chemistry

Where major ion data are available for groundwater sampled from each bore and the ionic balance is suitable (see Appendix C.3), a water type plot is presented as Figure 2-5. The piper plot shows a similar water type across the site, with the exception of MB4AB. The general water quality is dominated by bicarbonate, whereas the dominant anion at MB4AB is chloride. No dominant cation is apparent, with cation distribution evenly spread. BDH (2017) states that the groundwater chemistry is a reflection of the competing influences of recharge and residence time within the fractured metasediments hosting the groundwater.

The groundwater across the site in is mostly fresh to brackish, with salinity concentrations ranging between 92 and 12,000 mg/L TDS. The minimum, median and maximum concentrations reported since 2010 are shown in Table 2-2 alongside threshold values for various uses. The water is generally suitable for stock watering and irrigation of cotton (although there is no irrigated agriculture in the area). The groundwater is marginally suitable for drinking water, depending on location.

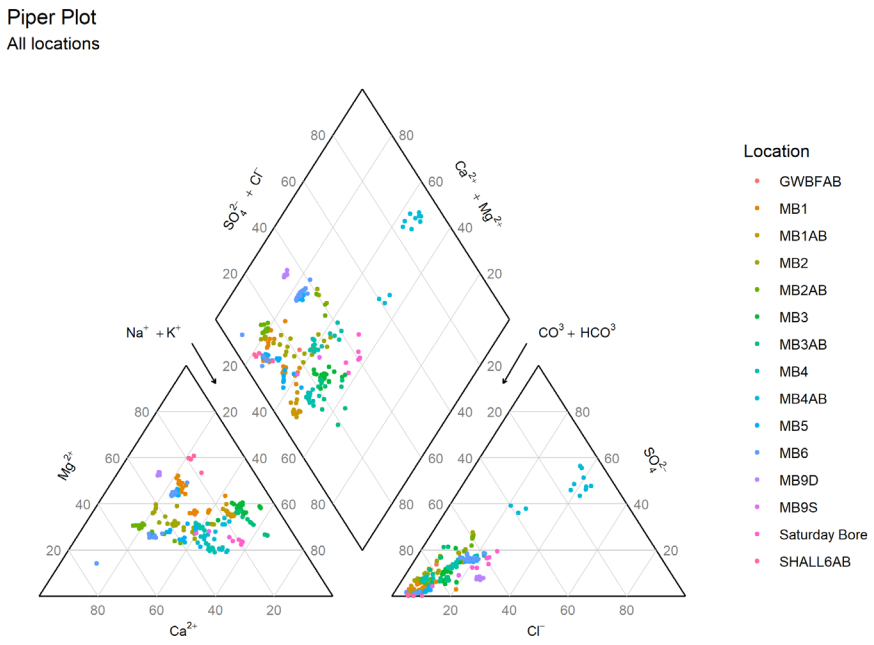


Figure 2-5 Piper diagram for all water samples with available data and an ionic balance <10%

Table 2-2 Reported groundwater salinity for each bore compared to suitability criteria

Bore ID	TDS (mg/L)			Suitability (based on median)		
	Min	Median	Max	Drinking water (900 mg/L)	Irrigation (2,700 mg/L)	Stock (4,000 mg/L)
MB1	449	631	749	✓	✓	✓
MB1AB	552	797	850	✓	✓	✓
MB2	294	625	889	✓	✓	✓
MB2AB	329	498	758	✓	✓	✓
MB3	792	995	3400	X	✓	✓
MB3AB	770	928	1120	X	✓	✓
MB4	278	528	810	✓	✓	✓
MB4AB	1530	4360	11900	X	X	X
MB5	397	574	726	✓	✓	✓
SHALL6AB	685	789	892	✓	✓	✓
MB6	204	637	1070	✓	✓	✓
MB9D	614	660	695	✓	✓	✓
Saturday Bore	504	1020	1110	X	✓	✓
GWBFAB	642			✓	✓	✓

Suitability based on:

- *Drinking water – palatability (good to fair) water is 900 mg/L (NWQMS ADWG, 2011)*
- *Irrigation – ANZECC (2000) guideline for cotton is approximately 2,700 mg/L (irrigated agriculture is not established in the region)*
- *Stock watering – ANZECC (2000) guideline for beef cattle is 4,000 mg/L*

2.6 Conceptual Model

A schematic conceptual model for the general locality of the MIA is represented in Figure 2-6. This model is not intended to be to scale, but rather to show the key hydrogeological processes in the area. The model shows:

- The system is recharged via rainfall, predominately in the Knapdale Range ❶, although infiltration of rainfall will potentially occur across the site when rainfall exceeds evaporation. Recharge is also likely to occur via creek beds ❷ when flow events occur.
- Groundwater discharge mechanisms are likely to include baseflow to the Dugald River ❸ and possibly on a seasonal basis to lower reaches of tributary creeks in the area. In addition, deep throughflow ❹ may also occur.
- Losses via evapotranspiration ❺ from riparian zones and where water tables are shallow enough will occur.
- Enhanced groundwater flow is probable in the deeper fractured sections of the Mount Roseby Schist ❻.
- The mine is actively dewatered ❼ but the general low permeability of the metasediments is thought to mitigate the extent of groundwater depressurisation / drawdown in the surrounding hydrostratigraphic units.

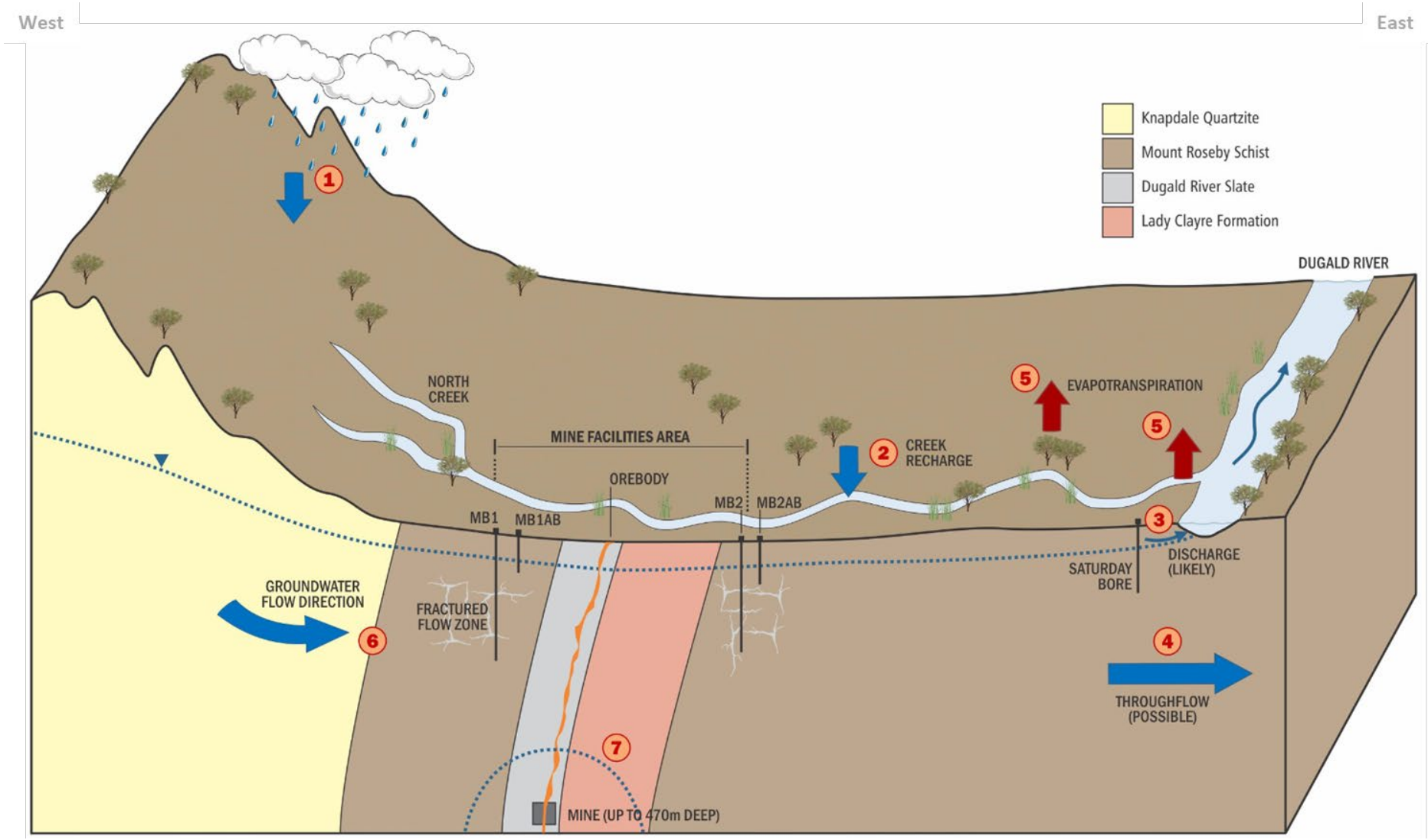


Figure 2-6 Conceptual hydrogeological model schematic

Section 3 Data Analysis

3.1 Overview

This section will focus on the groundwater quality data reported for bores identified in the EA – seven background bores, two compliance bores (from September 2017 onwards this becomes three background bores and five compliance bores) and eight interpretation bores. The scope of this data analysis includes:

- **Critical data quality review:** This task focused on validating the water quality data to confirm (where possible) appropriate sampling and shipping protocols have been followed, NATA-registration of laboratory for analyses undertaken, analysis of holding times, formal QA/QC checks, and comparison of laboratory levels of reporting (LoRs) against relevant guidelines and thresholds. Other data quality checks included ionic balances and correlation between EC and TDS. This task also focused on cleansing data received from MMG, and detected and corrected, or removed corrupted or incorrect data from the dataset. This involved the removal of erroneous data, anomalous data points or spikes, as per the Guidelines "Using Monitoring Data to Assess Groundwater Quality and Potential Environmental Impacts" (DSITI, 2017).
- **Analysis of groundwater data:** Following the critical data quality review, the data were imported into environmental management software ESdat to tabulate and format exceedances of groundwater trigger values outlined in EA Schedule C – Table 8 (Groundwater Levels and Contaminant Limits). This task formed the basis of interpretation of the tabulated data and this review is presented as compliance with EA conditions.

Data utilised for the analysis were compiled from the sources shown in Table 3-1 below.

Table 3-1 Biennial groundwater review data sources

Reporting Period	Description	Data Source/Lab Report	Date Samples Collected	Date Samples Received by Laboratory
Historical data (pre-2017) and non-quarterly monitoring data[1]	Raw data set provided by MMG (including field data), which was sorted and cleansed before being imported into ESdat.	• Raw Data Set.xlsx	-	-
Quarterly monitoring data (2017-2019)	Laboratory data provided by Australian Laboratory Service (ALS), which was imported directly into ESdat. Field data (field pH and EC) for quarterly monitoring was extracted from MMG's database and imported into ESdat.	• EB1706945 • EB1713282 • EB1720574 • EB1803858 • ET1801163 • ET1802314 • ET1803049 • ET1900886	• 30/03/2017 • 26/06/2017 • 29/09/2017 • 06/03/2018 • 28/04/2018 • 09/09/2018 • 23/11/2019 • 12/03/2019	• 06/04/2017 • 29/06/2017 • 06/10/2017 • 09/03/2018 • Unknown • 12/09/2018 • 29/11/2018 • 14/03/2019

[1]It should be noted, although additional data outside quarterly monitoring data are not required for compliance purposes, a complete dataset assists in identifying long term groundwater trends and may assist in interpretation of quarterly results, and therefore additional data collected over the monitoring period (primarily at MB2) has been imported into the database.

3.2 Critical data quality review

The critical review of data quality is included in Appendix C, and included an assessment of:

- Field parameters vs laboratory measured parameters (Appendix C.1);
- Total dissolved solids (TDS) vs electrical conductivity (EC) (Appendix C.2);
- Ionic balances and TDS ratios (calculated vs measured) (Appendix C.3);
- Laboratory limits of reporting (LORs) vs adopted guideline values (Appendix C.4);
- Total metal concentrations vs filtered concentrations (Appendix C.5); and
- Program quality assurance and quality control samples (duplicates and field blanks) (Appendix C.6).

In general, the data quality review demonstrates the data are adequate for interpreting groundwater conditions at the site across the review period. In summary:

- There is generally a good correlation between laboratory measured EC and field measured EC, although the latter is usually slightly higher than the former, as would be expected given the difference in temperature between the two analysis environments (higher temperatures result in higher EC readings). Specific conductance should be included in the field reporting (EC correlated to a standard temperature of 25°C). Given the results, the laboratory EC is considered to be more reliable than field EC.
- For pH the correlation is not as strong between field and laboratory measured data. Field pH is generally lower than laboratory pH but not along a consistent trend, with the difference ranging from 0 to 2 pH units. Holding times for pH (6 hours) are consistently breached due to the distance between the site and the laboratory and this means degassing of CO_2 from solution has an opportunity to occur, raising the pH. Therefore, field measured pH should be relied upon for analysis rather than laboratory pH.
- The laboratory EC data has been used to assess whether samples fall within expected ratios of TDS over EC, given its higher reliability. The data indicates that the majority of TDS/EC ratios for samples collected over the reporting period fall within the expected range for fresh water (0.55 to 0.75), with the exception of MB3 (September 2018; 0.80) and Saturday bore (March 2017; 0.50).
- The majority of the water samples show ionic balances and TDS ratios within acceptable limits or only slightly exceeding data quality objectives. The exceptions are usually due to a missed analysis. However, at MB3 a continued trend of high charge balance errors and high TDS ratios indicate something is amiss with samples from this bore. This could be an omission of an important anion such as nitrate or silicate or could be error introduced during sampling or analysis. It is recommended duplicate samples are taken from this bore and that major ion analysis is undertaken on filtered water to rule out the influence of a contaminated sample.
- The LoRs for the analytes are all below the relevant guidelines and limits set out in the EA, which allows for comparison of detectable concentrations.
- Filterable metal concentrations are generally less than total metal concentrations for samples collected during the review period (96% of comparisons). There were 24 instances where the filterable concentration exceeded the total concentration, although the majority of these are minor exceedances. There are three instances where the filterable concentration is higher than the total concentration where the results could impact on the interpretation. These are lead at MB2 in Q4 2017 and zinc at MB2 in Q4 2017 and Q2 2018, however the results were compliant with the EA.
- Only one duplicate sample and one field blank were collected during the 2017-2018 review period on 8th September 2018. The results of these QA/QC samples comply with the data quality objectives.

Given the above, no data have been removed from the 2017-2018 dataset, as any data quality objective breaches are not considered likely to alter the interpretation of the results against the EA conditions.

Based on data provided by MMG and the subsequent data review, groundwater chemistry and groundwater level data are considered reliable for the interpretation of groundwater conditions at the Site across the review period (2017-2018).

However, the following is recommended:

- *Specific conductance (SPC) of samples should be collected in the field to mitigate temperature dependant conductivity values. This may increase the quality of the data.*
- *Analysis of major ions at MB3 should include filtered samples to rule out sediment causing charge balance errors and TDS ratios outside of data quality objectives. A duplicate sample from this bore should be sent to a secondary laboratory to rule out laboratory error.*
- *Laboratory certificate of analysis' should be checked as soon as practicable to ensure filterable metal concentrations are not greater than total metal concentrations and identify other potentially erroneous data (e.g. TDS values higher than EC values). Reanalysis can be requested (if required) once this check has been completed.*
- *For each round of sampling the following QA/QC samples should be collected in line with national and state guidelines: Intra-laboratory and inter-laboratory duplicates, field blank, trip blank and rinsate sample (if reusable equipment is used). This will validate results and assess whether cross contamination has been introduced to the sample during sampling, handling and transportation.*

3.3 Compliance with gauging and sampling condition (EA condition C36)

3.3.1 Groundwater level gauging frequency

Quarterly groundwater level gauging is required to be undertaken at all monitoring bores listed in Table 2-1 (compliance, background and interpretation) during the review period, as per the EA. Compliance with this condition is displayed in Figure 3-1 as a traffic light diagram. Only Q1,Q2 and Q4 in 2018 had full compliance with the groundwater gauging condition. The following non-compliances related to groundwater gauging are noted:

- Q1 2017: MB2AB (interpretation bore)
- Q2 2017: all bores except compliance bores MB2 and MB4
- Q3 2017: GWBFAB and SHALL6AB (interpretation bores)
- Q4 2017: all bores except compliance bore MB2
- Q3 2018: GWBFAB, MB4AB and SHALL6AB (interpretation bores)

3.3.2 Groundwater chemistry sampling frequency

Groundwater sampling is required to be undertaken at compliance bores and background bores, as outlined in the EA (see Table 2-1). Compliance with this condition is shown in Figure 3-2 as a traffic light diagram. A green light is indicated when a sample was collected for field and/or laboratory analysis. Samples were collected at all required compliance point for all quarters in 2018 and Q1 and Q3 in 2017, with the exception of at MB9S which was identified as dry during those events. Compliance with the required analytical suite (see Table 3) is shown in Appendix D. The following non-compliances related to sampling frequency and analytical suite are noted:

- Q2 2017: samples only collected at MB2 and MB4
- Q3 2017: samples collected at all required bores but for MB5, MB6 and MB9D only field parameters recorded
- Q4 2017: samples only collected at MB2, alkalinity not analysed for that sample
- Q1 2018: samples collected at all required bores but for MB5 only field parameters recorded

Minor non compliances with Condition 36 of the EA (EPML00731213) and the objectives of the GMP (2014) are evident in the data set, primarily related to water level gauging, especially at interpretation bores. More major non compliances occurred in Quarters 2 and 4 of 2017, when only 1 or 2 required bores were gauged or sampled.

In some instances, bores were sampled but not gauged, which is likely to be a record keeping error.

Given the results (see below) the missing data is not likely to impact the overall outcome of the groundwater monitoring review (i.e. groundwater conditions generally appear to be stable).

A more simplified or summarised GMP may assist in meeting Condition 36 of the EA, giving field staff a simple set of instructions or tick boxes to ensure that all required bores are gauged and sampled. More frequent (quarterly) internal reporting may also help to identify omissions in a timeframe where these can be acted on.

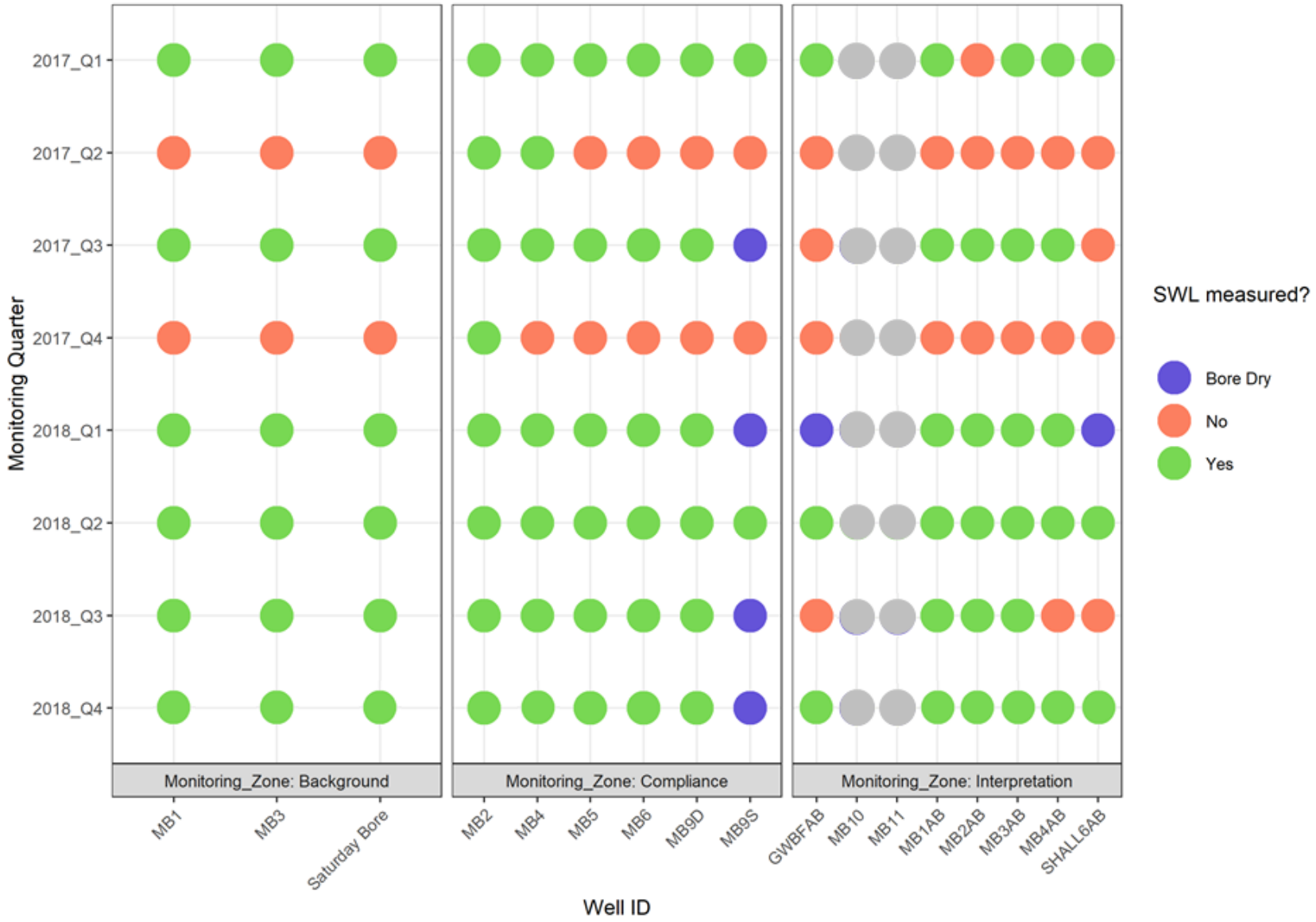


Figure 3-1 **Groundwater level gauging frequency at the Site**

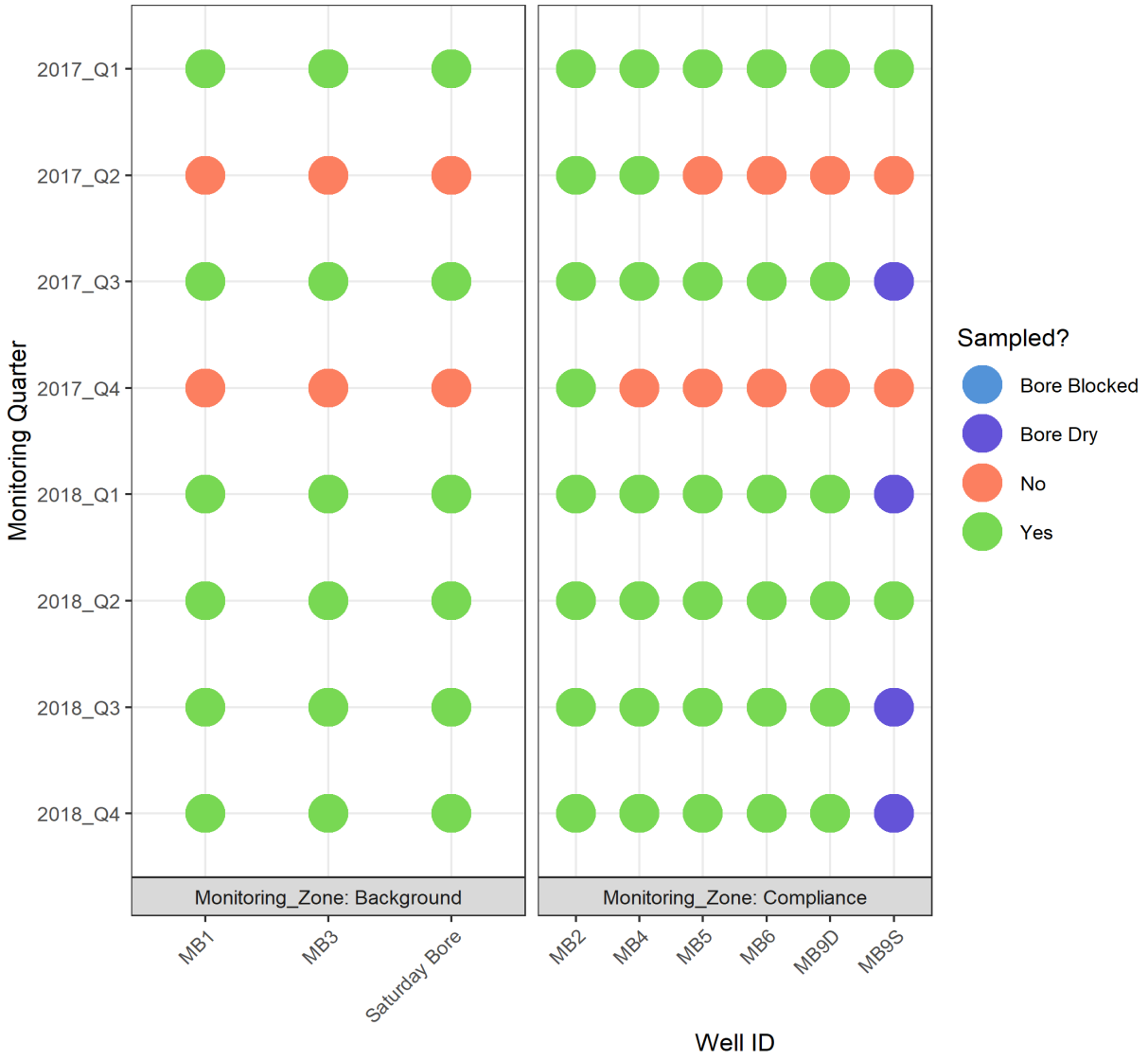


Figure 3-2 Frequency of groundwater sampling for all monitoring bores across the Site

3.4 Compliance with trigger level condition (EA condition C37)

Groundwater chemistry data from compliance bores (where available) have been compared to trigger levels as defined in Schedule C – Table 8 (Groundwater Trigger Levels and Contaminant Limits) in the EA and the site specific GMP. The compliance bores consist of MB2 and MB4 and include MB5, MB6, MB9S and MS9D from Q3 2017 onwards due to the beginning of use of the TSF. HMTV for cadmium, copper, lead, nickel and zinc were calculated for individual samples as per ANZECC/ARMCANZ (2000) Table 3.4.2 based on sample specific hardness results.

Exceedances of the trigger levels for each bore can be seen as a traffic light diagram on Figure 3-3 to Figure 3-7. Data are only displayed where a sample was collected (see Section 3.3.2). Exceedances of trigger levels (including HMTVs where appropriate) can be summarised by the following:

- MB2: sulfate in Q4 2017 (152 mg/L) and Q1 2018 (152 to 161 mg/L) and copper throughout the monitoring period;
- MB4: field measured EC in Q1 and Q4 2018 – note that laboratory EC is below trigger values for these samples and that laboratory measurements are considered more reliable for this parameter (see Section 3.2). These exceedances are therefore not considered further;
- MB5: field measured EC in Q3 2018 – note that laboratory EC is below the trigger value for this sample and that laboratory measurements are considered more reliable for this parameter (see Section 3.2). This exceedance is therefore not considered further;
- MB6: zinc in Q2 (0.485 mg/L) and Q4 (0.086 mg/L) of 2018 and field measured EC in Q3 2018 – note that laboratory EC is below the trigger value for this sample and that laboratory measurements are considered more reliable for this parameter (see Section 3.2). This exceedance is therefore not considered further;
- MB9D: no exceedances; and
- MB9S: no relevant samples collected over the reporting period.

As per Condition C37 of the EA, where level of characteristics of groundwater from compliance bores exceed trigger values, compliance bore results have been compared to groundwater chemistry data at background bores. This is shown as timeseries charts (<LOR is plotted as half the LOR on all charts) and box and whisker plots (where applicable). Tabulated analytical results have been provided in Appendix E. Where trigger levels have been exceeded and concentrations are higher than background conditions, further investigations have been recommended in Section 4.3.2.

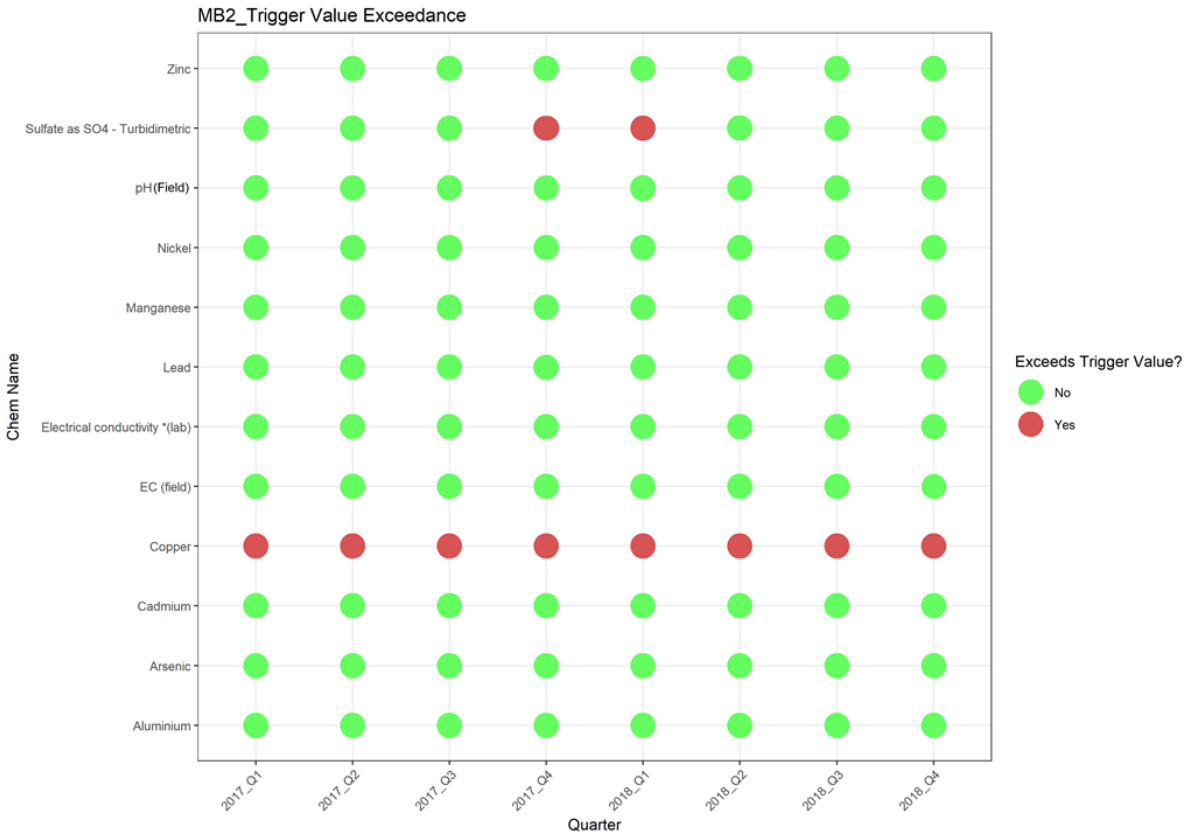


Figure 3-3 Exceedances of trigger levels at MB2

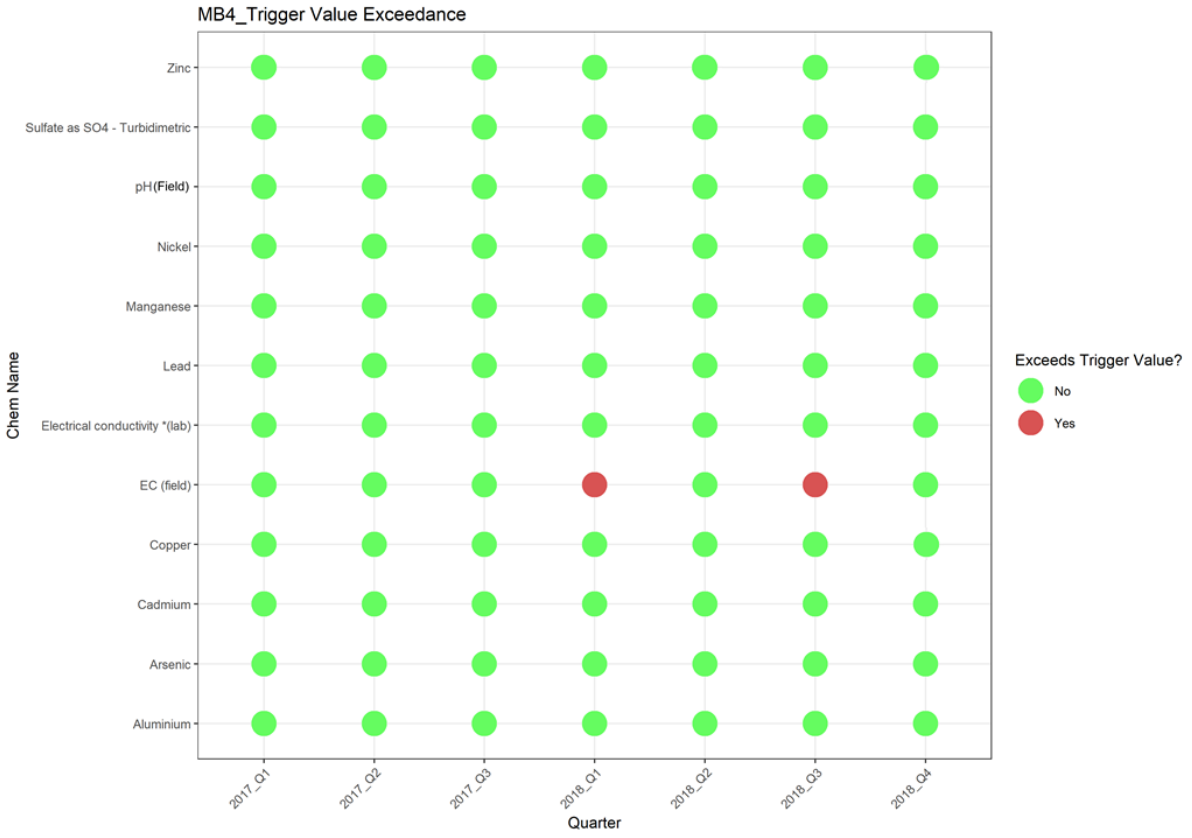


Figure 3-4 Exceedances of trigger values at MB4

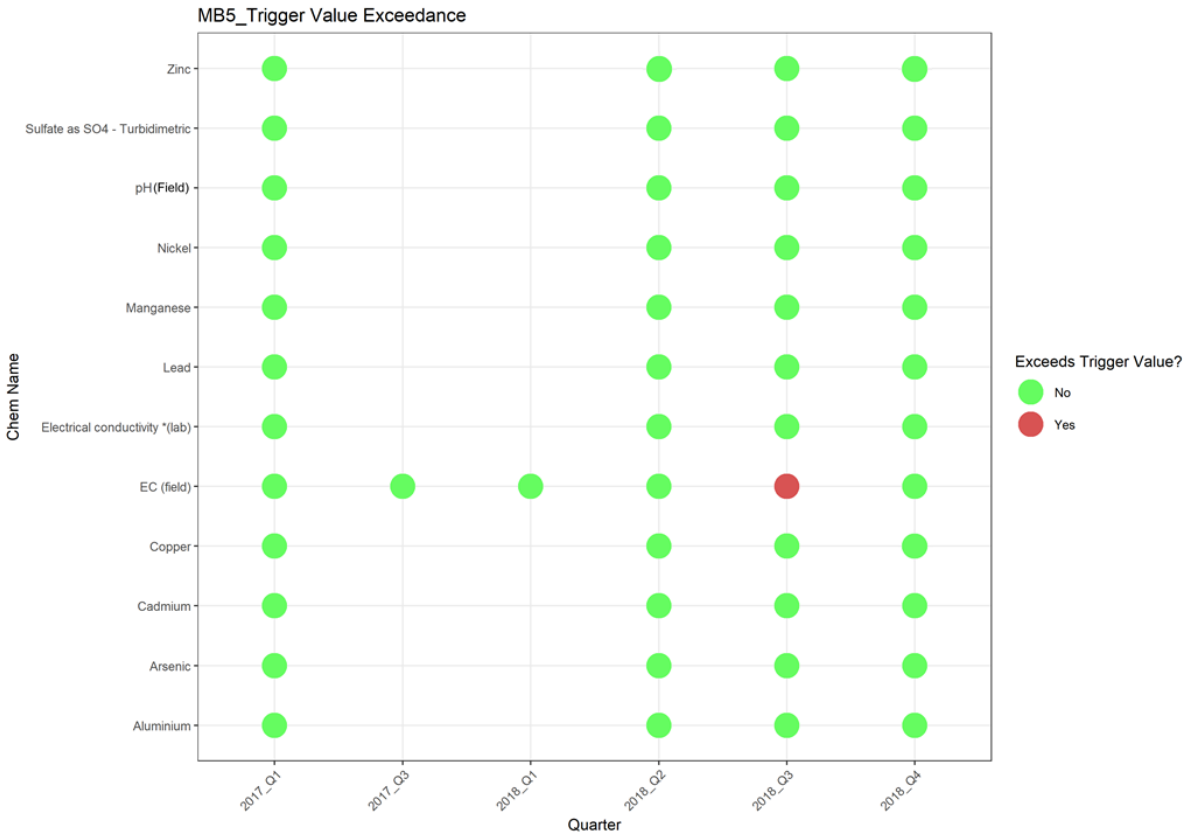


Figure 3-5 Exceedances of trigger levels at MB5

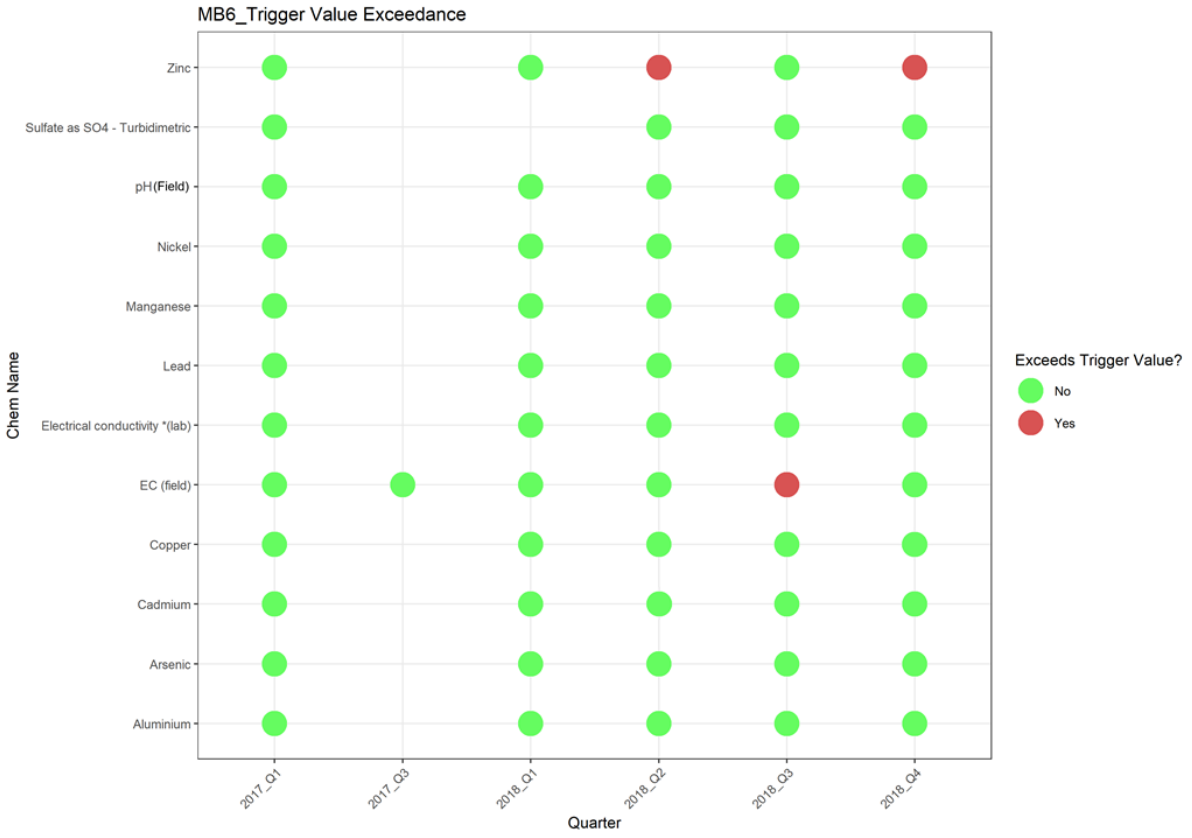


Figure 3-6 Exceedances of trigger values at MB6

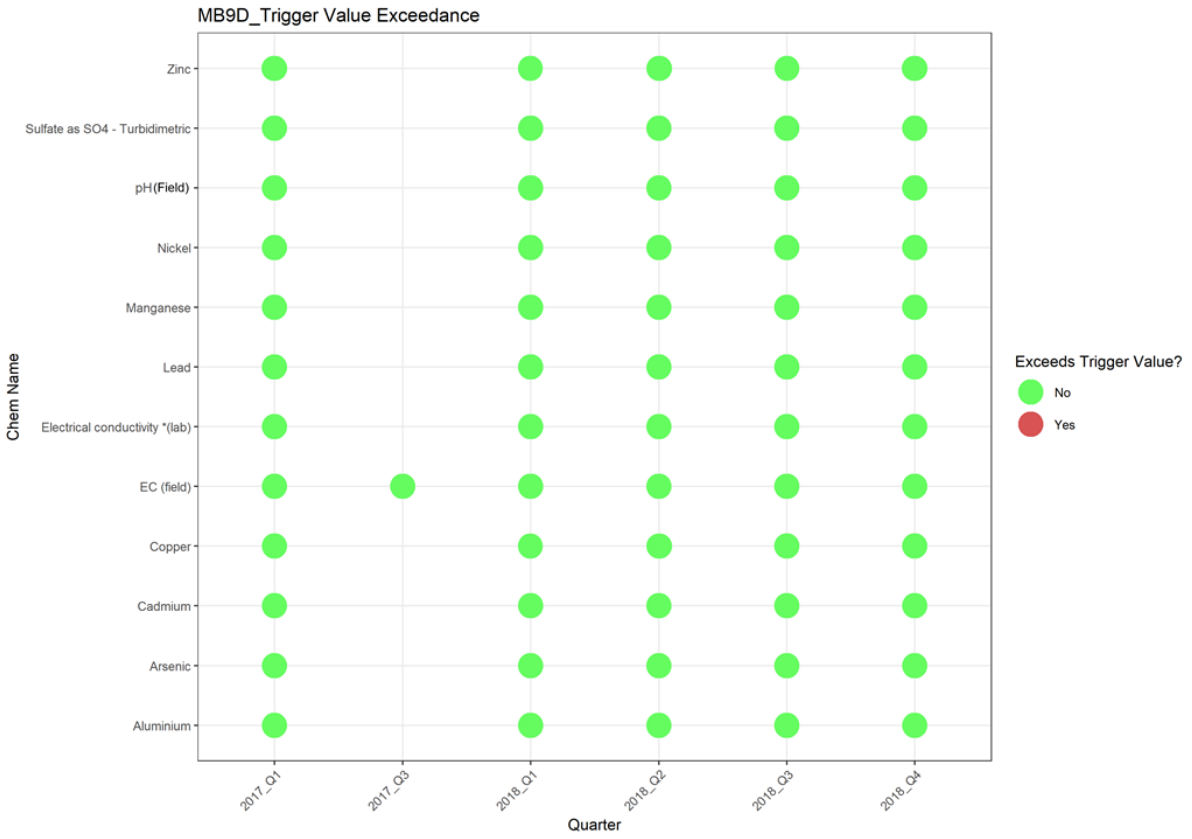


Figure 3-7 Exceedances of trigger values at MB9D

3.4.1 Sulfate at MB2

Four samples from MB2 indicate sulfate above the trigger level (Figure 3-8), although three of these occur in Q1 2018 (10th January, 18th January and 3rd February 2018), with one further exceedance Q4 2017 (18th December 2017). These are all minor exceedances, between 151 mg/L and 161 mg/L compared to the trigger level of 150 mg/L. BDH (2017) attribute elevated sulfate across the site to the influences of naturally occurring mineralisation. As can be seen on the box and whisker plot (Figure 3-9), the concentration of sulfate seen at MB2 are comparable to the background bore concentrations and lower than background bore MB3. No further action is recommended.

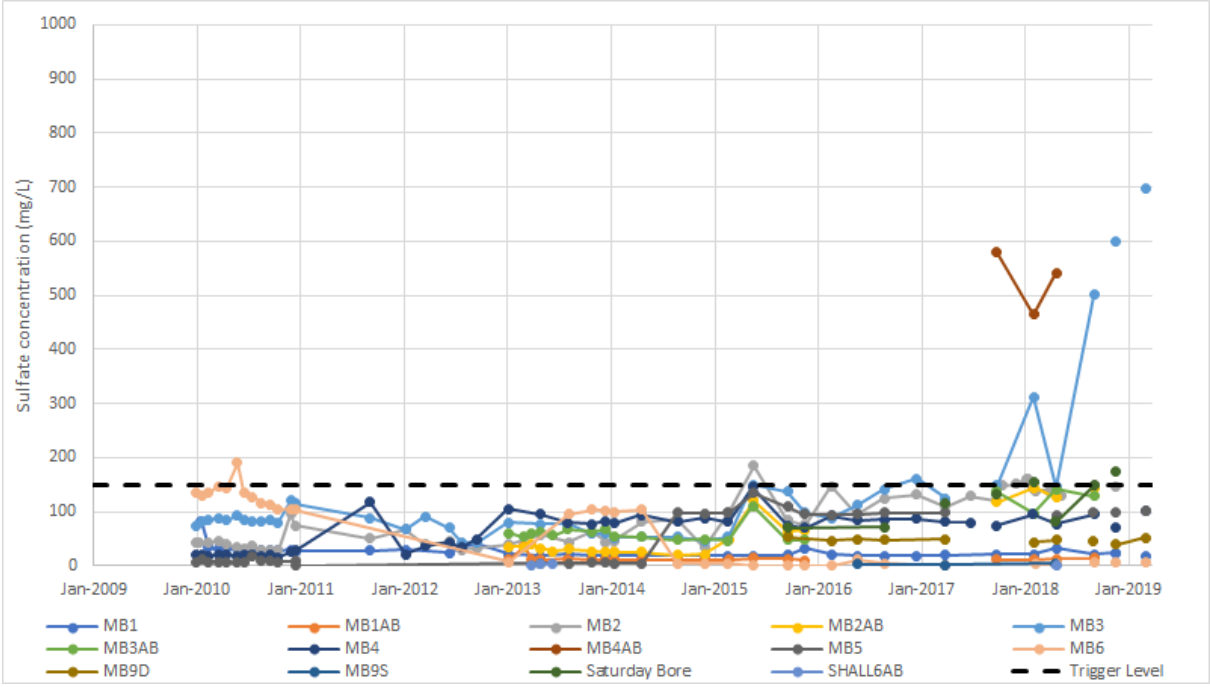


Figure 3-8 Sulfate concentrations in all bores across the site

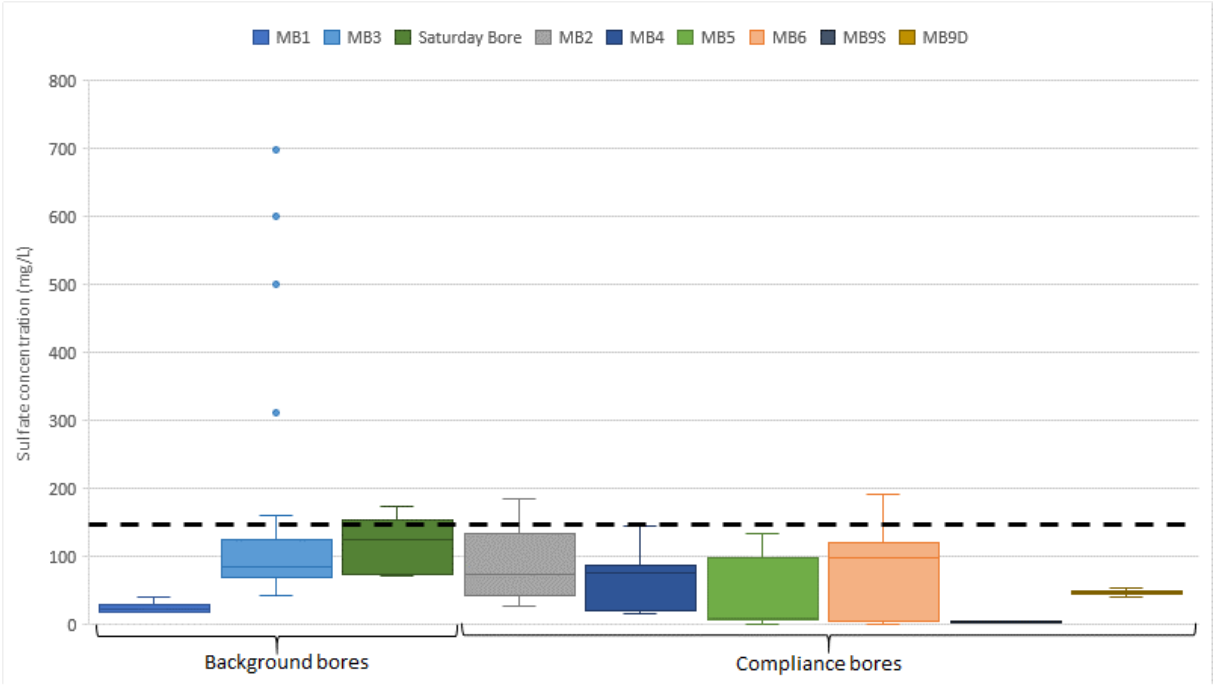


Figure 3-9 Box and whisker plot to show compliance bore sulfate concentrations compared to background bore concentrations

3.4.2 Zinc at MB6

The trigger value for zinc is hardness dependent and calculated per sample. The majority of the groundwater across the site is hard, meaning that a higher trigger level than the one defined in the EA is used. The HMTV for zinc is calculated as follows:

HMTV = Trigger Value x (Hardness/30)$^{0.85}$

The HMTV at MB6 varies from 0.37 to 0.68 mg/L across the reporting period, depending on the hardness. The exceedances of the sample specific HMTV occurred during April 2018 (0.485 mg/L) and November 2018 (0.086 mg/L). The box and whisker plot (Figure 3-11) identifies both of these exceedances as outliers when compared to the overall MB6 dataset. MB6 is located at the TSF and has been a compliance bore since September 2017. The TSF is located on the western side of the groundwater divide and, whilst MB5 may be considered upgradient of MB6, there are no bores upgradient of the TSF (i.e. background). Instead, the concentrations at MB6 can be compared to the other background bores (MB1, MB3 and Saturday Bore) as they are located within the same formation and represent unimpacted groundwater conditions in the Mount Roseby Schist.

A comparison with background conditions indicates, whilst MB6 generally records zinc concentrations within the range observed in background bores, the concentrations recorded during the reporting period are above background conditions, especially the April 2018 concentration, which is an order of magnitude higher than average conditions across the site. Further action to investigate this is recommended in Section 4.3.2.

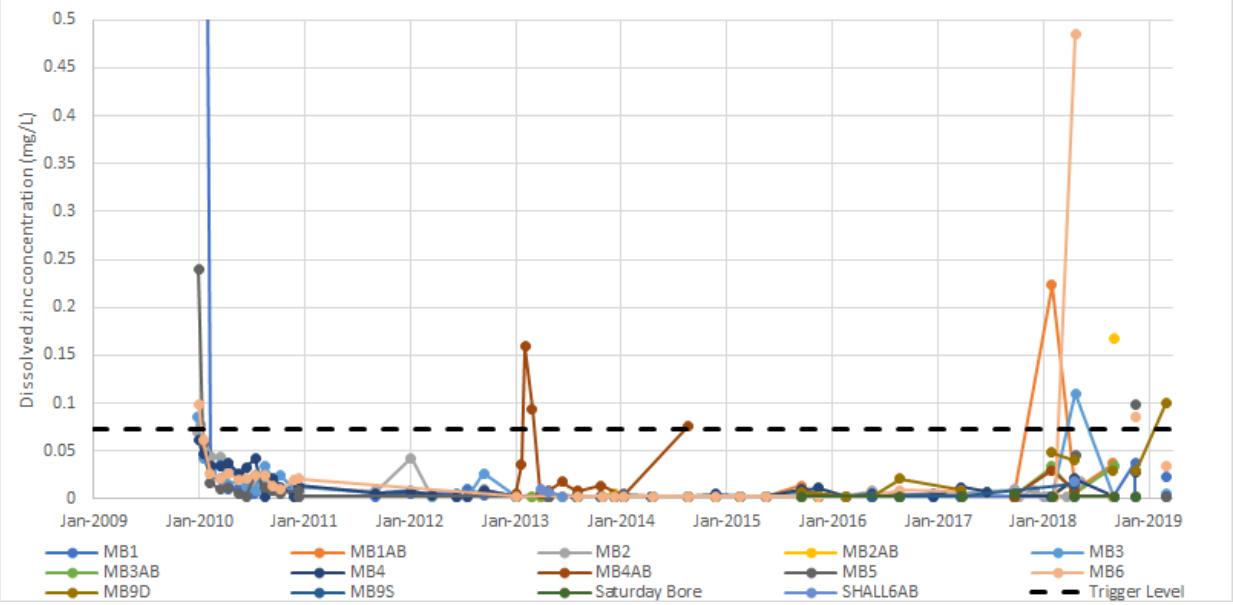


Figure 3-10 Dissolved zinc concentrations in all bores across the site

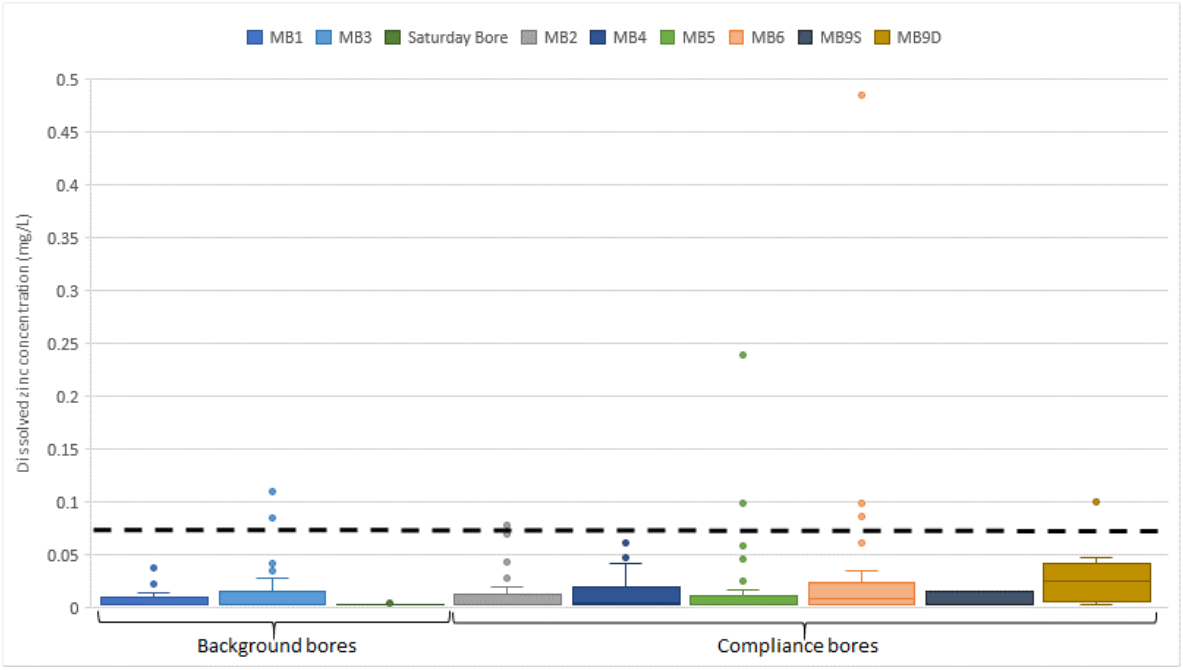


Figure 3-11 Box and whisker plot to show compliance bore dissolved zinc concentrations compared to background bore concentrations

3.4.3 Copper at MB2

Dissolved copper concentrations at MB2 were consistently above the sample specific HMTVs (0.011 to 0.013 mg/L) throughout the reporting period, with concentrations ranging from 0.012 mg/L to 0.053 mg/L. Elevated copper concentrations have been evident at this bore since 2015 (Figure 3-12) and was highlighted in the previous biennial review (BDH, 2014). Investigations in to the elevated copper were undertaken by Golder (2017) and CDM Smith (2018). The CDM Smith (2018) report concluded the following:

- Elevated concentrations of copper in the groundwater at MB2 have been evident since early 2015 with a sudden step change of 1 to 2 orders of magnitude. The highest concentrations were observed in 2016 up to almost 0.1 mg/L. Concentrations declined after 2016 and have been steady at between 0.01 and 0.06 mg/L from 2017 onwards.
- The most likely source of copper in the groundwater at MB2 is natural mineralisation of the Mount Roseby Schist. It is possible copper has been elevated at this location throughout the monitoring program but it was only detected in 2015 after a change in sampling staff and possible change in sampling technique (from a grab sample with a bailer to a purge and sample technique), although this is speculation and there are no documented sampling procedures for the pre 2015 sampling.
- Regardless of the source of copper at MB2, it is unlikely to be impacting groundwater values at the site given copper is below the drinking water and stock water guidelines (and groundwater is not currently used for drinking water or stock watering in the vicinity of MB2), and that interaction between the deeper groundwater monitored in this bore and surface water features is unlikely.

The concentrations of dissolved copper recorded at MB2 during 2017 and 2018 are lower than those recorded in 2015 and 2016, as can be seen in the timeseries plot (Figure 3-12).

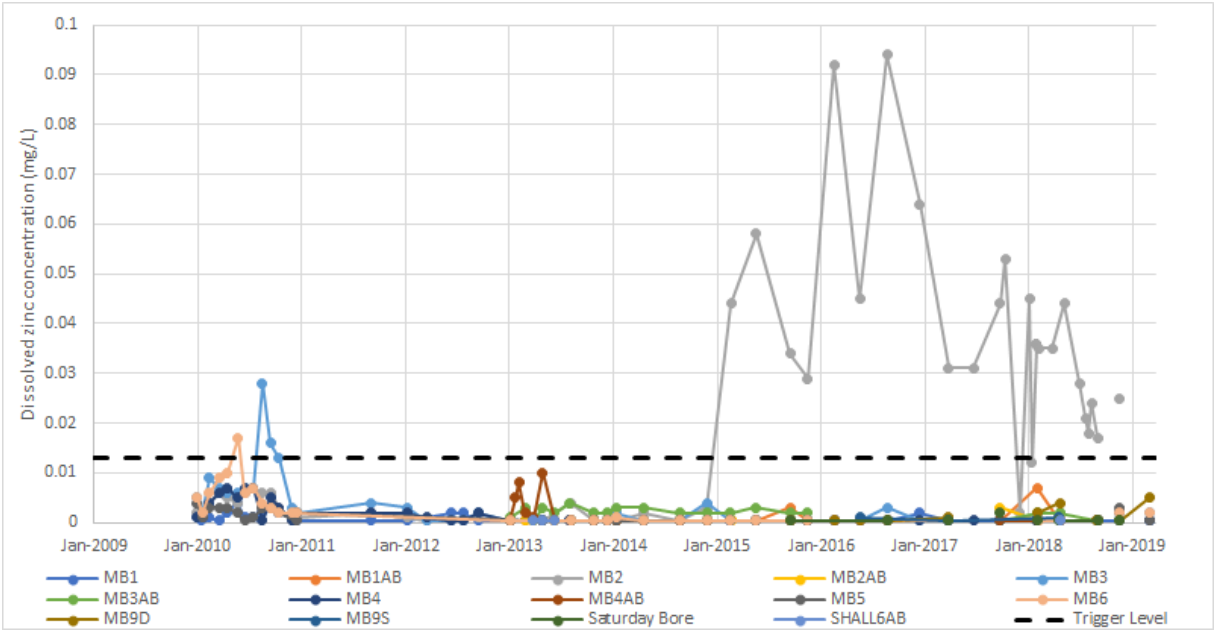


Figure 3-12 Dissolved copper concentrations in all bores across the site (trigger levels is average HMTV for MB2)

The CDM Smith (2018) report assessed the appropriateness of control charting in accordance with the DSITI (2017) guidelines and recommended the use of control charting as a method of assessing compliance at MB2 as it can provide a sound basis to continue using the current bore as a compliance bore. The use of National Guidelines or site specific trigger limits (based on background bores) will result in continued exceedances of the triggers and will not serve the function of protecting the groundwater values from mining activities.

Based on this, control charting has been used to assess the current groundwater data in line with the CDM Smith 2018 recommendations (Figure 3-13). The two-tiered nonparametric trigger control charting method has been adopted, as it allows for gradual and short-term changes to be assessed and allows for a non-normally distributed dataset. Only post-2015 data have been used to set the triggers and assess compliance as these data are thought to represent the true groundwater quality at MB2, and pre-2015 data are thought to be compromised. The rolling median has been set to include the previous two years of data to account for seasonal variability. Quarterly sampling would result in eight datapoints in the rolling median (2015 to 2017), but as more frequent sampling has been undertaken in 2018, the rolling median has been extended to up to 18 data points to include the previous two years of data.

The control charting shows that concentrations of dissolved copper have been decreasing since the end of 2016 and that the 2017 and 2018 concentrations are within control trigger limits.

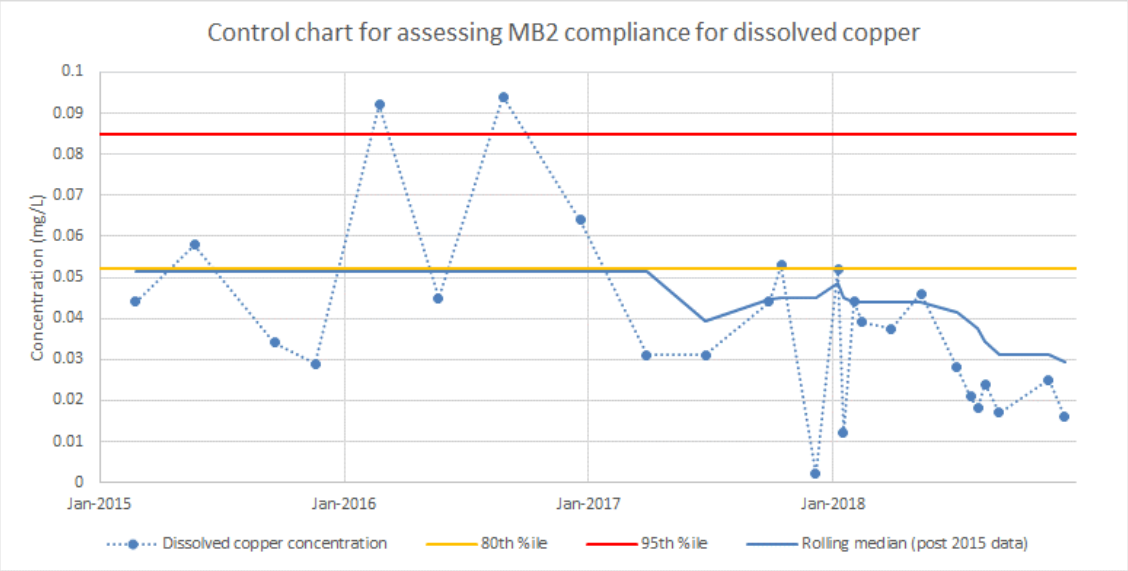


Figure 3-13 Control chart method used to assess compliance at MB2 for dissolved copper (as recommended CDM Smith, 2018)

Groundwater chemistry data (where available) has been assessed in line with Condition 37 of the EA (EPML00731213) and the objectives of the GMP (2014).

Recommendations based on this assessment include:

- *Resample MB6 and analyse sample for dissolved zinc and hardness. Further investigation may be required depending on the results of this analysis.*
- *Continue to use control charting as a method for assessing compliance at MB2 for dissolved copper concentrations*

3.5 Compliance with contaminant limits (EA condition C38)

Groundwater chemistry data have been compared to contaminant limits as defined in Schedule C – Table 8 (Groundwater Trigger Levels and Contaminant Limits) in the EA and the site specific GMP.

Exceedances of the contaminant limits for each bore can be seen as a traffic light diagram on Figure 3-14 to Figure 3-18. Data are only displayed where a sample was collected (see Section 3.3.2). Exceedances of contaminant limits can be summarised by the following:

- MB2 – fluoride in Q1, Q2 and Q3 2017 and Q2 2018 (2.2, 2.2, 2.9 and 2.4 mg/L, respectively)
- MB9D – total lead in Q3 2018 (0.125 mg/L)
- MB4, MB5 and MB6 – no exceedances

These exceedances have been compared to background conditions at the Site in the following sections. Where contaminant limits have been exceeded and concentrations are higher than background conditions, further investigations have been recommended in Section 4.3.2.

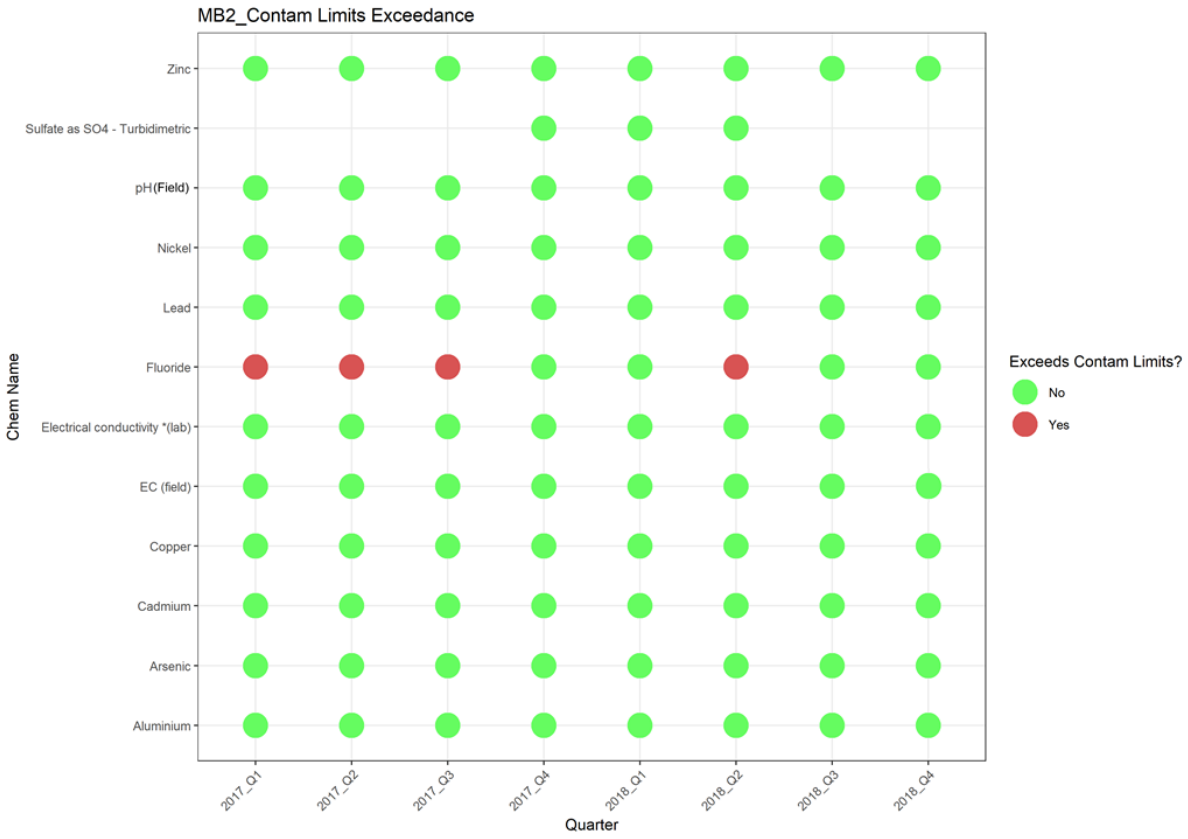


Figure 3-14 Exceedances of contaminant limits at MB2

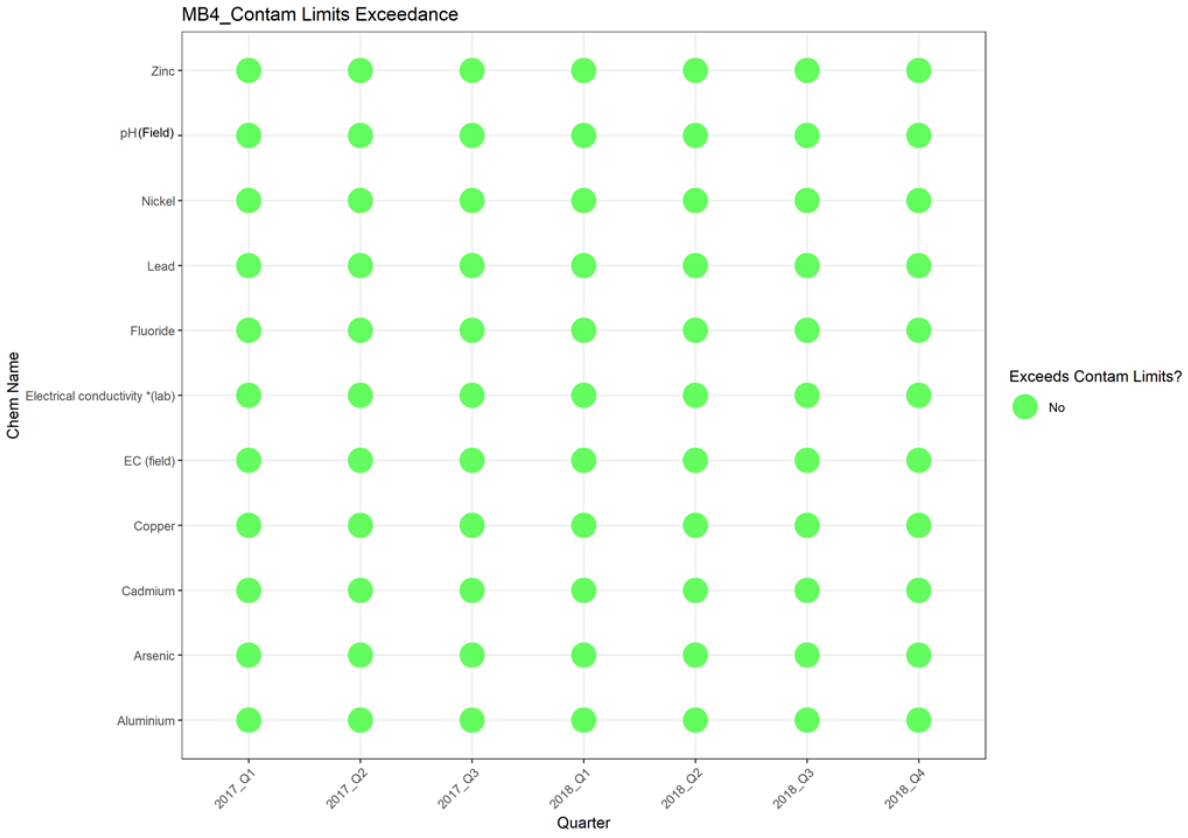


Figure 3-15 Exceedances of contaminant limits at MB4

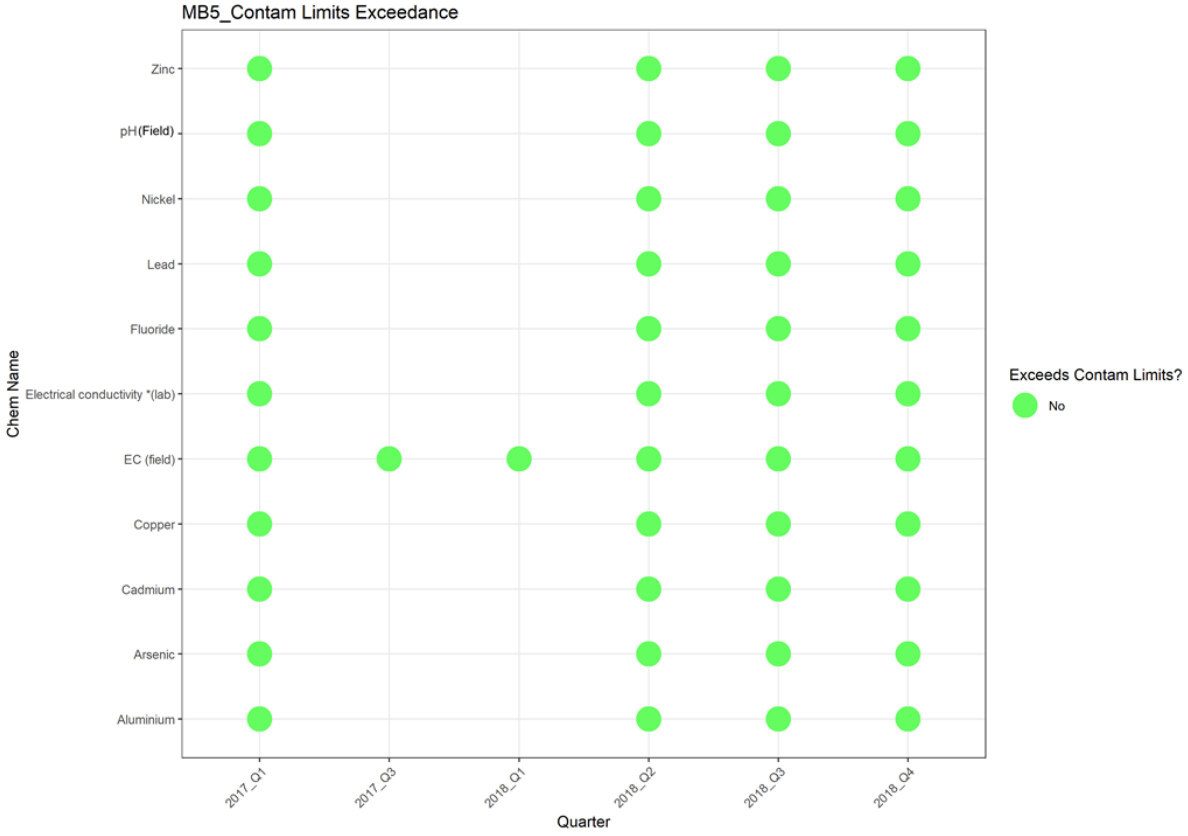


Figure 3-16 Exceedances of contaminant limits at MB5

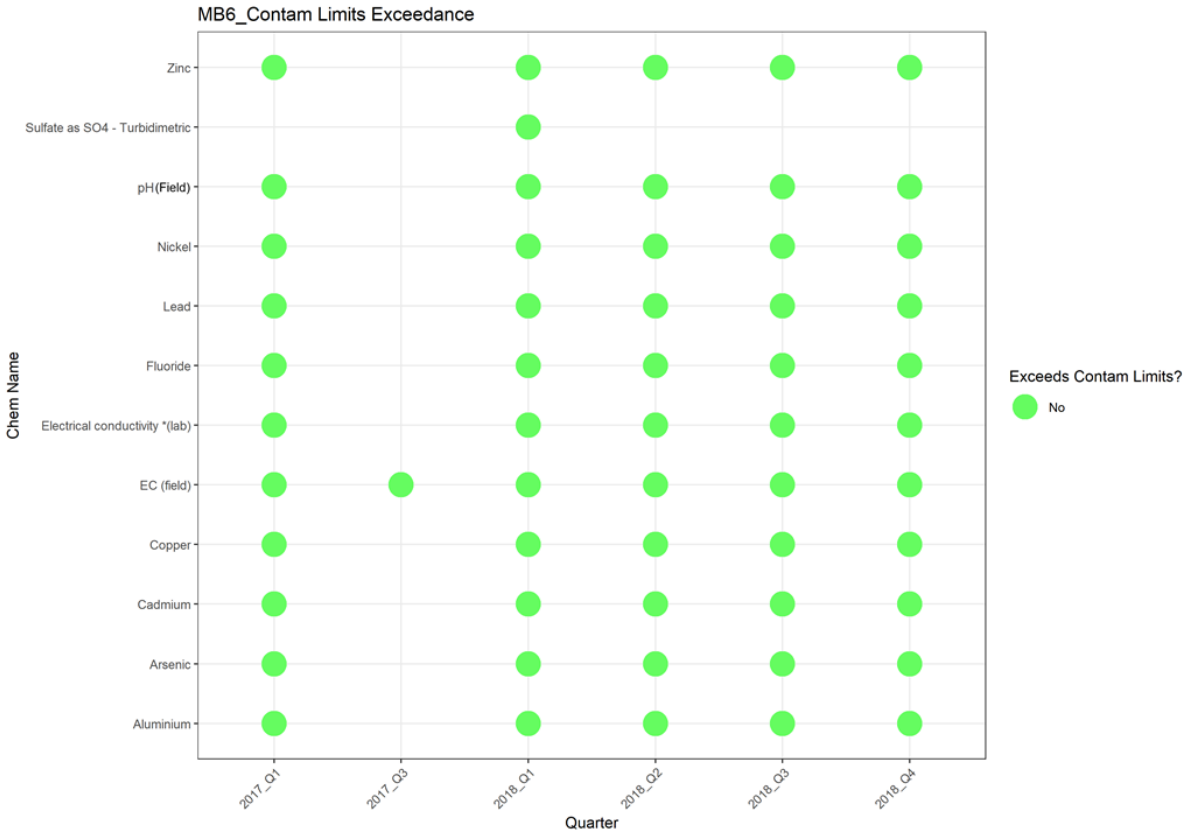


Figure 3-17 Exceedances of contaminant limits at MB6

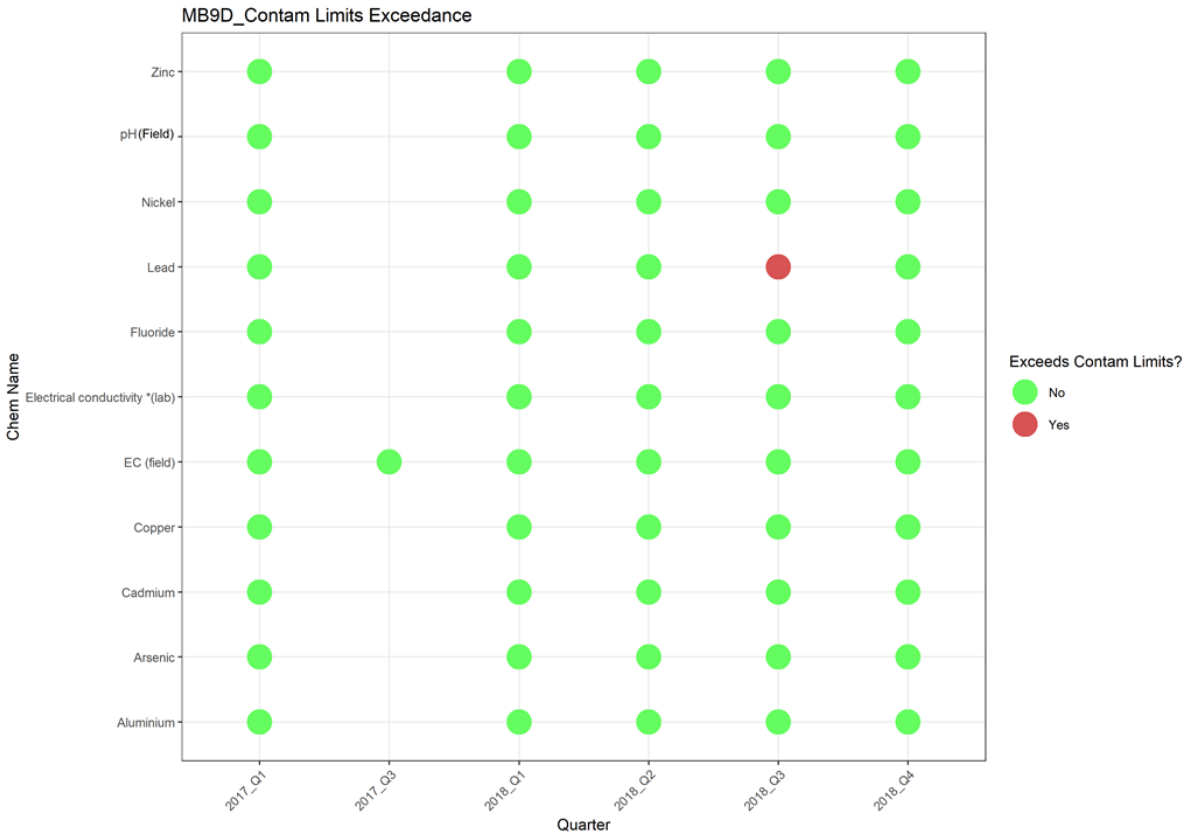


Figure 3-18 Exceedances of contaminant limits at MB9D

3.5.1 Fluoride at MB2

Fluoride at MB2 has been reported above the contaminant level in previous years but these concentrations are within the ranges seen at background bores across the Site (Figure 3-19). Additionally, based on pre-mining sampling conducted in 1990 and 2008 reported in the EIS for the Project (1994) and BDH (2014), fluoride concentrations were elevated across the site, with concentrations up to 2 mg/L reported at Saturday Bore. BDH (2017) also noted naturally elevated regional fluoride concentrations have been well documented, with the highest regional fluoride concentration exceeding 10 mg/L.

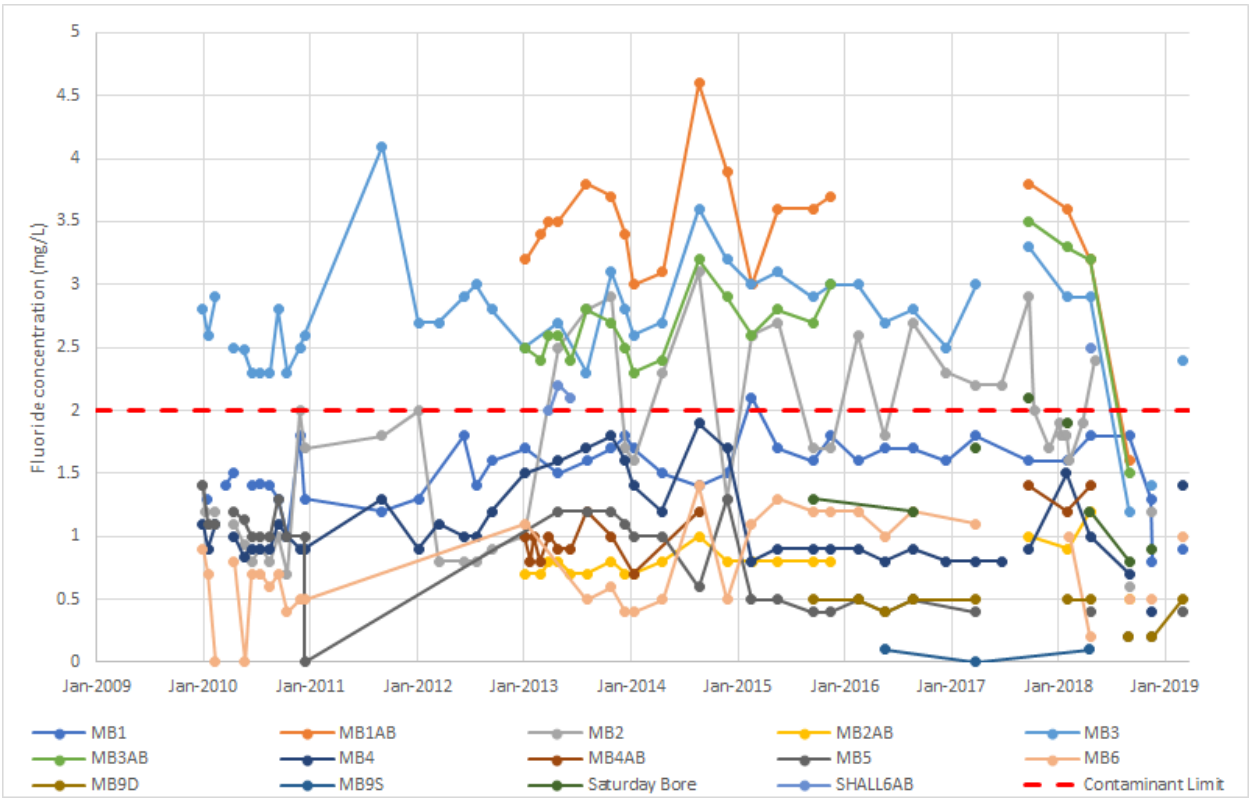


Figure 3-19 Fluoride concentrations in all bores across the site

3.5.2 Lead at MB9D

The exceedance of the lead contaminant limit at MB9D is minor (concentration of 0.125 mg/L compared to the limit of 0.1 mg/L) and isolated. Concentration of total lead at this bore shows a steady rise over 2018, although dissolved lead has remained below the LOR (<0.001 mg/L). Total suspended solids measured in this bore have been high throughout 2018. Further action to investigate this is recommended in Section 4.3.2.

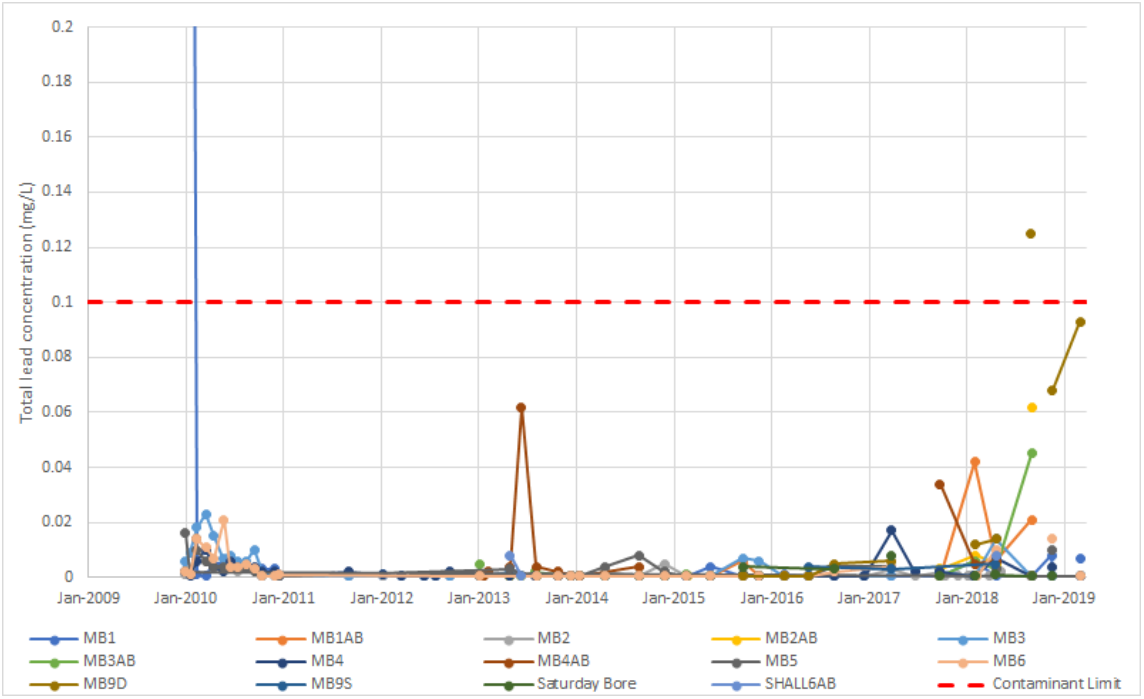


Figure 3-20 Total lead concentrations in all bores across the site

Groundwater chemistry data (where available) has been assessed in line with Condition 38 of the EA (EPML00731213) and the objectives of the GMP (2014).

Minor non-compliances have been identified:

- *Fluoride concentration at MB2 – fluoride is known to be naturally elevated across the site and the current contaminant limit is within the range of natural variation, resulting in repeated exceedances. It is therefore recommended (in line with previous reviews) that this limit is reviewed.*
- *Total lead concentration at MB9D – a minor exceedance that may be related to high suspended solids in the bore. It is recommended that this bore is redeveloped prior to the next sampling round.*

Section 4 Conclusions and Recommendations

4.1 Summary

A summary of the data analysis undertaken on the data provided by MMG is provided below:

- Overall, groundwater chemistry and groundwater level data are considered reliable for the interpretation of groundwater conditions at the Site.
- Non-compliances of condition C36 include
  - **Gauging:** Multiple non-compliance predominately related to interpretation bores (five out of eight quarters at least one interpretation bore was missed) and background bores (three out of eight quarters at least one background bore was missed). Some compliance bores were also not gauged on two occasions (Q4 2017 and Q4 2018).
  - **Sampling:** Q2 and Q4 2017 – missed samples for all background bores, Q3 2017 – only field parameters measured for the new compliance bores (MB5, MB6 and MB9D), Q1 2018 – only field parameters measured for MB5.
  - **Chemical analysis:** alkalinity not analysed in the MB2 Q4 2017 sample.
- Groundwater analyses were assessed against trigger levels as per condition C37 with the outcomes presented in Table 4-1.

Table 4-1 Biennial groundwater review data sources

Exceedance of trigger level	Comparison to background conditions	Action recommended?
MB2: sulfate in Q4 2017 (152 mg/L) and Q1 2018 (152 to 161 mg/L)	• Comparable to the background bore concentrations	No further action is recommended
MB2: copper throughout the monitoring period (between 0.012 mg/L to 0.053 mg/L)	• Concentrations are above background conditions but below the 2016 concentrations and decreasing • Control charting assessment of compliance indicates concentrations are within control trigger limits	Yes – see Section 4.3.2.
MB6: zinc in Q2 (0.485 mg/L) and Q4 (0.086 mg/L) of 2018	• These concentrations are above background conditions	Yes – see Section 4.3.2.

- Groundwater analyses were assessed against contaminant limits as per condition C37 with the following outcomes:
  - Non-compliance for fluoride at MB2 in Q1, Q2 and Q3 2017 and Q2 2018 – these concentrations are within natural variations across the site; and
  - Non-compliance for total lead at MB9D in Q3 2018 – may be related to high suspended solids in the bore. It is recommended that this bore is redeveloped prior to the next sampling round.

4.2 Conclusions

Compliance with the EA groundwater conditions has generally occurred throughout the 2017/2018 monitoring period:

- C36 – Quarterly groundwater chemistry data and groundwater level were usually collected at the required frequency outlined by the EA. However, data gaps are evident (e.g. only Q1 and Q2 in 2018 had full compliance with the groundwater gauging condition).
- C37 – Most analytes were below trigger levels or below background levels. Zinc at MB6 requires further investigation and copper at MB2 should be assessed using control charting.

- C38 – Most analytes were below contaminant limits with the exception of fluoride at MB2 (within natural variation) and lead at MB9D (potentially due to high suspended sediment in the bore).
- C39 – Bore maintenance requirements and condition assessments have not been carried out as part of this review. It is assumed that no maintenance work has been carried out across the network over the review period.
- C40 – This report represents compliance of this condition as it has been completed by a suitably qualified person and includes:
  - An assessment of groundwater monitoring results against the objectives of the MMG Dugald River Mine Groundwater Monitoring Program;
  - A review of groundwater compliance against requirements specified in the environmental authority;
  - Any proposed refinement or update to the groundwater monitoring program or environmental authority, with respect to monitoring locations, frequencies, parameters, specified trigger values and/or specified contaminant limits, that may be applicable on review of the collected data or other relevant information (see below).

The GMP provides a comprehensive assessment of groundwater monitoring requirements at the site, as per the groundwater conditions and mine plans of 2014. However, it does not include monitoring of groundwater chemistry in the Cabbage Creek catchment for impacts from the TSF. As this facility is now in use, monitoring of the relevant bores (required in the EA) should continue. The monitoring frequency set out in the GMP is still appropriate and should be continued.

4.3 Recommendations

Recommendations below are categorised into three types:

- Way to improve data quality and promote more frequent compliance with Condition 36 of the EA;
- Actions that should be taken as a result of the assessment against trigger levels and contaminant limits; and
- Proposed changes to the GMP or EA.

4.3.1 Data quality improvements

- Although the GMP is detailed, a more simplified or summarised GMP may assist in meeting Condition 36 of the EA, giving field staff a simple set of instructions or tick boxes to ensure that all required bores are gauged and sampled. More frequent (quarterly) internal reporting may also help to identify omissions in a timeframe where these can be acted on and ensure good record keeping.
- Specific conductance (SPC) of samples should be collected in the field to mitigate temperature dependant conductivity values.
- Analysis of major ions at MB3 should include filtered samples to rule out sediment causing charge balance errors and TDS ratios outside of data quality objectives. A duplicate sample from this bore should be sent to a secondary laboratory to rule out laboratory error.
- Laboratory certificate of analysis' should be checked as soon as practicable to ensure filterable metal concentrations are not greater than total metal concentrations and identify other potentially erroneous data (e.g. TDS values higher than EC values). Reanalysis can be requested (if required) once this check has been completed.
- To validate results and assess whether cross contamination has been introduced to the sample during sampling, handling and transportation, during each round of sampling the following QA/QC samples should be collected in line with national and state guidelines (DES, 2018)
  - Intra-laboratory and inter-laboratory duplicates; and

- Field blank, trip blank and rinsate sample (if reusable equipment is used).

4.3.2 Groundwater quality assessment actions

- Resample MB6 for dissolved zinc and hardness.

  If the repeated sample indicates dissolved zinc above the HMTV, conduct an investigation into the repeated exceedances. This could include:

  - Redeveloping MB6 to remove sediment and assessing the bore integrity.
  - Investigating the source of zinc in the groundwater, which should include comparing groundwater concentrations to concentrations in the TSF water.
  - Considering whether it would be appropriate and/or possible to install a groundwater bore up-gradient of the TSF.
- Continue to use control charting as a method for assessing compliance at MB2 for dissolved copper concentrations
- Assess the appropriateness of sampling techniques at MB9D. Resample using appropriate sampling techniques and assess the results against compliance limits. If compliance limit is still exceeded, it is recommended that MB9D is redeveloped so that sediment is removed and discounted from effecting the results from this bore.

4.3.3 Proposed changes to the GMP or EA

The requirement of the EA and the monitoring proposed in the GMP are suitable for monitoring potential changes to groundwater conditions and risk to environmental values. Minor changes could include the below.

4.3.3.1 EA updates

- Investigation of the fluoride contaminant limit in the EA to take into account background and historical concentrations and bring this in line with natural variations; and
- Inclusion of the use of control charting to assess copper concentrations at MB2 in the EA.

4.3.3.2 GMP updates

The GMP is out of date and requires updating. The following items should be included in the updated GMP:

- Establish clear objectives for the GMP to protect groundwater and groundwater related environmental values;
- Details of current operations, locations and mine plan;
- Inclusion of the Cabbage Creek catchment bores in the GMP (MB5, MB6, MB9S and MB9D) and consider whether an up gradient TSF bore can be established;
- Details of data quality assurance and control procedures and objectives;
- Details of monitoring work instructions and field sheets; and
- Details of protocols for data management and investigations.

Section 5 References

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Blake, D.H. 1987. *Geology of the Mount Isa Inlier and environs, Queensland and Northern Territory*. Bureau of Mineral Resources, Geology and Geophysics.

CDM Smith, 2018 *Dugald River Mine groundwater quality report*. Issued 20th December 2018. Report no. MMG-1000290-RPT-001-1

DES. 2018. *Monitoring and Sampling Manual: Environmental Protection (Water) Policy*. Brisbane: Department of Environment and Science Government.

DSITI. 2017. *Guidelines Using monitoring data to assess groundwater quality and potential environmental impacts.* Version 1. Department of Science, Information Technology and Innovation (DSITI), Queensland Government, Brisbane

Environmental Authority (EA) Permit EPML00731213 MMG Dugald River Pty. Ltd

Geoscience Australia. 2018. *Stratigraphic Unit Details – Knapdale Quartzite.* Accessed on the 13 June 2019. Available from <https://asud.ga.gov.au/search-stratigraphic-units/results/9656>.

Golder. 2017. *Dugald River Groundwater Quality Assessment*. Report number 1782878-001-R-Rev0, November 2017

Section 6 Disclaimer and Limitations

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If further information becomes available, or additional assumptions need to be made, CDM Smith reserves its right to amend this report.

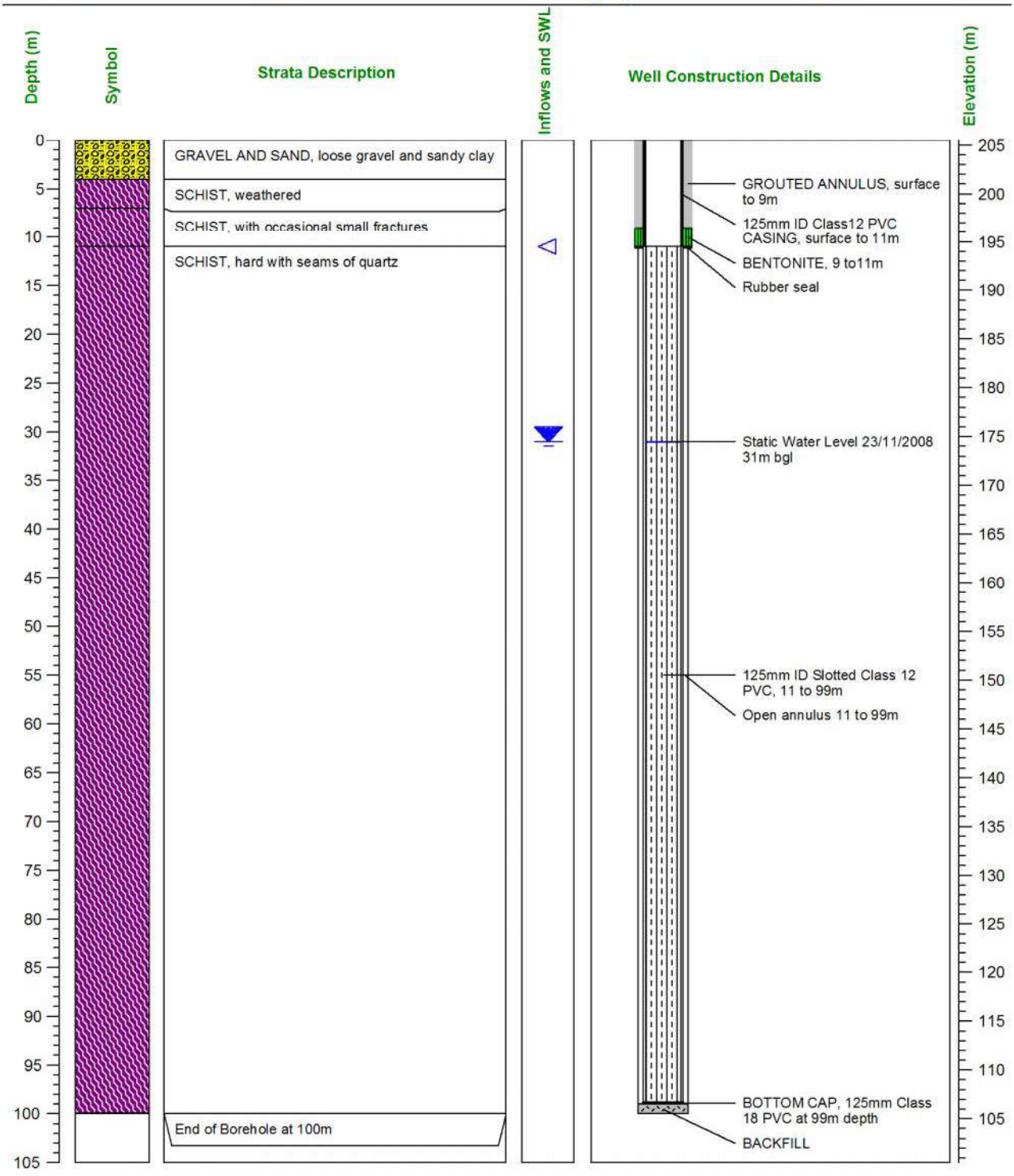
Appendix A Bore Logs

Borehole No: MB1 **Client: MM Group**

Location: Dugald River **Date Drilled:** 21/11/2008 **Project No:** 116

Easting: 411160 **Northing:** 7761020 **Elevation (m):** 205.506

Method: Rotary Air Blast **Driller:** J E Brown **Drilling Rig:**



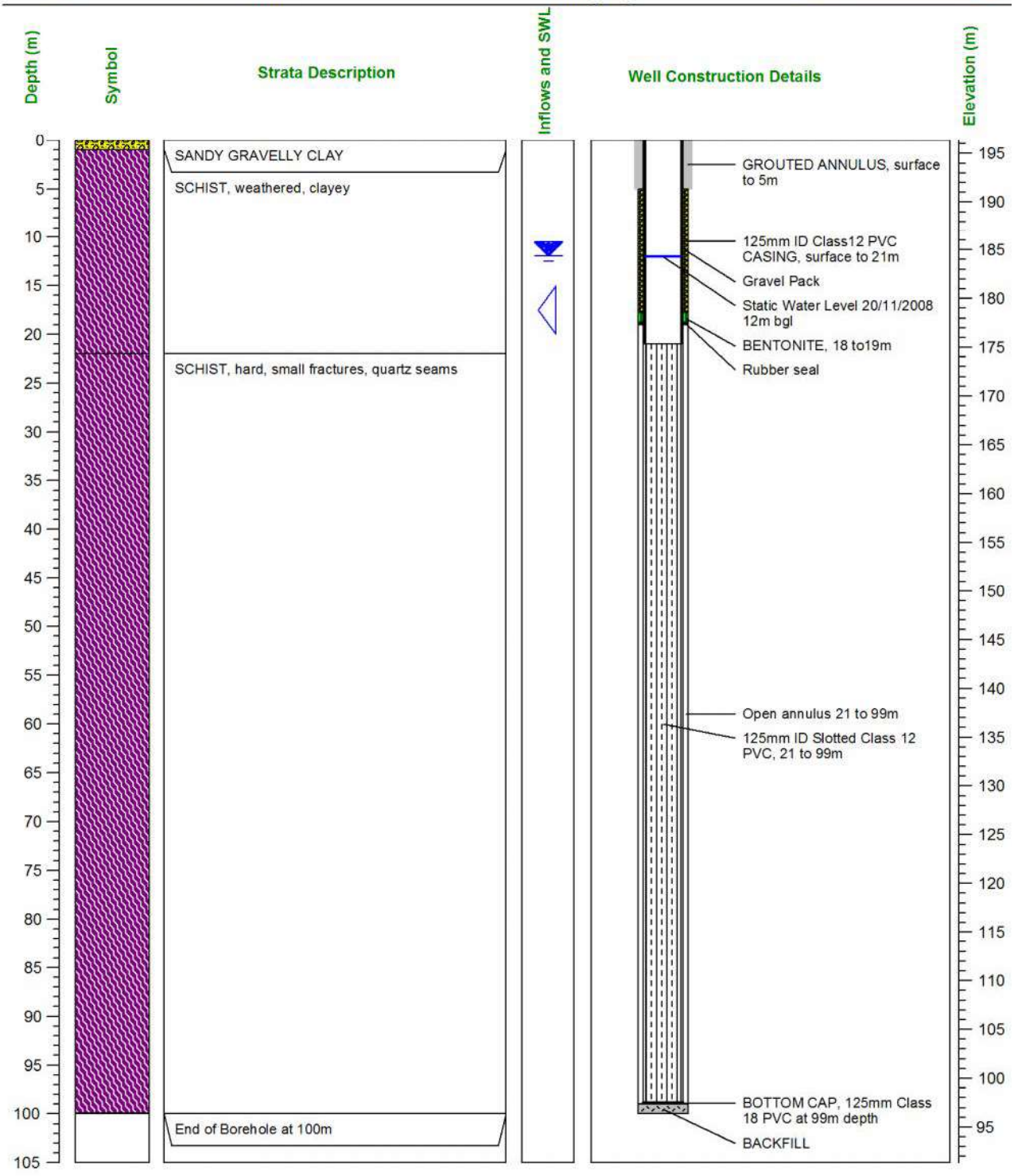
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Dugald River Project MB1
Strata description compiled by driller

Borehole No: **MB2**
Client: **MM Group**

Location: Dugald River
Date Drilled: 20/11/2008
Project No: 116
Easting: 412070
Northing: 7760970
Elevation (m): 196.345
Method: Rotary Air Blast
Driller: J E Brown
Drilling Rig:



Notes:

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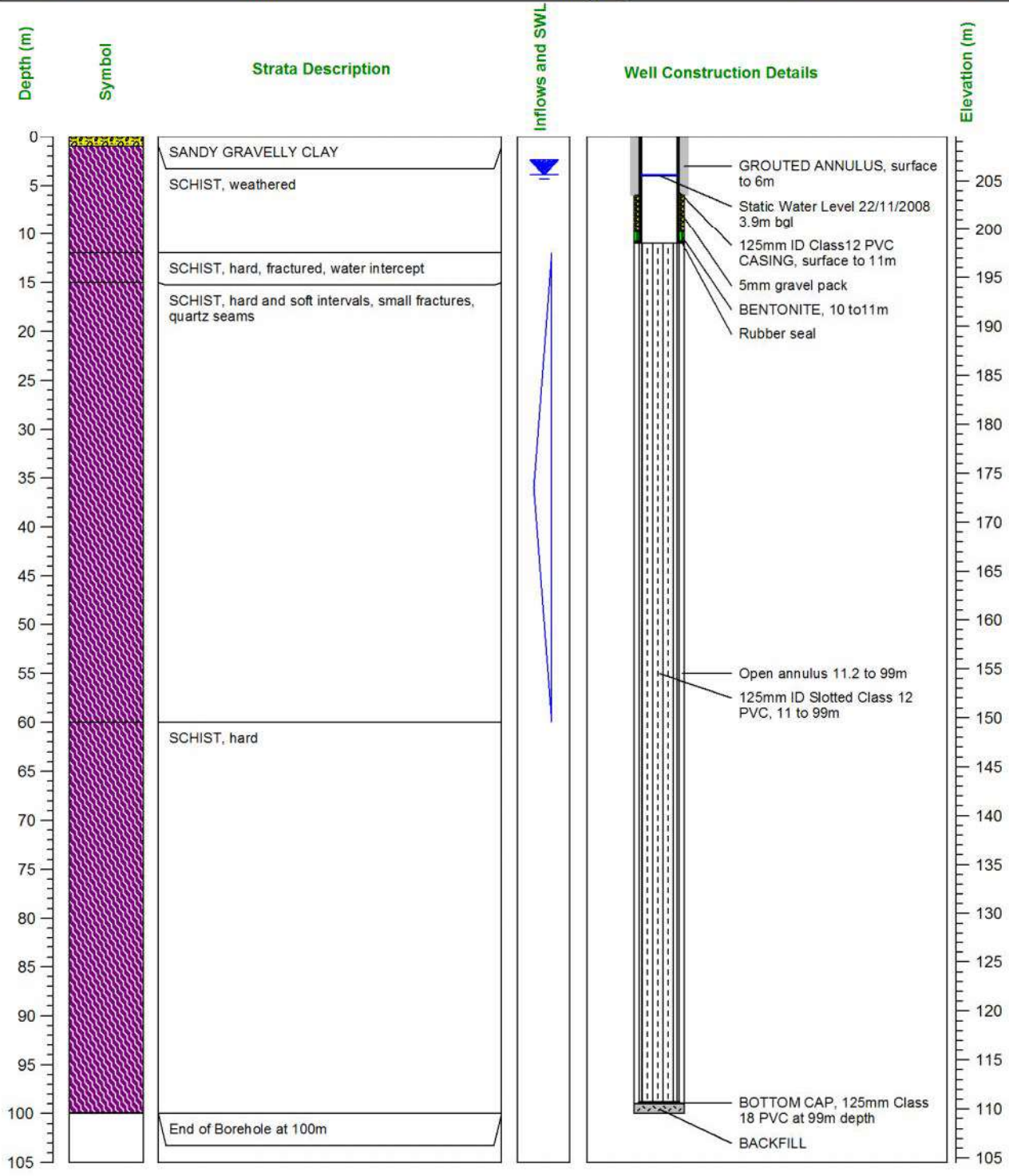
Dugald River Project MB2
Strata description compiled by driller

Borehole No: MB3 **Client: MM Group**

Location: Dugald River **Date Drilled:** 22/11/2008 **Project No:** 116

Easting: 411240 **Northing:** 7759940 **Elevation (m):** 209.518

Method: Rotary Air Blast **Driller:** J E Brown **Drilling Rig:**



Notes:

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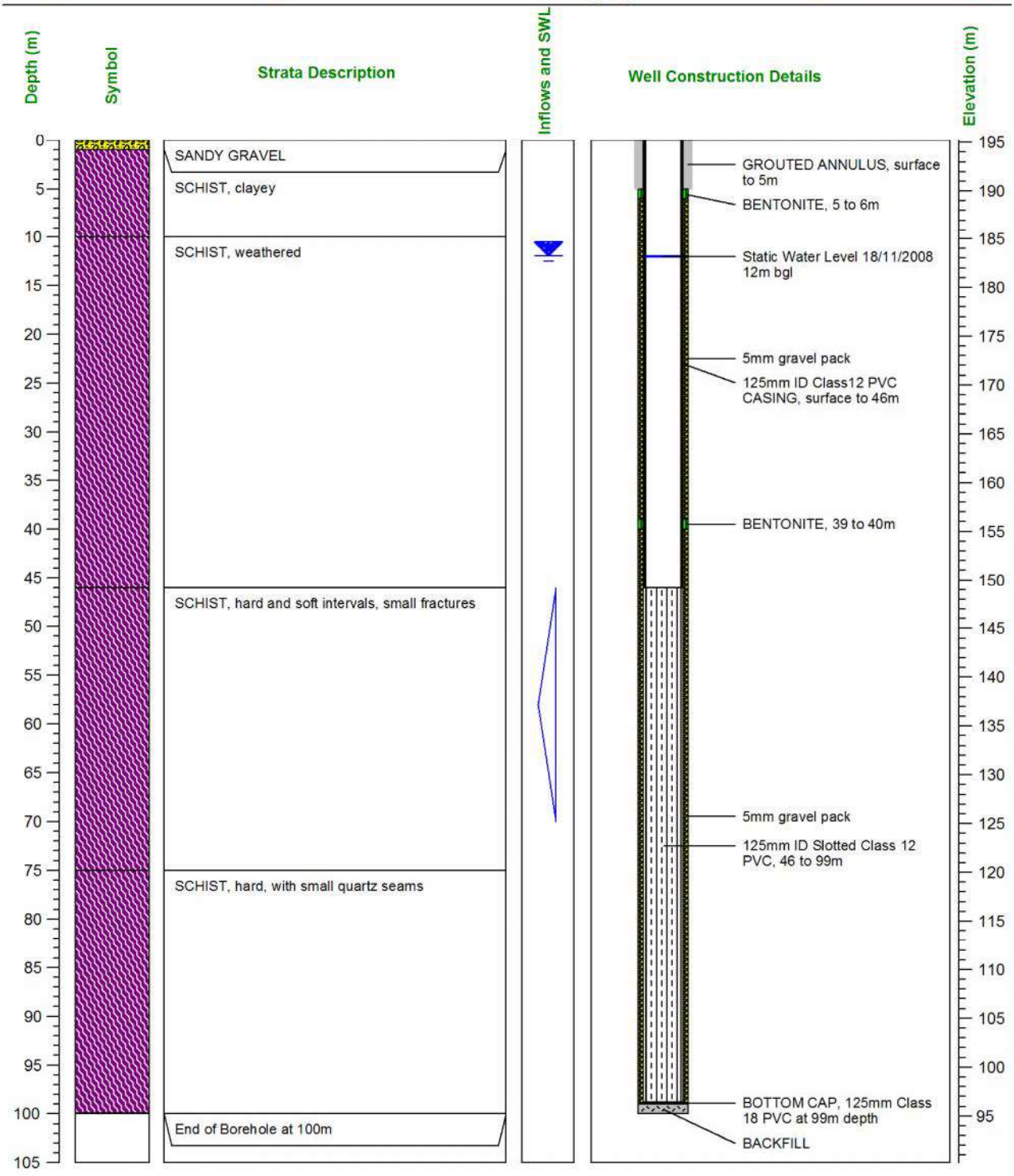
Dugald River Project MB3
Strata description compiled by driller

Borehole No: **MB4** **Client:** **MM Group**

Location: Dugald River **Date Drilled:** **18/11/2008** **Project No:** 116

Easting: 412635 **Northing:** 7759854 **Elevation (m):** 195.211

Method: Rotary Air Blast **Driller:** J E Brown **Drilling Rig:**



Notes:

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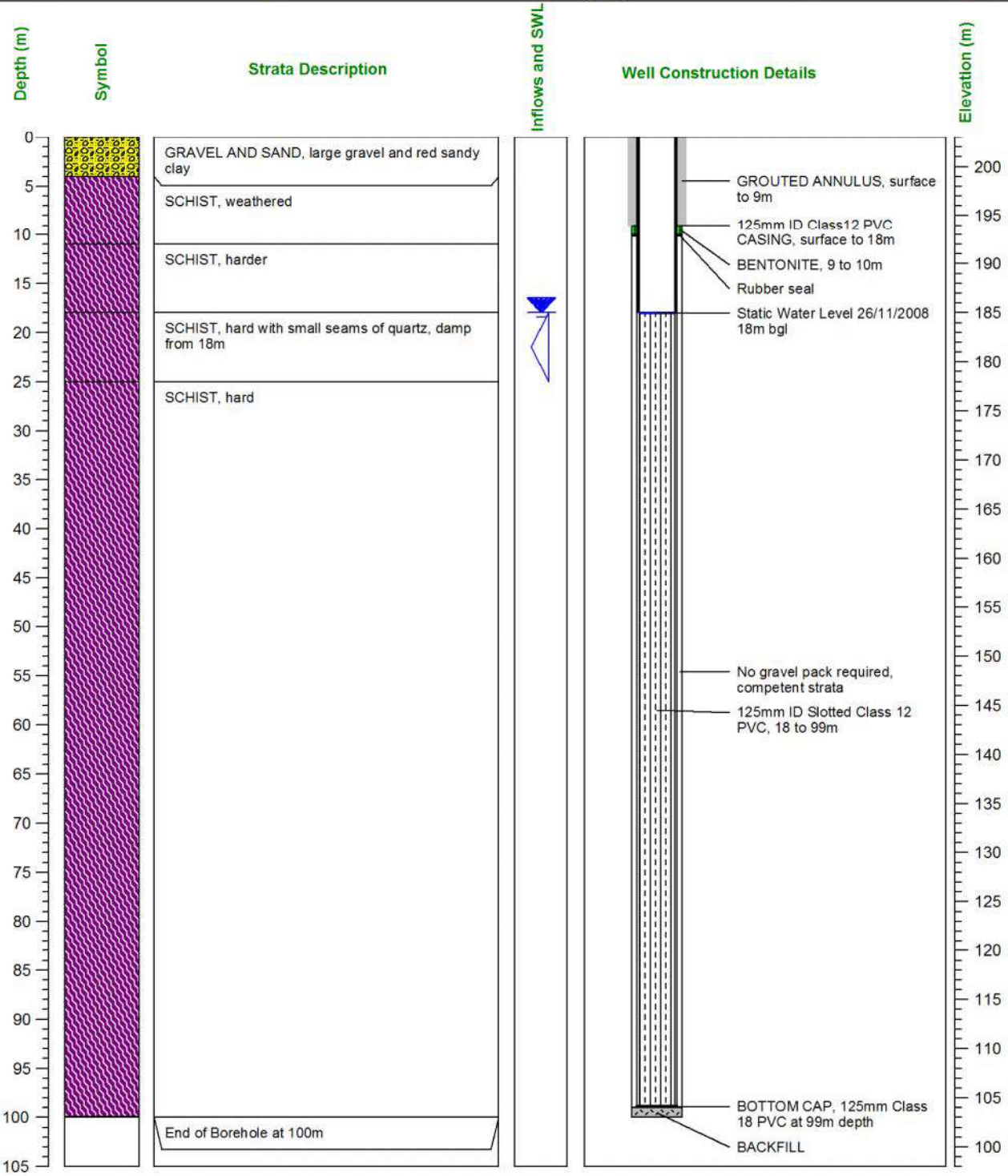
Dugald River Project MB4
Strata description compiled by driller

Borehole No: MB5 **Client: MM Group**

Location: Dugald River **Date Drilled:** 26/11/2008 **Project No:** 116

Easting: 408240 **Northing:** 7763180 **Elevation (m):** 203.0

Method: Rotary Air Blast **Driller:** J E Brown **Drilling Rig:**



Notes:

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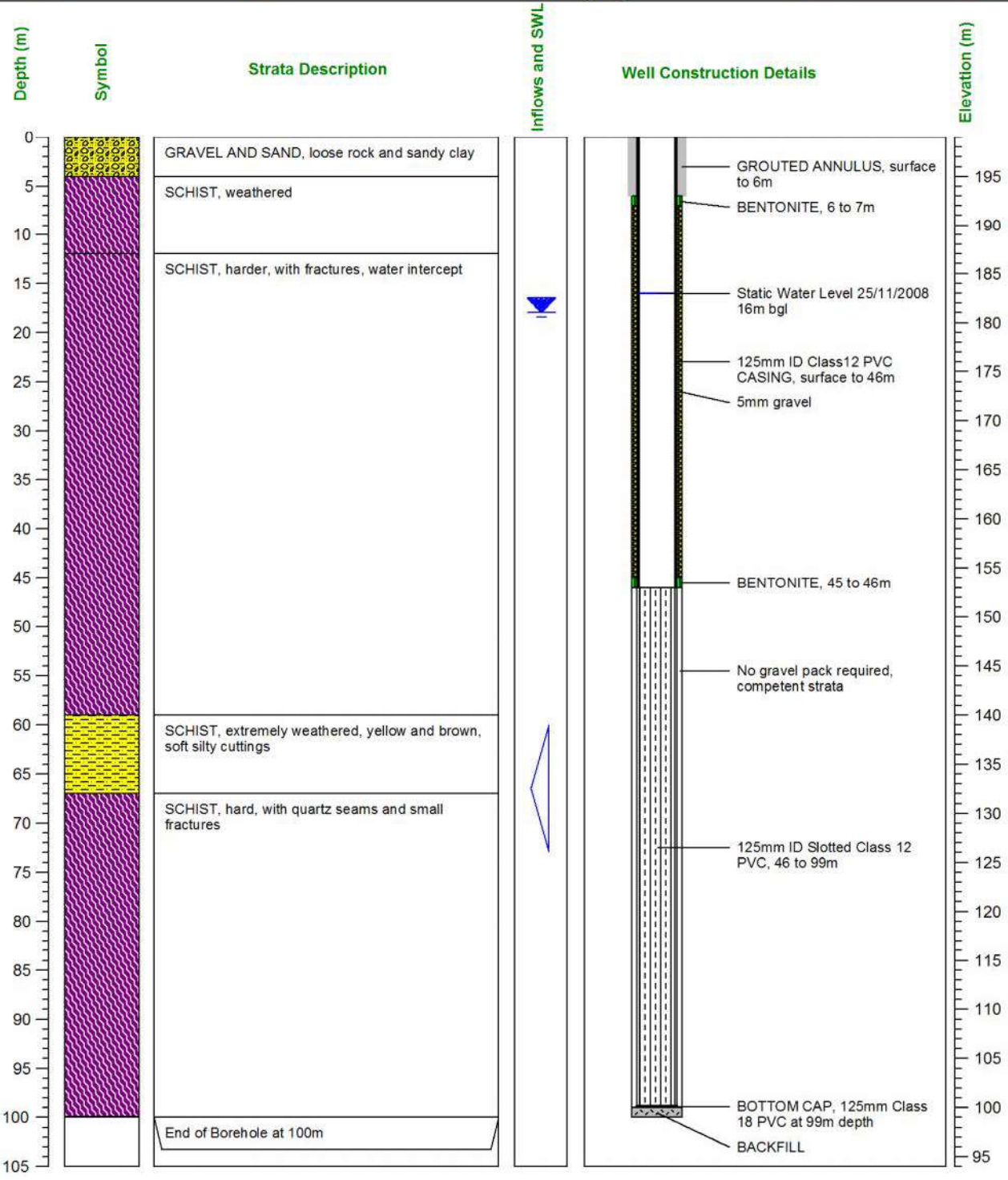
Dugald River Project MB5
Strata description compiled by driller

Borehole No: MB6 **Client: MM Group**

Location: Dugald River **Date Drilled:** 25/11/2008 **Project No:** 116

Easting: 407990 **Northing:** 7763100 **Elevation (m):** 199.0

Method: Rotary Air Blast **Driller:** J E Brown **Drilling Rig:**



Page 1 of 1 **Notes:**

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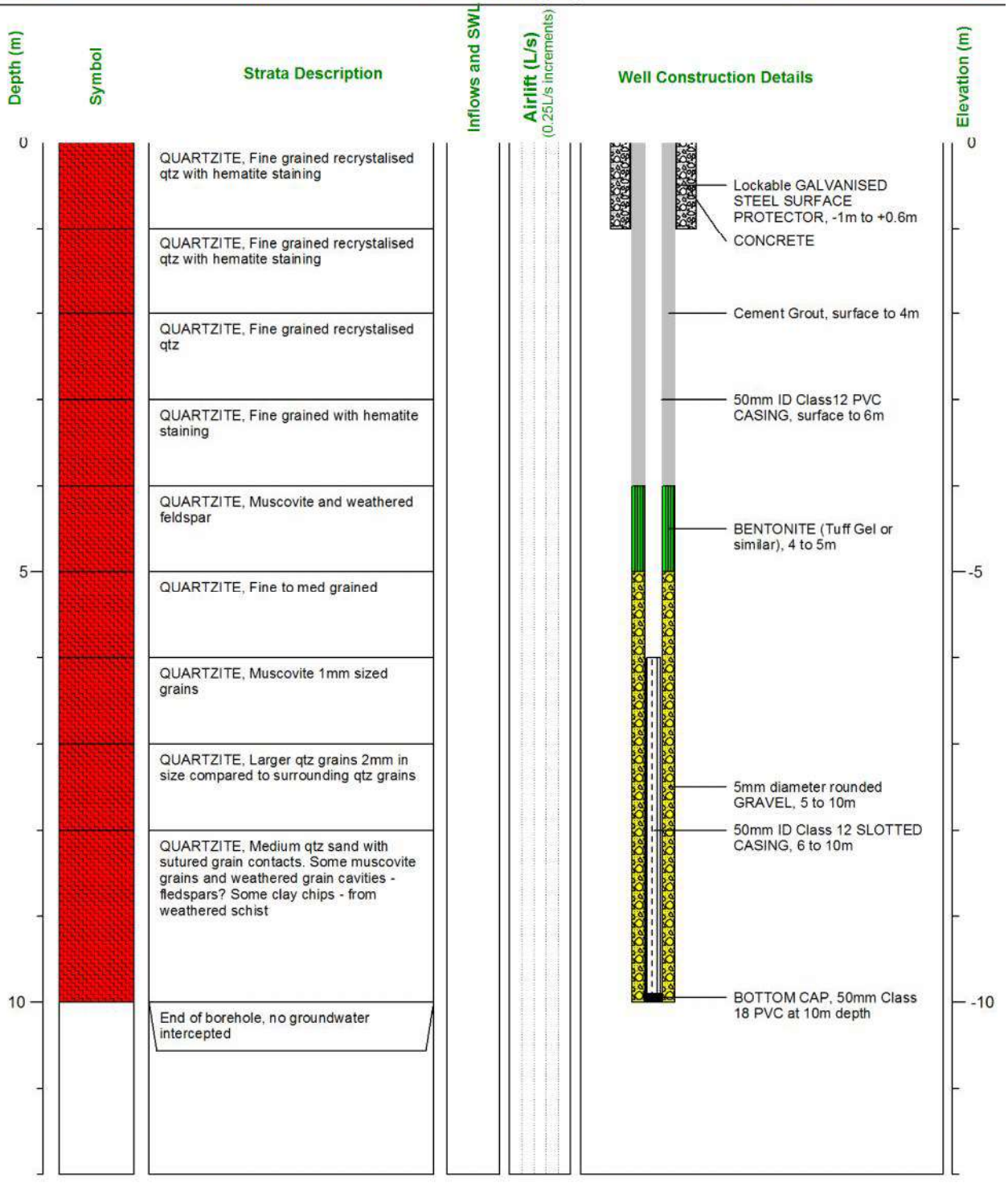
Dugald River Project MB6
Strata description compiled by driller

Borehole No: **MB9 Shallow Bore** **Client:** **MMG**

Location: Dugald River **Date Drilled:** **Dec.2010** **Project:** TSF Site

Easting: 406592 **Northing:** 7763278 **Elevation (m):**

Method: Rotary Air Blast **Driller:** Fox Drilling **Drilling Rig:**



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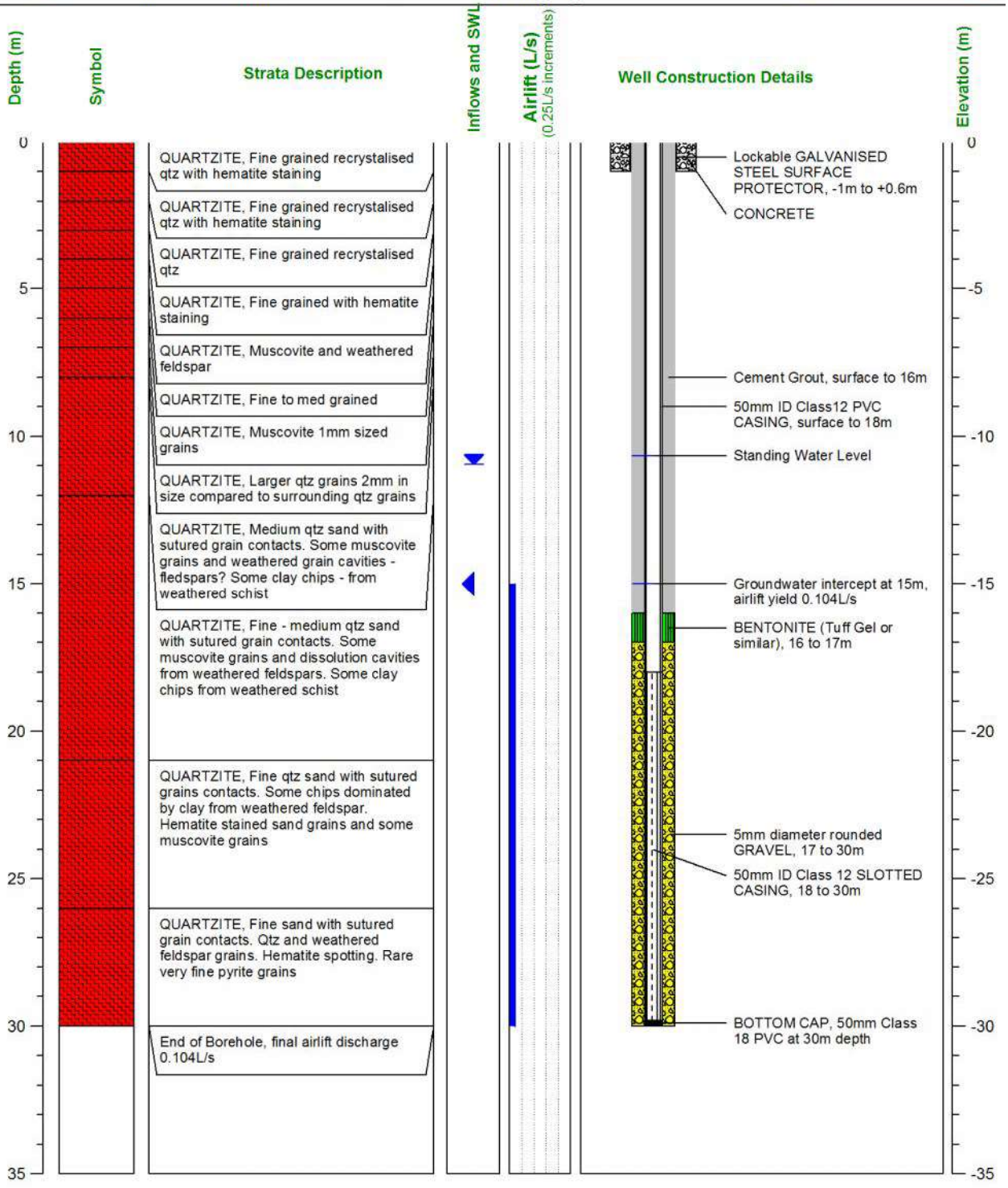
Shllow monitoring bore in watercourse downstream of TSF

Borehole No: **MB9 Deep Bore** **Client:** **MMG**

Location: Dugald River **Date Drilled:** **Dec. 2010** **Project:** TSF Site

Easting: 408783 **Northing:** 7763334 **Elevation (m):**

Method: Fox Drilling **Driller:** Derek McDonald **Drilling Rig:**



Notes:

Datum:MGA

Deep monitoring bore at downstream toe of proposed TSF embankment

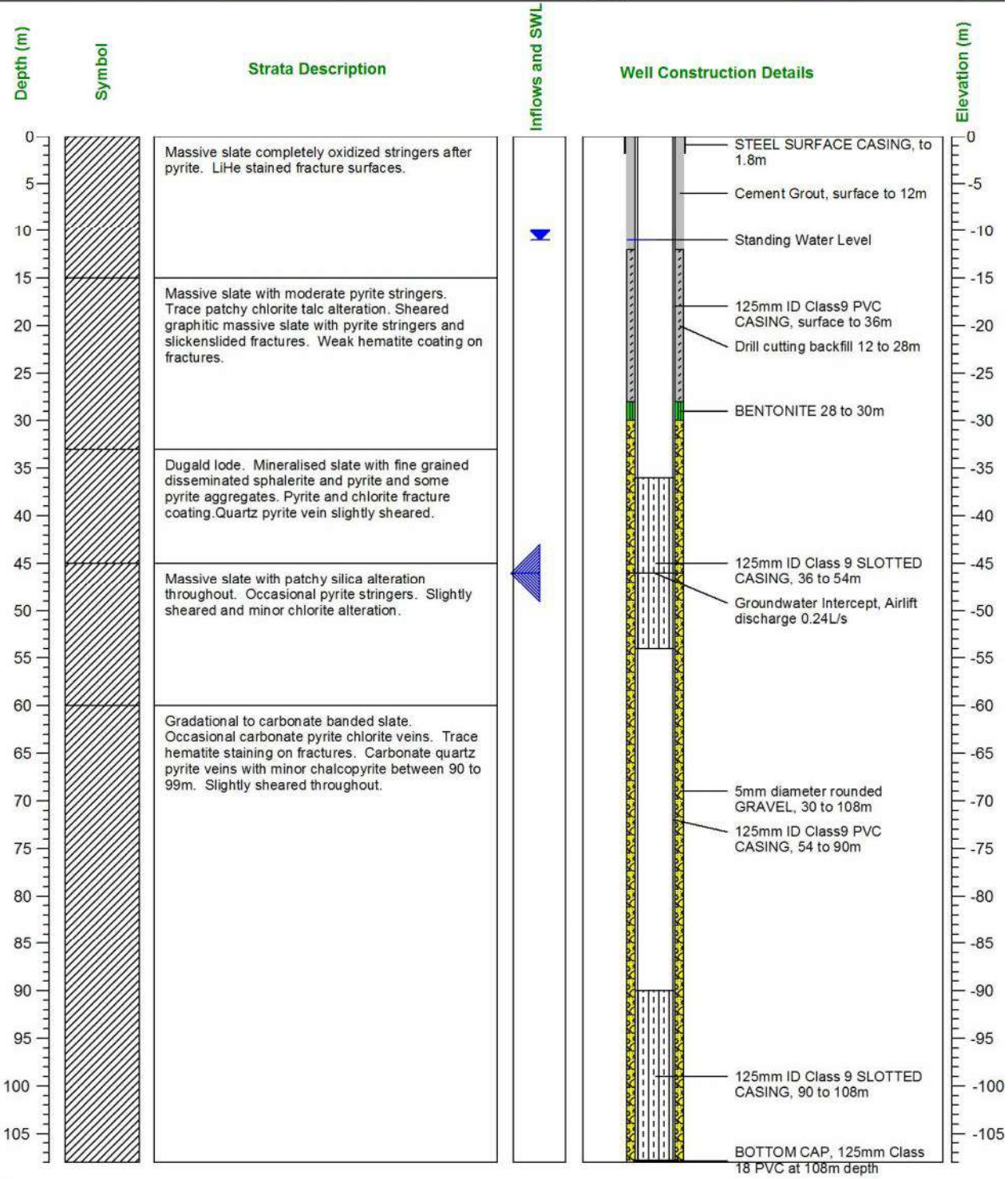
Borehole No: **MB10 North Portal** **Client:** **MMG**

Location: Dugald River **Date Drilled:** **Project No:**

Easting: 411682 **Northing:** 7760040 **Elevation (m):**

Method: Rotary Air Blast **Driller:** Fox Drilling **Drilling Rig:**





Notes:

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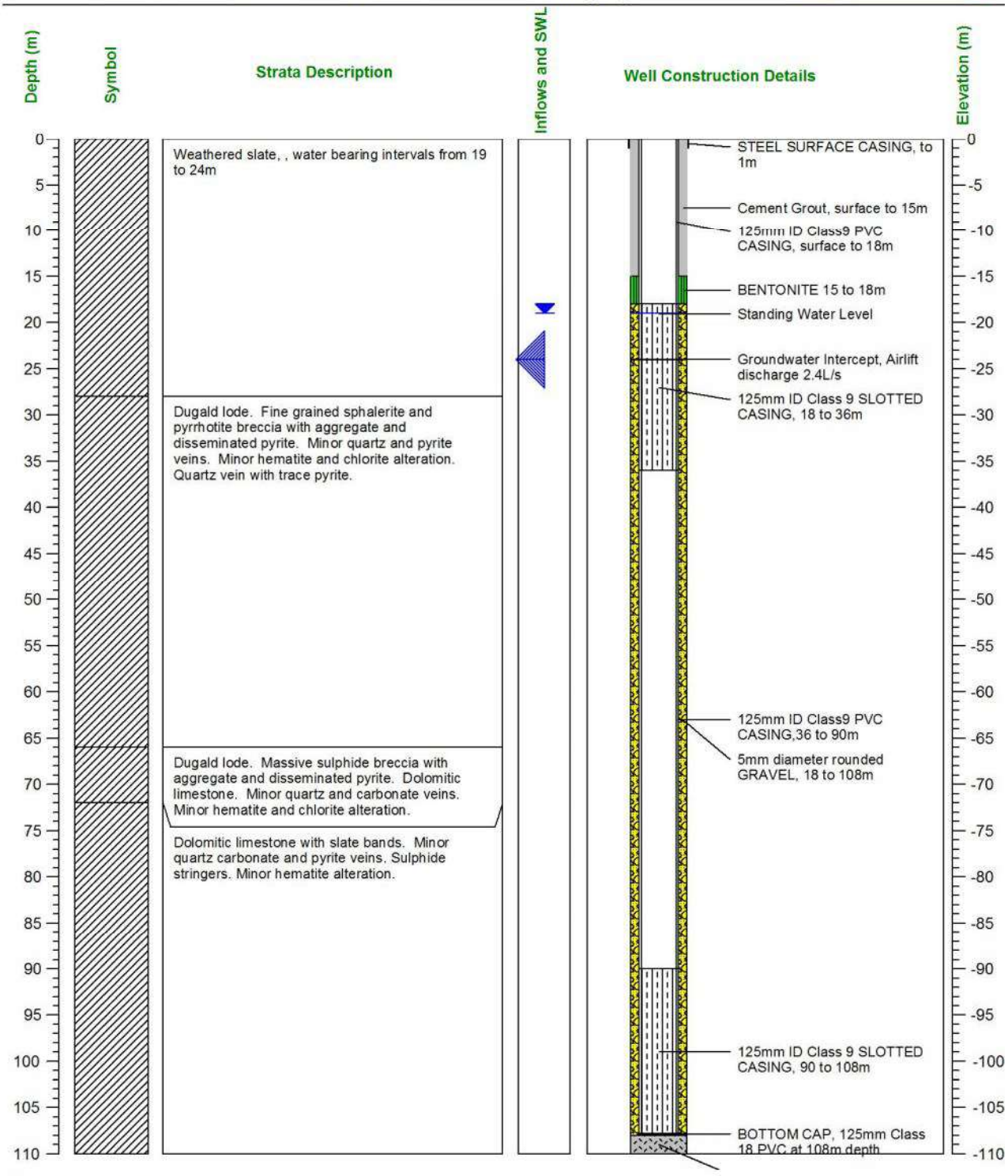
Groundwater investigation at North Portal site

Borehole No: MB11 South Portal **Client: MMG**

Location: Dugald River **Date Drilled:** **Project No:**

Easting: 411403 **Northing:** 7760919 **Elevation (m):**

Method: Rotary Air Blast **Driller:** Fox Drilling **Drilling Rig:**



Notes:

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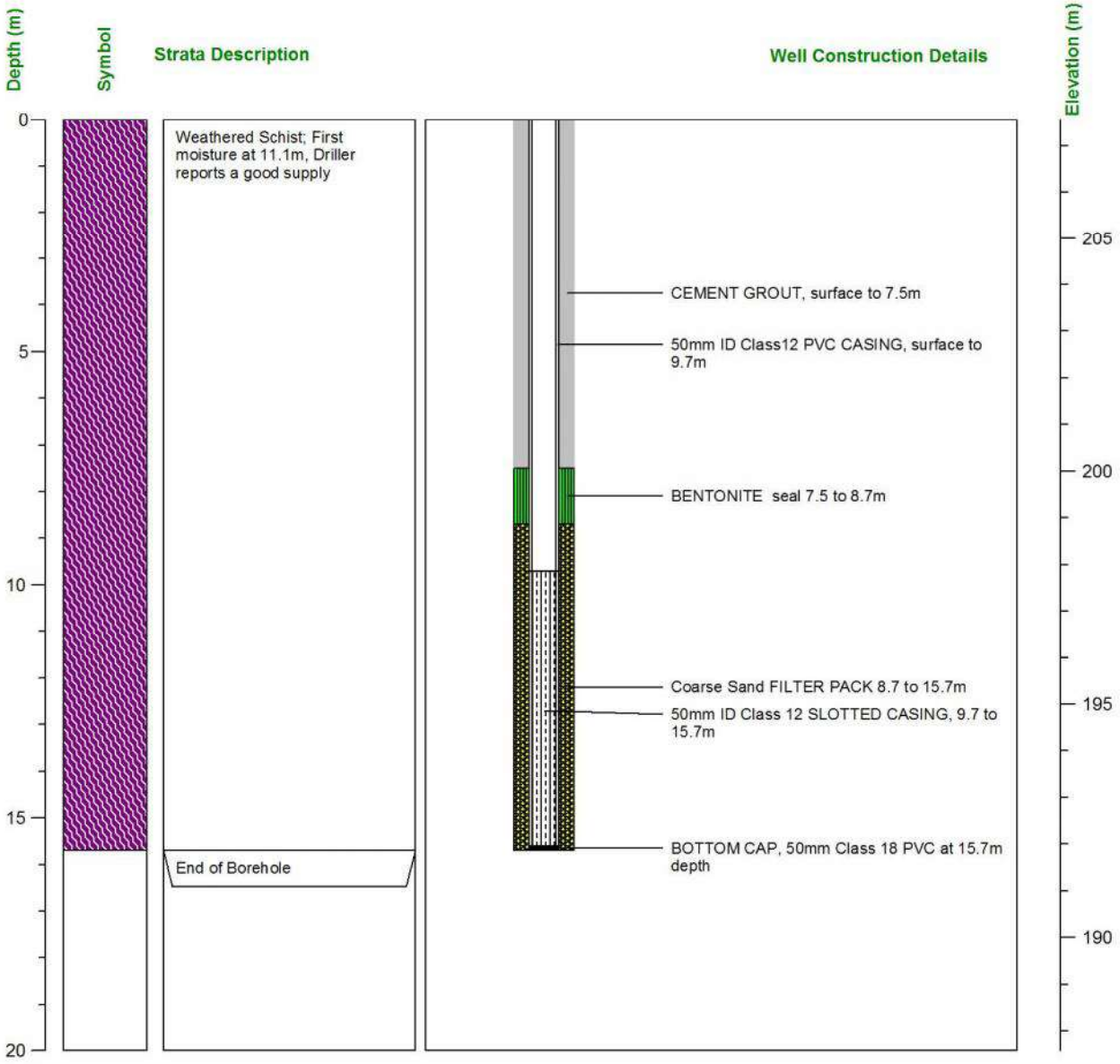
Groundwater investigation at South Portal site

Borehole No: **DRMB1-AB** **Client:** **MMG**

Location: Dugald River **Date Drilled:** **Nov.2012** **Project No:** 116

Easting: 411199 **Northing:** 7761205 **Elevation (m):** 207.562

Method: Rotary Air Blast **Driller:** Walker Drilling **Drilling Rig:**



Notes:

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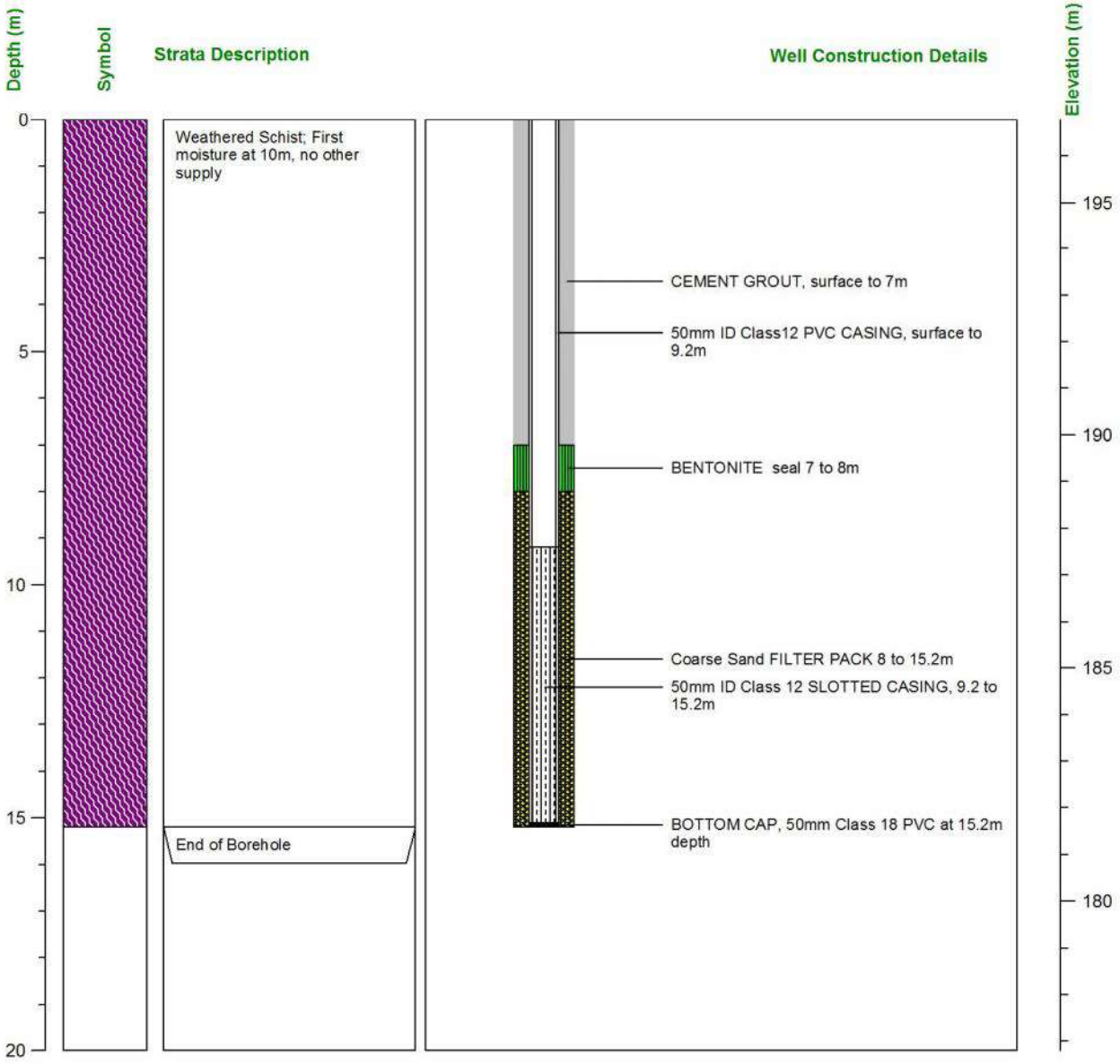
Shllow monitoring bore

Borehole No: **DRMB2-AB** **Client:** **MMG**

Location: Dugald River **Date Drilled:** **Nov.2012** **Project No:** 116

Easting: 412187 **Northing:** 7761185 **Elevation (m):** 196.788

Method: Rotary Air Blast **Driller:** Walker Drilling **Drilling Rig:**



Notes:

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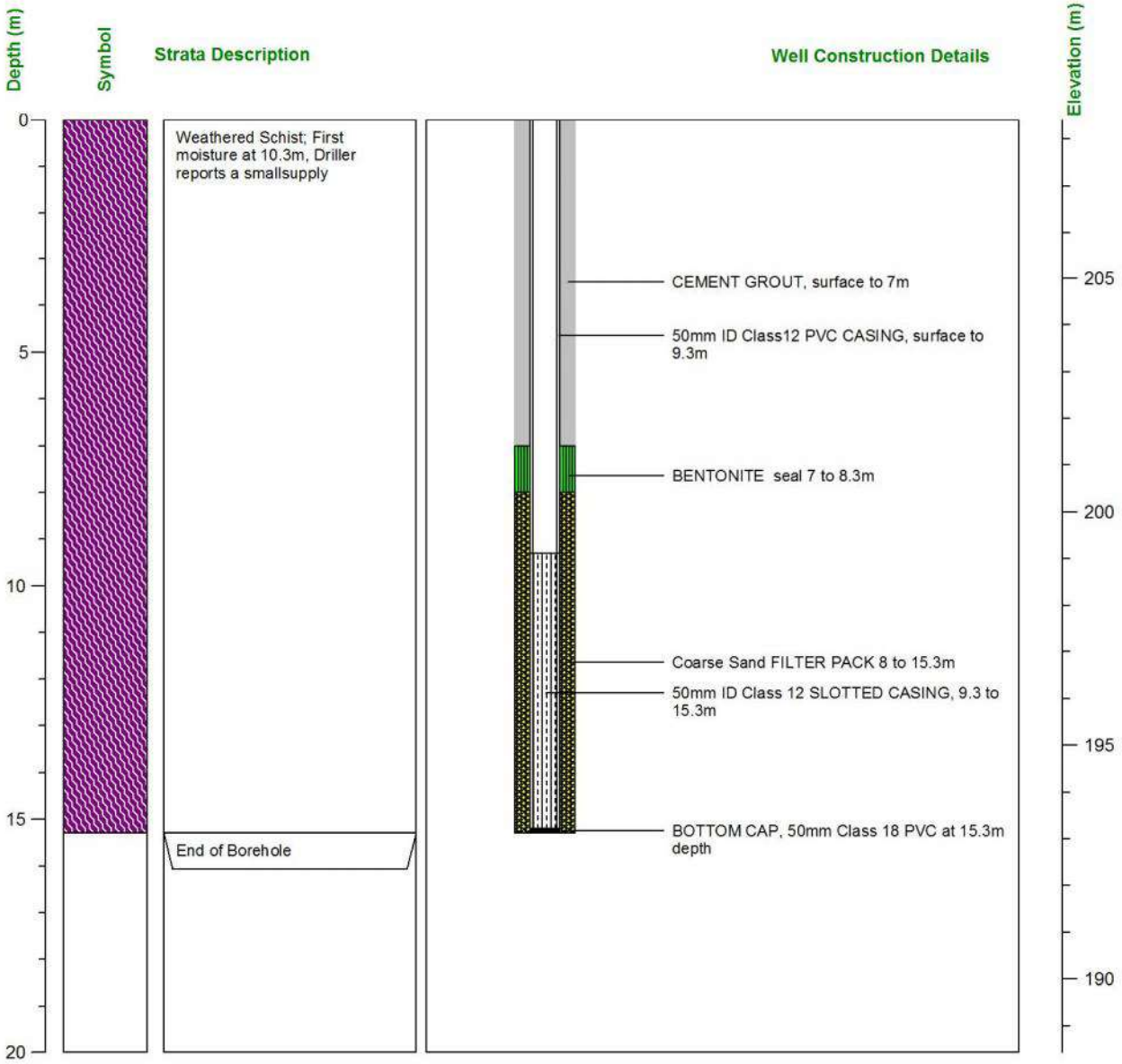
Shllow monitoring bore

Borehole No: **DRMB3-AB** **Client:** **MMG**

Location: Dugald River **Date Drilled:** **Nov.2012** **Project No:** 116

Easting: 411421 **Northing:** 7760107 **Elevation (m):** 208.416

Method: Rotary Air Blast **Driller:** Walker Drilling **Drilling Rig:**



Notes:

Datum:MGA94/AHD

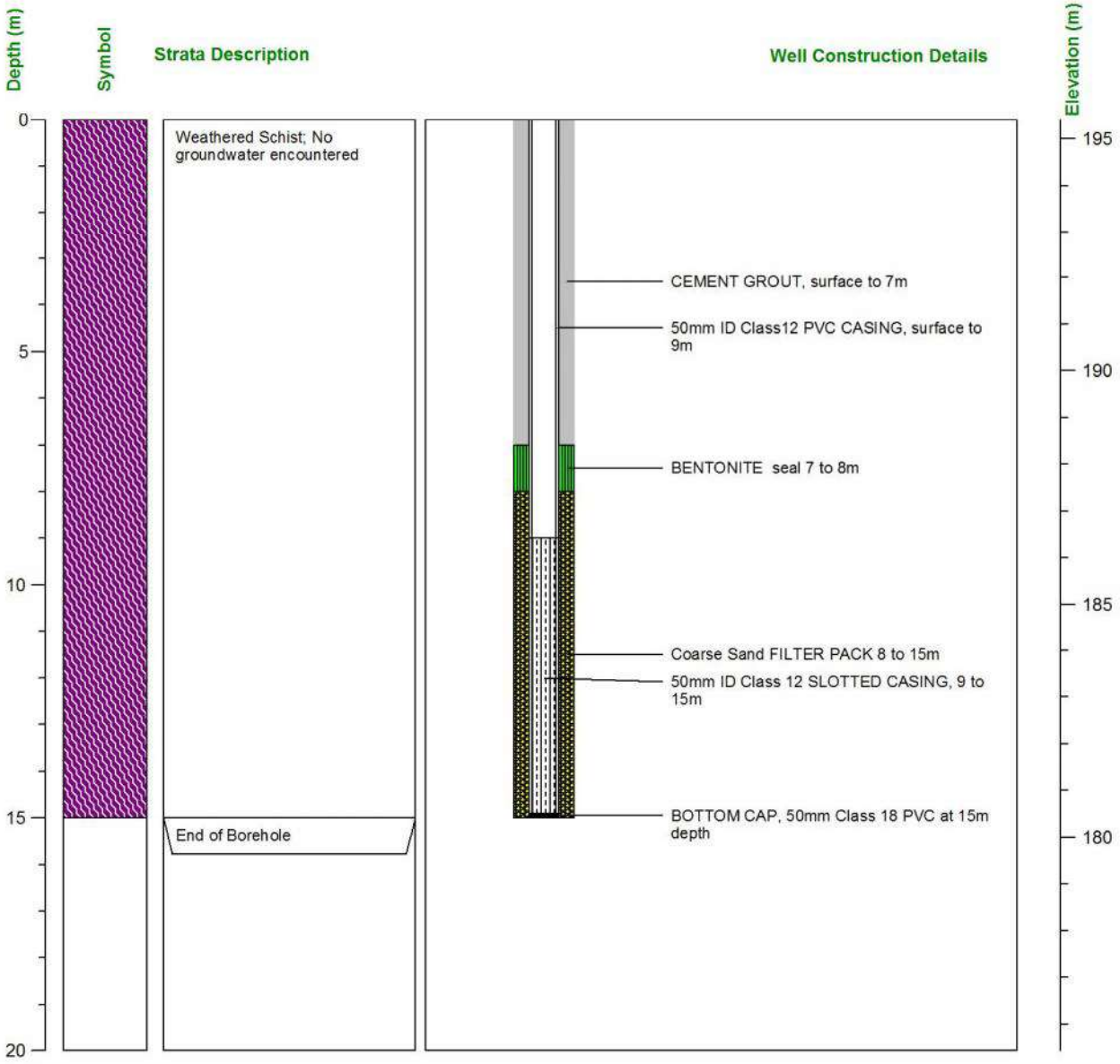
Shllow monitoring bore

Borehole No: **DRMB4-AB** **Client:** **MMG**

Location: Dugald River **Date Drilled:** **Nov.2012** **Project No:** 116

Easting: 412743 **Northing:** 7760042 **Elevation (m):** 195.413

Method: Rotary Air Blast **Driller:** Walker Drilling **Drilling Rig:**



Notes:

Datum:MGA94/AHD

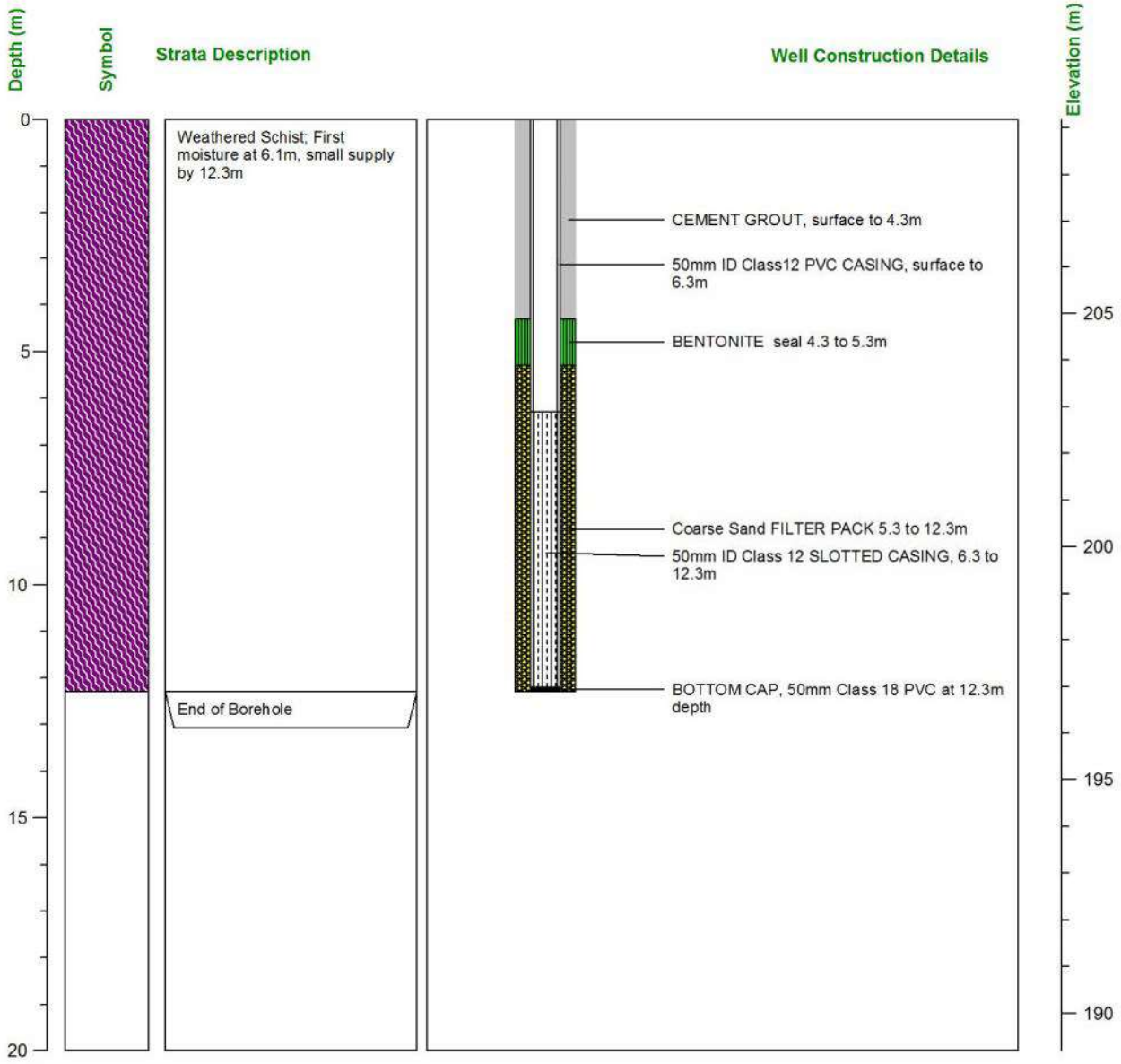
Shllow monitoring bore

Borehole No: **GWBF-AB** **Client:** **MMG**

Location: Dugald River **Date Drilled:** **Nov.2012** **Project No:** 116

Easting: 411394 **Northing:** 7761383 **Elevation (m):** 209.182

Method: Rotary Air Blast **Driller:** Walker Drilling **Drilling Rig:**



Notes:

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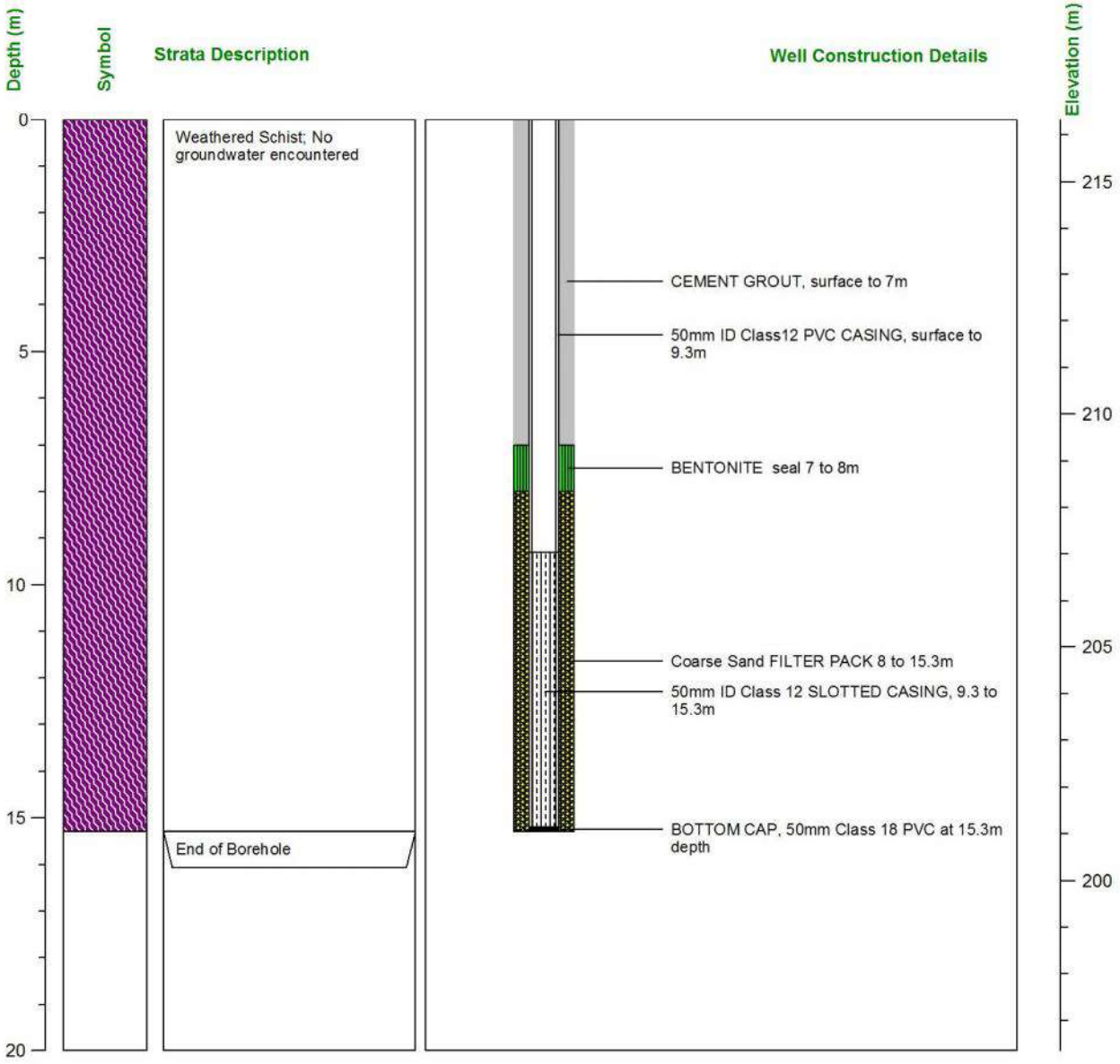
Shllow monitoring bore

Borehole No: **SHALL6-AB** **Client:** **MMG**

Location: Dugald River **Date Drilled:** **Nov.2012** **Project No:** 116

Easting: 410983 **Northing:** 7760929 **Elevation (m):** 216.34

Method: Rotary Air Blast **Driller:** Walker Drilling **Drilling Rig:**

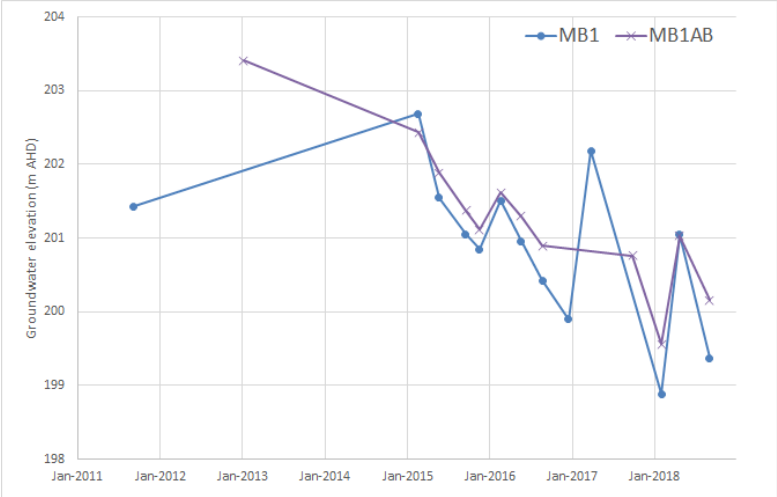
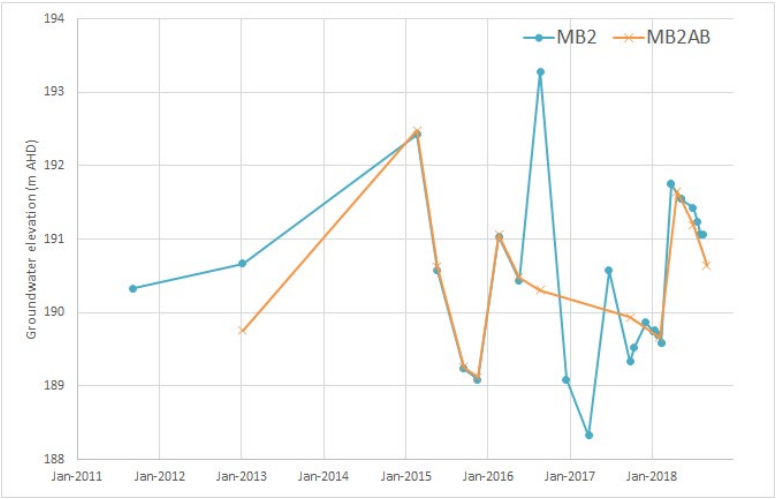
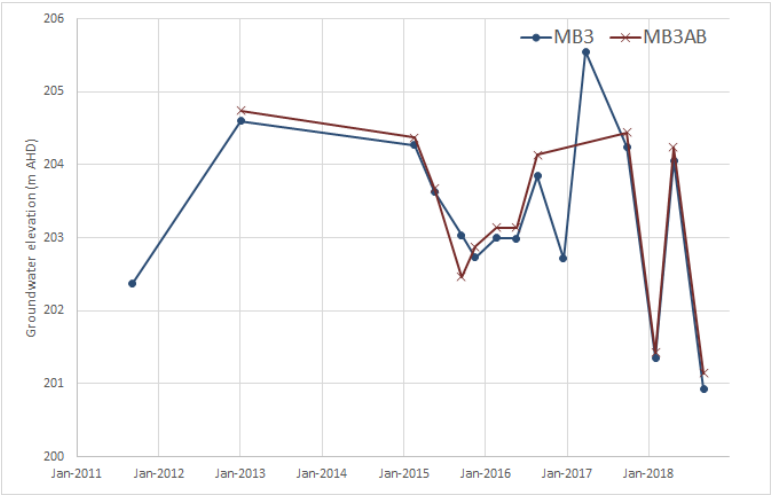


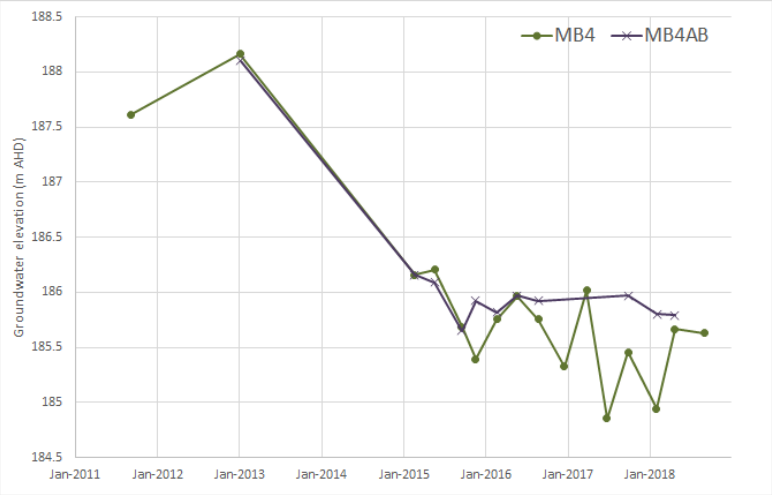
Notes:

Datum:MGA94/AHD

Shllow monitoring bore

Appendix B Paired Bores Hydrographs

Bore pair	Hydrograph
MB1 (11 to 99 m screen) MB1AB (9.7 to 15.7 m screen) Bore log for MB1: 0 to 4 m gravel and sand 5 to 7 m SCHIST, weathered 7 to 11 m SCHIST, with occasional small fractures 11 to 100 m SCHIST, hard with seams of quartz Groundwater inflow: 11 m	
MB2 (21 to 99 m screen) MB2AB (9.2 to 15.2 m screen) Bore log for MB2: 0 to 1 m sandy gravelly clay 1 to 22 m SCHIST, weathered, clayey 22 to 100 m SCHIST, hard, small fractures, quartz seams Groundwater inflow: 15 to 20 m	
MB3 (11 to 99 m screen) MB3AB (9.3 to 15.3 m screen) Bore log for MB3: 0 to 1 m sandy gravelly clay 1 to 12 m SCHIST, weathered 12 to 15 m SCHIST, hard, fractured 15 to 60 m SCHIST, hard and soft intervals, small fractures, quartz seams 60 to 100 m SCHIST, hard Groundwater inflow: 7 to 60 m	

Bore pair	Hydrograph
MB4 (46 to 99 m screen) MB4AB (9 to 15 m screen) Bore log for MB4: 0 to 1 m sandy gravel 1 to 10 m SCHIST, clayey 10 to 46 m SCHIST, weathered 46 to 75 m SCHIST, hard and soft intervals, small fractures 75 to 100 m SCHIST, hard with small quartz seams Groundwater inflow: 46 to 70 m	

Appendix C Critical data quality review

C.1 Laboratory vs field measurements

Both pH and electrical conductivity (EC) are measured in the field and analysed at the laboratory, however, both data points are not available for every sample. For the available samples, these data have been plotted to assess the calibration of field meters. In general, it is thought that field measurements of these parameters is preferred, as changes in these parameters may occur during handling and transportation of the samples to the laboratory.

The plots show that for EC there is generally a good correlation between field measured and laboratory measured EC, although field measurements are generally slightly higher than laboratory measurements (the majority of laboratory measurements are 80 to 90% the field measurements). The individual sampling events appear to show linear trends, which may be due to temperature differences in the field samples. A general rule of thumb is that EC rises by 2% per 1 degrees C. Laboratory EC corresponds to a standard temperature of 25°C, whereas temperature at the site varies between 23 °C and 37.5 °C over the reporting period.

For pH there is a greater difference between laboratory and field measurements, with laboratory pH generally higher than field pH by anywhere from 0 to 2 pH units. There is a greater range of field pH (majority over 3 pH units) measurements than laboratory results (majority of results over 2 pH units). The 2018 Q1 results indicate either a faulty machine or error in recording, as almost all results recorded a pH of 7, despite the laboratory results ranging from 7.11 to 8.03.

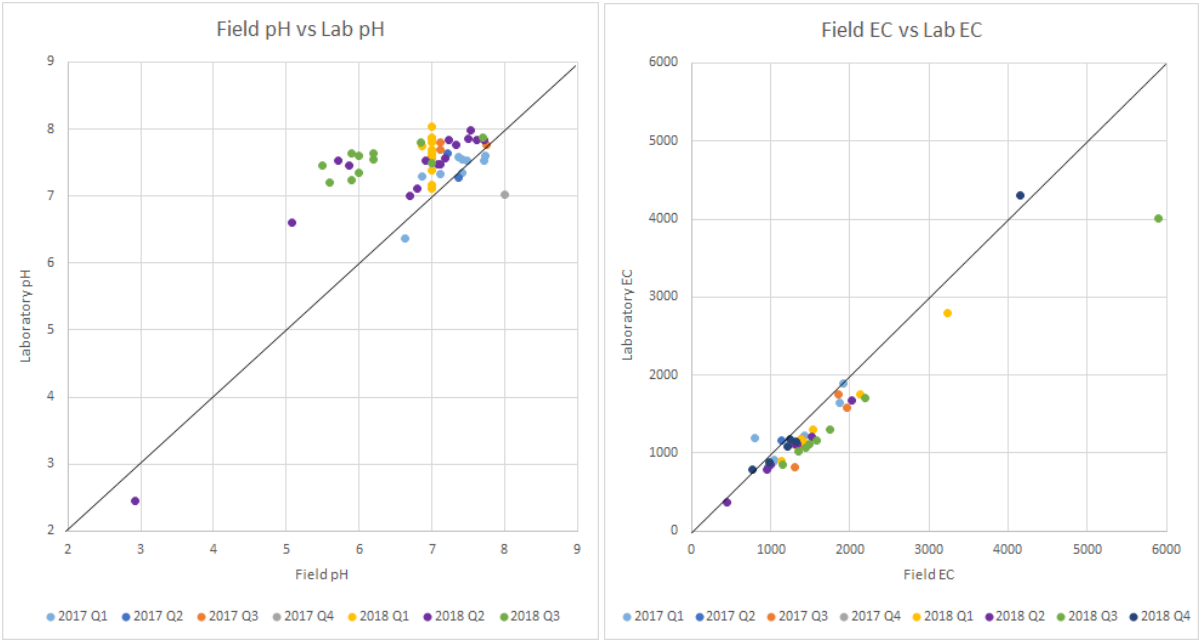


Figure 21 Field parameter measurements vs laboratory measurements (Left hand side is pH, right hand side is EC)

C.2 TDS vs EC

Salinity is measured as both electrical conductivity (EC) and total dissolved solids (TDS). EC is measured both in the field and laboratory. TDS is measured by evaporation in the laboratory. The relationship between EC and TDS in fresh to brackish water is generally linear.

TDS (mg/L) = EC (µS/cm) x k

Where k is constant of proportionality usually between 0.55 and 0.75.

Field and laboratory EC values have been compared to laboratory measured TDS values collected in the review period. For the overall data set (all compliance and background bores, with the exception of MB9S) the correlation is good

and indicates k values of 0.58 for field fata and 0.68 for laboratory data. These k values are similar to those reported in the groundwater quality review previously conducted by CDM Smith (2018).

The k values vary bore to bore and sample event to sample event. The variation between bores and between sampling events is greater in the field derived k values than the laboratory derived k values. This is likely to be due to the temperature variations in the field data, as described above. Given this, the laboratory measured EC values have been used to calculate the ratio to check whether samples fall within expected k values. For samples collected and analysed in the reporting period, the majority of TDS/EC ratios fall within the expected range for fresh water (0.55 to 0.75), with the exception of MB3 (September 2018; 0.80) and Saturday bore (March 2017; 0.50).

Table 6-1 TDS to EC ratios

Bore ID	Date	Field EC	Lab EC	TDS	Ratio TDS:lab EC
MB1	30/03/2017	1295	1140	635	0.56
MB1	29/09/2017	1360	1090	643	0.59
MB1	5/02/2018	1325	1100	640	0.58
MB1	27/04/2018	949	794	456	0.57
MB1	8/09/2018	1445	1070	634	0.59
MB1	23/11/2018	1214	1090	620	0.57
MB2	30/03/2017	1351	1150	646	0.56
MB2	26/06/2017	1141	1170	723	0.62
MB2	29/09/2017	1310	1120	680	0.61
MB2	17/10/2017	1210	1120	617	0.55
MB2	8/12/2017	1401	1190	764	0.64
MB2	10/01/2018	1356	1150	651	0.57
MB2	18/01/2018	1344	1180	732	0.62
MB2	3/02/2018	1343	1150	636	0.55
MB2	3/02/2018	1345	1150	792	0.69
MB2	15/02/2018	1403	1140	702	0.62
MB2	31/03/2018	921	1010	748	0.74
MB2	15/05/2018	1258	1050	608	0.58
MB2	8/09/2018	1343	1030	686	0.67
MB2	22/11/2018	-	1030	630	0.61
MB3	30/03/2017	1870	1640	1030	0.63
MB3	29/09/2017	1963	1590	1080	0.68
MB3	6/02/2018	3237	2790	2000	0.72
MB3	28/04/2018	2018	1680	1080	0.64
MB3	9/09/2018	5905	4010	3220	0.80
MB3	22/11/2018	4146	4300	3220	0.75
MB4	30/03/2017	1037	907	516	0.57
MB4	26/06/2017	968	816	538	0.66
MB4	29/09/2017	1310	822	559	0.68

Bore ID	Date	Field EC	Lab EC	TDS	Ratio TDS:lab EC
MB4	4/02/2018	1535	1310	801	0.61
MB4	27/04/2018	1001	855	518	0.61
MB4	8/09/2018	1751	1310	810	0.62
MB4	23/11/2018	978	879	508	0.58
MB5	30/03/2017	1426	1220	687	0.56
MB5	28/04/2018	1335	1110	632	0.57
MB5	6/09/2018	1585	1160	676	0.58
MB5	24/11/2018	1243	1180	682	0.58
MB6	30/03/2017	1026	889	509	0.57
MB6	16/02/2018	1128	895	496	0.55
MB6	28/04/2018	438.3	365	204	0.56
MB6	7/09/2018	1155	855	526	0.62
MB6	24/11/2018	762	786	444	0.56
MB6	9/03/2019	-	806	454	0.56
MB9D	30/03/2017	791	1200	660	0.55
MB9D	6/02/2018	1378	1180	670	0.57
MB9D	26/04/2018	1309	1110	614	0.55
MB9D	6/09/2018	1491	1120	660	0.59
MB9D	24/11/2018	1319	1140	646	0.57
MB9D	9/03/2019	-	1130	662	0.59
Saturday Bore	31/03/2017	1911	1900	943	0.50
Saturday Bore	29/09/2017	1854	1750	1110	0.63
Saturday Bore	8/02/2018	2128	1750	1040	0.59
Saturday Bore	24/04/2018	1516	1210	734	0.61
Saturday Bore	8/09/2018	2193	1700	1020	0.60
Saturday Bore	9/09/2018	-	1680	1080	0.64
Saturday Bore	22/11/2018	-	1760	1070	0.61

C.3 Ionic balances and TDS ratios

The ionic balances for samples collected during this reporting period are shown in Table 6-2. The data quality objective for ionic balance values if the sum of ions is greater than 10 meq/L is ±10% and ±5% for samples which have a sum of ions which is less than 10 meq/L. Positive ionic balances indicate anions have either been under-reported or omitted or major cations have been over-reported. A negative value indicates anions have been over-reported or cations have been under-reported or omitted.

Table 6-2 also shows the calculated TDS vs measured TDS (laboratory reported). TDS values were calculated according to the below formula (APHA, 2005):

$TDS\ (mg/L) = (0.6 \times total\ alkalinity\ as\ CaCO_3) + Na^+ + Mg^{2+} + K^+ + Ca^{2+} + SO_4^{-} + Cl^- + NO_3^- + Fl^- + SiO_3^{2-}$

(Note: results for NO^{3-}, SiO_3^{2-}, were not available).

The TDS measured by the laboratory is divided by the calculated TDS. A value greater than 1 indicates measured TDS is higher than the calculated TDS, and major ions have been under-reported or not analysed (or TDS has been over-reported). A value less than 1 indicates calculated TDS is higher than measured TDS and that major ions have been over-reported (or TDS under-reported). An acceptable range for this value is between 1 and 1.2. Whether it is anions or cations skewing the measured vs calculated TDS ratio can be indicated by the ionic balance value.

Most samples collected during the review period reported ionic balances and calculated vs measured TDS values within acceptable limits. Cells highlighted in grey indicate minor exceedances of these limits, which could be attributed to the effects of rounding or minor errors. The cells highlighted in blue indicate major exceedances which are more likely to be due to laboratory error or transcription error. Major exceedances were reported at MB2 in 2017 and MB3 throughout 2018, as well as all samples from MB9S and MB11.

For the major exceedances at MB2 and MB3 the analysis indicates an under-reporting of anions whereas the exceedances at MB9S and MB11 indicate an underreporting or omission of cations. For the MB2 and MB11 analyses, alkalinity was not analysed. For the MB9S and MB11 analyses, the laboratory reporting of EC and TDS appears to be in error, with the TDS the same as or higher than the reported EC.

At MB3 the continued exceedances appear to coincide with increases in TDS and increases in concentration of all major cations, sulfate and chloride. Fluoride and alkalinity have decreased over this period and pH has remained stable and neutral. It could be that an omitted anion, such as silicate or nitrate, has become important at this bore. However, the concentration of this untested anion would have to be very high to balance out the charge balance error. Alternatively, sampling procedures at this bore or inundation of silt could be responsible.

Table 6-2 Ionic balances and TDS ratios for monitoring wells at the Site

Bore ID	Date	Ionic balance (%)	Measured TDS / Calculated TDS	Comment
MB2	30/03/2017	0.58	0.99	Cations overreported
MB2	26/06/2017	-9.25	1.00	
MB2	29/09/2017	-1.20	1.03	
MB2	17/10/2017	43.12	1.33	Anions underreported or omitted (alkalinity not analysed)
MB2	8/12/2017	41.17	1.74	Anions underreported or omitted (alkalinity not analysed)
MB2	10/01/2018	0.94	0.96	Cations overreported
MB2	18/01/2018	-0.35	1.05	
MB2	3/02/2018	0.93	0.97	Cations overreported
MB2	3/02/2018	3.90	1.17	
MB2	15/02/2018	-1.70	1.07	
MB2	31/03/2018	0.49	1.16	
MB2	15/05/2018	4.18	1.01	
MB2	8/09/2018	6.42	1.04	
MB2	22/11/2018	-2.47	1.06	
MB4	30/03/2017	-0.04	1.02	
MB4	26/06/2017	-5.08	1.08	
MB4	29/09/2017	-2.37	1.20	Cations underreported or omitted
MB4	4/02/2018	2.72	1.05	
MB4	27/04/2018	-1.97	0.98	Anions overreported
MB4	8/09/2018	6.54	0.98	Cations overreported
MB4	23/11/2018	0.34	1.09	
MB1	30/03/2017	0.24	1.02	
MB1	29/09/2017	-2.78	1.04	
MB1	5/02/2018	3.77	1.04	
MB1	27/04/2018	0.66	0.98	Cations overreported
MB1	8/09/2018	5.25	1.00	

Bore ID	Date	Ionic balance (%)	Measured TDS / Calculated TDS	Comment
MB1	23/11/2018	-6.41	1.02	
MB3	30/03/2017	6.51	1.20	Anions underreported or omitted
MB3	29/09/2017	6.74	1.29	Anions underreported or omitted
MB3	6/02/2018	20.38	1.52	Anions underreported or omitted
MB3	28/04/2018	10.57	1.20	Anions underreported or omitted
MB3	9/09/2018	31.63	1.85	Anions underreported or omitted TDS is higher than expected compared to EC
MB3	22/11/2018	26.99	1.76	Anions underreported or omitted
Saturday Bore	31/03/2017	-7.66	0.95	Anions overreported
Saturday Bore	29/09/2017	-3.69	1.07	
Saturday Bore	8/02/2018	0.24	0.99	Cations overreported
Saturday Bore	24/04/2018	-1.58	1.00	Anions overreported
Saturday Bore	8/09/2018	5.24	0.96	Cations overreported
Saturday Bore	9/09/2018	5.44	0.99	Cations overreported
Saturday Bore	22/11/2018	-6.10	1.09	
MB5	30/03/2017	-0.99	1.01	
MB5	28/04/2018	0.97	0.93	Cations overreported
MB5	6/09/2018	3.19	0.95	Cations overreported
MB5	24/11/2018	-0.70	1.05	
MB6	30/03/2017	1.34	1.07	
MB6	16/02/2018	-5.91	0.98	Anions overreported
MB6	28/04/2018	1.25	1.01	
MB6	7/09/2018	1.35	1.06	
MB6	24/11/2018	-3.65	1.07	
MB9D	30/03/2017	0.90	1.05	
MB9D	6/02/2018	3.72	1.05	
MB9D	26/04/2018	0.64	0.97	Cations overreported
MB9D	6/09/2018	1.04	1.03	
MB9D	24/11/2018	0.29	1.09	
MB9S	30/03/2017	-2.40	3.22	Cations underreported or omitted – TDS is very high compared to EC – suspect laboratory error
MB9S	26/04/2018	-1.41	1.88	Cations underreported or omitted – appear to be errors in laboratory TDS or EC reporting
GWBFAB	27/04/2018	-0.31	0.98	Anions overreported
MB10	28/04/2018	-0.78	0.97	Anions overreported
MB11	27/04/2018	-2.29	2.11	Cations underreported or omitted – TDS is very high compared to EC – suspect laboratory error
MB1AB	29/09/2017	-2.89	1.07	
MB1AB	6/02/2018	1.79	1.08	
MB1AB	27/04/2018	0.50	0.95	Cations overreported
MB1AB	7/09/2018	4.03	1.00	
MB2AB	29/09/2017	-0.81	1.07	
MB2AB	8/02/2018	1.91	1.14	
MB2AB	27/04/2018	0.93	1.00	
MB2AB	8/09/2018	6.63	1.03	
MB3AB	29/09/2017	6.72	1.31	Anions underreported or omitted
MB3AB	6/02/2018	7.07	1.13	
MB3AB	26/04/2018	6.96	1.15	
MB3AB	9/09/2018	8.76	1.14	
MB4AB	29/09/2017	-3.24	1.05	
MB4AB	6/02/2018	-0.58	0.99	Anions overreported
MB4AB	26/04/2018	-1.10	0.96	Anions overreported
SHALL6AB	26/04/2018	2.78	0.92	Cations overreported

C.4 LOR vs guidelines/thresholds

Table 6-4 shows the analytes included in the EA alongside the EA trigger and contaminant levels and national guideline values for the various uses shown in Table 2-2. The laboratory level of reporting (LOR) values for each analyte are also shown.

The LORs for the parameters listed in the table are all below the relevant guidelines, which allows for comparison of detectable concentrations. However, some of the LORs are only marginally below the guidelines (cadmium, copper, lead and zinc). For these parameters, a detection above the LOR will exceed the guidelines (i.e. where LOR is 0.001 mg/L and guideline is 0.0014 mg/L, a detect at 0.002 mg/L would be an exceedance). This increases the risk of false exceedances for these guidelines and prevents the application of statistical analysis at the lower end of the concentration range.

Table 6-4 also shows the national guideline values for various beneficial uses. As can be seen, the EA trigger limits are predominately based upon protection of ecosystems. For metals, the soft water trigger values have been used in the EA. However, groundwater at the Site is classified as hard to very hard (median hardness of 420 mg/L CaCO3). It would therefore be more appropriate to use the hardness modified trigger values (HMTV), as per ANZECC/ARMCANZ (2000) Table 3.4.2. These are roughly an order of magnitude higher than the soft water guidelines and have been used in the reporting by BDH and Golder. The HMTVs are well above the LORs, and therefore there is no need to request ultra-trace analysis from the laboratory.

C.5 Total metal concentrations vs filtered concentrations

Samples collected during the review period were analysed for total and filterable metals (filtered on site through 0.45 um filter paper). Theoretically, reported filterable metal concentrations should be less than or equal to total concentrations, as filtered metals are a component of total metals. If filterable metal concentrations exceed total metal concentrations, a laboratory error during analysis or reporting may have occurred.

Filterable metal concentrations were generally less than total metal concentrations for samples collected during the review period (96% of comparisons). Table 6-3 provides a summary of filterable metal concentrations which exceed total concentrations (24 instances). Exceedances were generally minor with filtered metal concentrations two to three times higher (at this level of reporting this is a single unit higher) than total metal concentrations. However, three results have the potential to impact the interpretation of the data:

- One filterable lead concentration reported at MB2 in Q4 2017 exceeds the EA trigger limit, with the total lead concentration reported as less than the LOR
- Two filterable zinc concentration reported at MB2 in Q4 2017 and Q2 2018 exceeds the EA trigger limit, with the total zinc concentration reported as less than the trigger limit

If the HMTVs are used to assess the data, the trigger levels are not exceeded by the total metal concentrations. All discrepancies could be attributed to a lab error or cross contamination during analysis. However, as the errors were not identified at the time of sample receipt, potentially erroneous data outlined above cannot be removed from the dataset.

Table 6-3 Total metal concentrations compared to filtered concentrations

Bore ID	Sampled Date	Metal	Total Concentration	Filtered Concentration
MB1	5/02/2018	Nickel	0.003	0.004
MB2	26/06/2017	Zinc	0.005	0.007
MB2	29/09/2017	Zinc	0.009	0.01
MB2	17/10/2017	Lead	<0.001	0.011
MB2	8/12/2017	Arsenic	<0.001	0.002
MB2	8/12/2017	Zinc	0.006	0.009

Bore ID	Sampled Date	Metal	Total Concentration	Filtered Concentration
MB2	8/12/2017	Aluminium	0.01	0.02
MB2	3/02/2018	Manganese	0.03	0.031
MB2	8/09/2018	Manganese	0.04	0.042
MB2	22/11/2018	Manganese	0.088	0.101
MB2	3/02/2018	Nickel	<0.001	0.003
MB2	3/02/2018	Nickel	<0.001	0.003
MB2	15/05/2018	Zinc	0.007	0.018
MB3	6/02/2018	Nickel	<0.001	0.003
MB4	4/02/2018	Nickel	<0.001	0.003
MB5	6/09/2018	Manganese	0.638	0.665
MB6	24/11/2018	Manganese	0.481	0.549
MB9D	6/02/2018	Nickel	<0.001	0.003
Saturday Bore	9/09/2018	Arsenic	0.001	0.002
Saturday Bore	9/09/2018	Iron	0.16	0.17
Saturday Bore	8/09/2018	Manganese	1.13	1.25
Saturday Bore	22/11/2018	Manganese	0.877	0.96
Saturday Bore	9/09/2018	Manganese	1.09	1.27
Saturday Bore	29/09/2017	Nickel	<0.001	0.006

C.6 Duplicate and field blank samples

Intra laboratory duplicates are used to test the repeatability of sampling and analysis (the precision of the laboratory). Duplicate results are compared with Primary Sample results using Relative Percentage Differences (RPDs). RPDs are calculated using the following formula:

$$\%RPD = \left|\frac{A-B}{A+B}\right| \times 200$$

Where: A is the concentration of the primary laboratory result per analyte; and

B is the corresponding duplicate result.

A low RPD indicates low variability between the samples. In calculating RPD values, the following protocols have been adopted:

- Where both samples have reported levels below the detection limit an RPD of '0' has been assumed.
- Where one sample has reported below a reporting limit and the other has identified reported above the LOR, an RPD has been calculated. This has been achieved by using the LOR for the unreported sample and comparing that to the concentration of the reported sample.
- Where both samples report concentrations above the analyte LOR, an RPD has been calculated.
- Acceptably precise results are indicated by an RPD of less than +/-20%, although higher RPDs can be acceptable where the results are close to the LOR.

Based on data provided by MMG, one field duplicate sample was submitted for analysis during the 2017/2018 quarterly monitoring period (duplicate of Saturday bore sampled on 8 September 2018). This sample was analysed by the primary laboratory (ALS) and is therefore a, intra-laboratory duplicate. The reported RPD between the primary sample and the duplicate were generally with the acceptable range (+/-20%), except for filtered and total arsenic (each with an RPD of 67%). For the arsenic results, the reported concentrations were only marginally above the LOR and were therefore only minor exceedances of the data quality objectives.

Field blanks can assist in identifying if cross contamination has been introduced during the groundwater sampling process and are collected by filtering and bottling deionised water (provided by the laboratory) in the field. One field blank was collected during the review period on 9 September 2018. All analytes were within acceptable ranges. Tabulated data from duplicate and field blank samples are provided in Appendix F.

Table 6-4 Parameter LORs compared to EA trigger limits and national water quality guidelines

Parameter	Unit	LOR	EA Schedule C – Table 8		National guideline values (see text below for references and notes)			
			Trigger level	Contaminant limit	Drinking water	Protection of ecosystems	Stock watering	Irrigation
pH	pH unit	0.01	6 to 8	6 to 9	6.5 to 8.5	6 to 8	-	6 to 8.5
EC	µS/cm	1	1500	2000	-	250	-	4000 (cotton)
Hardness (CaCO3)	mg/L	1	Collected for interpretation purposes – no trigger or contaminant limits set		200 (A)	-	-	60 (corrosion trigger)
TDS	mg/L	10			600 (A)	-	4000 (beef cattle)	-
Major ions (Na, Ca, K, Mg, Cl, HCO3, total alkalinity (CaCO3)	mg/L	1			Cl: 250 (A) Na: 180 (A)	-	Ca: 1000	Cl: 175 Na: 115 (sensitive crops)
Sulfate	mg/L	1	150	1000	500 (H), 250 (A)	-	1000	-
Fluoride	mg/L	0.1	-	2	1.5 (H)	-	2	1 (LTV), 2 (STV)
Aluminium	mg/L	0.01	0.055	5	0.2 (A)	0.055	5	5 (LTV), 20 (STV)
Arsenic	mg/L	0.001	0.013	0.5	0.01 (H)	0.013 (As V) 0.024 (AS III)	0.5	0.1 (LTV), 2 (STV)
Cadmium	mg/L	0.0001	0.0002	0.01	0.002 (H)	0.0002 **[HMTV: 0.002]**	0.01	0.01 (LTV), 0.05 (STV)
Copper	mg/L	0.001	0.0014	1	2 (H), 1 (A)	0.0014 **[HMTV: 0.013]**	1 (cattle)	0.2 (LTV), 5 (STV)
Cyanide	mg/L	Not monitored	0.007	0.022	0.08 (H)	0.007	-	
Lead	mg/L	0.001	0.0034	0.1	0.01 (H)	0.0034 **[HMTV: 0.091]**	0.1	2 (LTV), 5 (STV)
Manganese	mg/L	0.001	1.9	-	0.5 (H), 0.1 (A)	1.9	-	0.2 (LTV), 10 (STV)
Nickel	mg/L	0.001	0.011	1	0.02 (H)	0.011 **[HMTV: 0.099]**	1	0.2 (LTV), 2 (STV)
Zinc	mg/L	0.005	0.008	20	3 (A)	0.008 **[HMTV: 0.072]**	20	2 (LTV), 5 (STV)

Based on ANZECC/ ARMCANZ (2000) Table 3.4.1 (high reliability trigger values) and Section 8.3 moderate or low reliability trigger values if no value available in Table 3.4.1

Based on ANZECC/ARMCANZ (2000) Table 4.3.2 for livestock drinking water

Based on ANZECC/ARMCANZ (2000) Section 4.3.3.4

MMG Dugald River site specific value

Based on International Cyanide Management Institute (2009) Implementation Guidance – Standard of Practice 4.5-receiving surface waterbody guideline value

Guidelines:

- *Drinking water – Australian Drinking Water guidelines 6 (2011) National Water Quality Management Strategy. H = health related guideline, A = aesthetic related guideline (e.g. taste or corrosion properties)*
- *Protection of ecosystems – Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000) National Water Quality Management Strategy, ANZECC and ARMCANZ. Chapter 3 Aquatic Ecosystems. HMTVs **[in bold]** are calculated as follows (ANZECC/ARMCANZ, 2000, Table 3.4.3)*

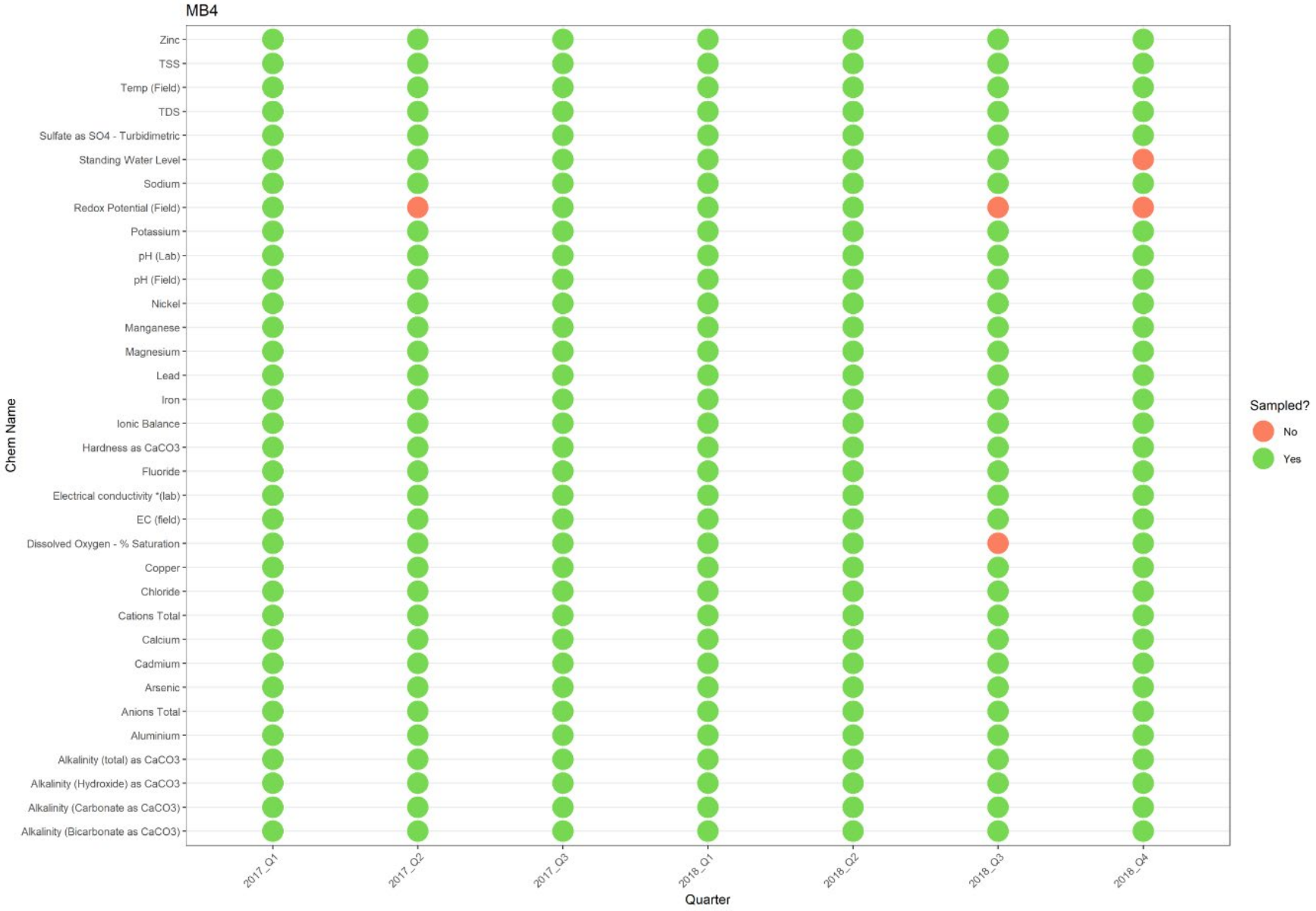
Metal	*Soft water trigger value (from Table 3.4.1 ANZECC/ARMCANZ, 2000) (TV)*	*Hardness dependant algorithm (from Table 3.4.2 ANZECC/ARMCANZ, 2000)*	*Hardness (median site wide value) (mg/L CaCO3)*	*Hardness modified trigger value (HMTV)*
Cadmium	*0.0002*	$HMTV = TV\ (H/30)^{0.89}$	*420*	*0.002*
Copper	*0.0014*	$HMTV = TV\ (H/30)^{0.85}$		*0.013*
Lead	*0.0034*	$HMTV = TV\ (H/30)^{1.27}$		*0.091*
Nickel	*0.011*	$HMTV = TV\ (H/30)^{0.85}$		*0.099*
Zinc	*0.008*	$HMTV = TV\ (H/30)^{0.85}$		*0.072*

Appendix D Chemical Sampling Frequency of Individual Bores

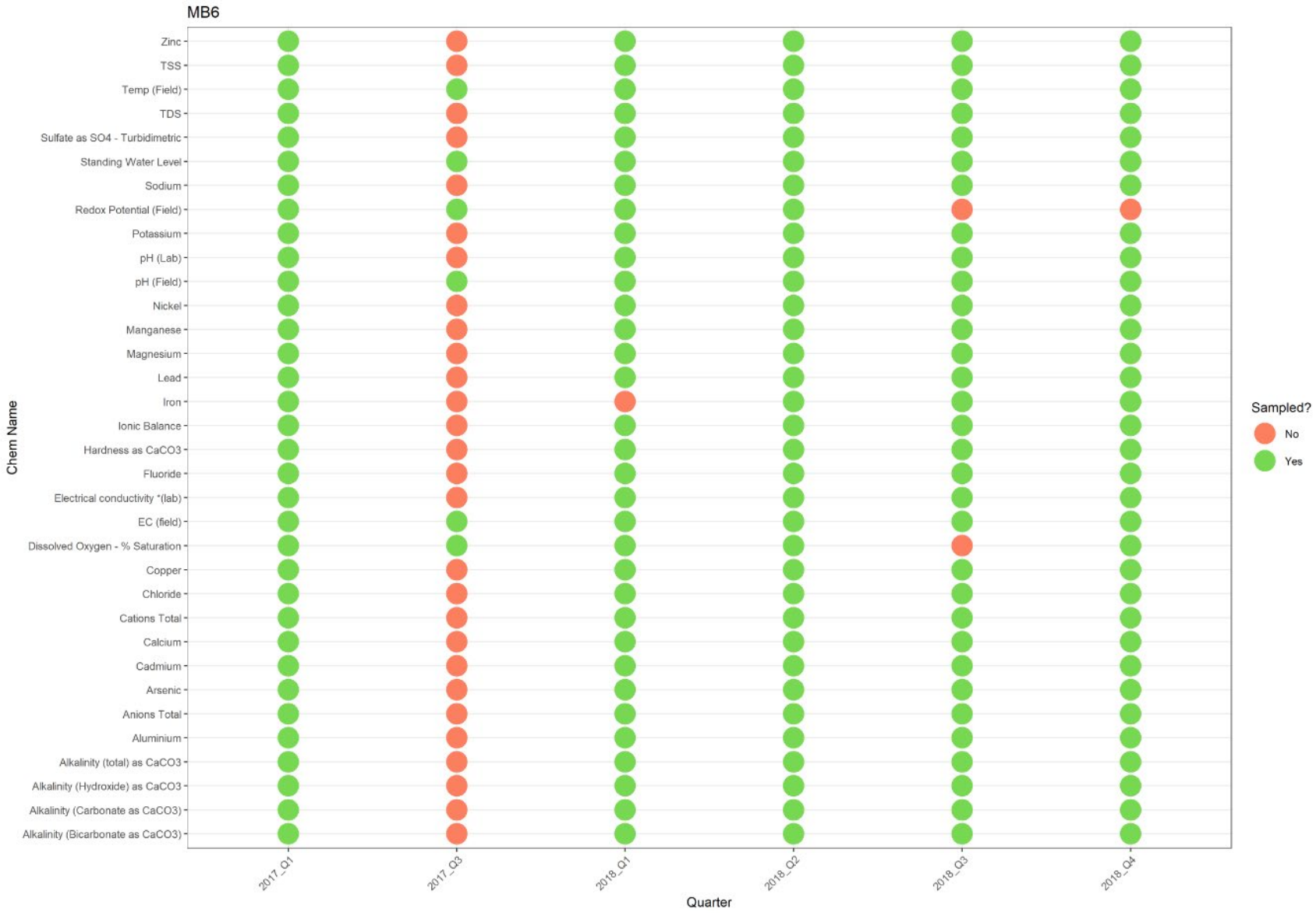

MB1
Zinc
TSS
Temp (Field)
TDS
Sulfate as SO4 - Turbidimetric
Standing Water Level
Sodium
Redox Potential (Field)
Potassium
pH (Lab)
pH (Field)
Nickel
Manganese
Magnesium
Lead
Iron
Ionic Balance
Hardness as CaCO3
Fluoride
Electrical conductivity *(lab)
EC (field)
Dissolved Oxygen - % Saturation
Copper
Chloride
Cations Total
Calcium
Cadmium
Arsenic
Anions Total
Aluminium
Alkalinity (total) as CaCO3
Alkalinity (Hydroxide) as CaCO3
Alkalinity (Carbonate as CaCO3)
Alkalinity (Bicarbonate as CaCO3)
Chem Name
2017_Q1
2017_Q3
2018_Q1
2018_Q2
2018_Q3
2018_Q4
Quarter
Sampled?
No
Yes

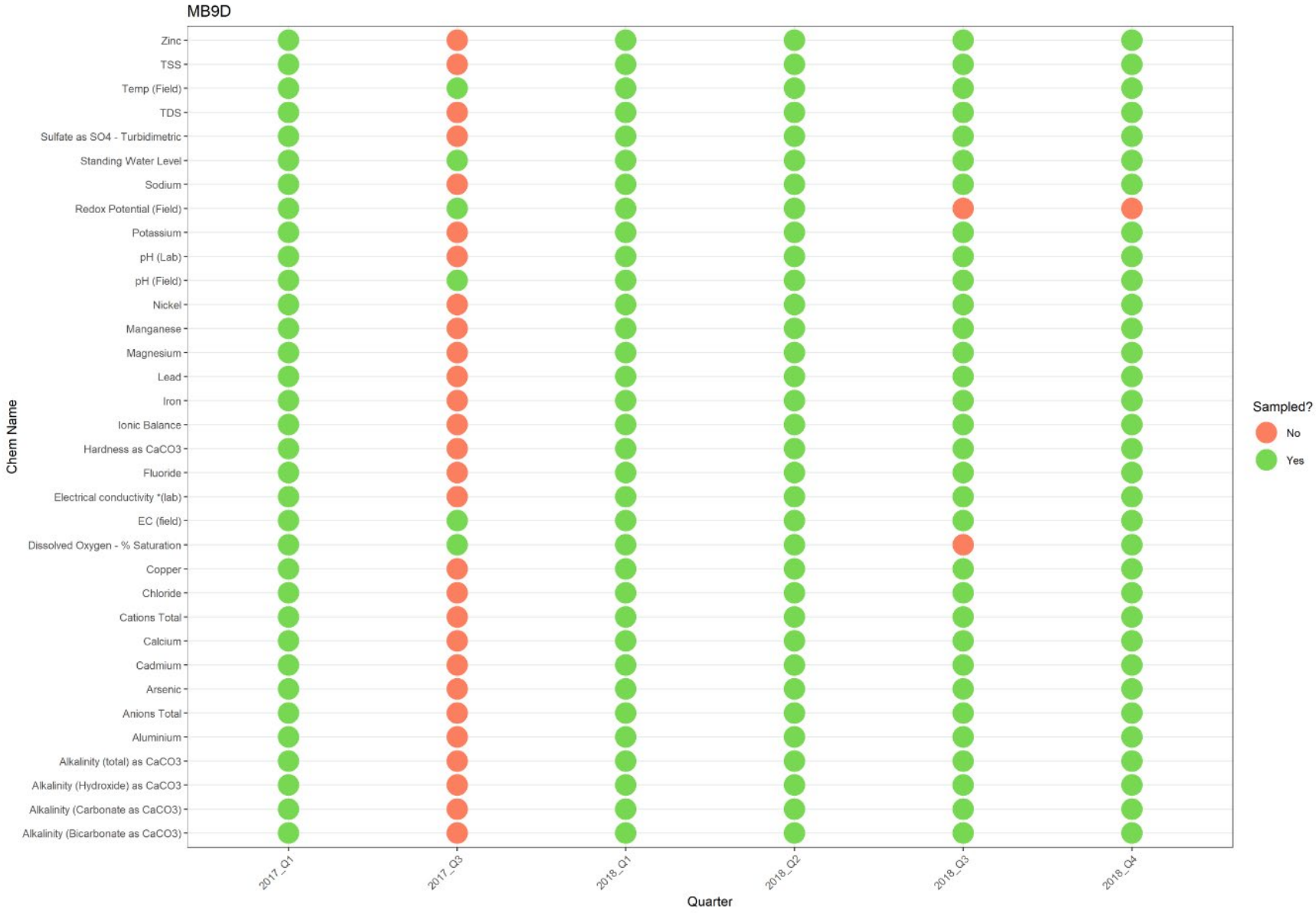

MB2
Zinc
TSS
Temp (Field)
TDS
Sulfate as SO4 - Turbidimetric
Standing Water Level
Sodium
Redox Potential (Field)
Potassium
pH (Lab)
pH (Field)
Nickel
Manganese
Magnesium
Lead
Iron
Ionic Balance
Hardness as CaCO3
Fluoride
Electrical conductivity *(lab)
EC (field)
Dissolved Oxygen - % Saturation
Copper
Chloride
Cations Total
Calcium
Cadmium
Arsenic
Anions Total
Aluminium
Alkalinity (total) as CaCO3
Alkalinity (Hydroxide) as CaCO3
Alkalinity (Carbonate as CaCO3)
Alkalinity (Bicarbonate as CaCO3)
Chem Name
2017_Q1
2017_Q2
2017_Q3
2017_Q4
2018_Q1
2018_Q2
2018_Q3
2018_Q4
Quarter
Sampled?
No
Yes

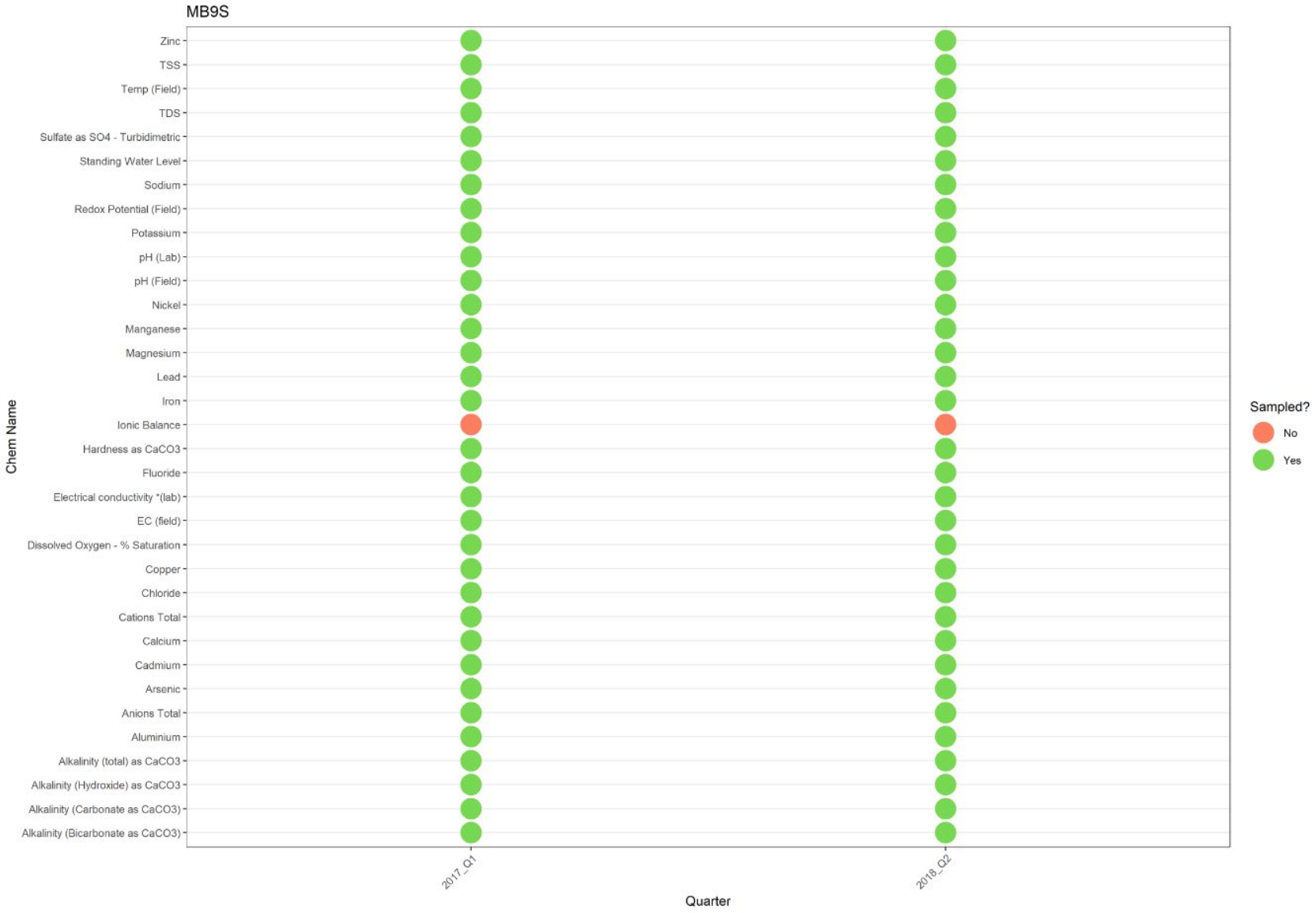

MB3
Zinc
TSS
Temp (Field)
TDS
Sulfate as SO4 - Turbidimetric
Standing Water Level
Sodium
Redox Potential (Field)
Potassium
pH (Lab)
pH (Field)
Nickel
Manganese
Magnesium
Lead
Iron
Ionic Balance
Hardness as CaCO3
Fluoride
Electrical conductivity *(lab)
EC (field)
Dissolved Oxygen - % Saturation
Copper
Chloride
Cations Total
Calcium
Cadmium
Arsenic
Anions Total
Aluminium
Alkalinity (total) as CaCO3
Alkalinity (Hydroxide) as CaCO3
Alkalinity (Carbonate as CaCO3)
Alkalinity (Bicarbonate as CaCO3)
Chem Name
2017_Q1
2017_Q3
2018_Q1
2018_Q2
2018_Q3
2018_Q4
Quarter
Sampled?
No
Yes


MB4
Zinc
TSS
Temp (Field)
TDS
Sulfate as SO4 - Turbidimetric
Standing Water Level
Sodium
Redox Potential (Field)
Potassium
pH (Lab)
pH (Field)
Nickel
Manganese
Magnesium
Lead
Iron
Ionic Balance
Hardness as CaCO3
Fluoride
Electrical conductivity *(lab)
EC (field)
Dissolved Oxygen - % Saturation
Copper
Chloride
Cations Total
Calcium
Cadmium
Arsenic
Anions Total
Aluminium
Alkalinity (total) as CaCO3
Alkalinity (Hydroxide) as CaCO3
Alkalinity (Carbonate as CaCO3)
Alkalinity (Bicarbonate as CaCO3)
Chem Name
2017_Q1
2017_Q2
2017_Q3
2018_Q1
2018_Q2
2018_Q3
2018_Q4
Quarter
Sampled?
No
Yes


MB5
Zinc
TSS
Temp (Field)
TDS
Sulfate as SO4 - Turbidimetric
Standing Water Level
Sodium
Redox Potential (Field)
Potassium
pH (Lab)
pH (Field)
Nickel
Manganese
Magnesium
Lead
Iron
Ionic Balance
Hardness as CaCO3
Fluoride
Electrical conductivity *(lab)
EC (field)
Dissolved Oxygen - % Saturation
Copper
Chloride
Cations Total
Calcium
Cadmium
Arsenic
Anions Total
Aluminium
Alkalinity (total) as CaCO3
Alkalinity (Hydroxide) as CaCO3
Alkalinity (Carbonate as CaCO3)
Alkalinity (Bicarbonate as CaCO3)
Chem Name
2017_Q1
2017_Q3
2018_Q1
2018_Q2
2018_Q3
2018_Q4
Quarter
Sampled?
No
Yes


MB6
Zinc
TSS
Temp (Field)
TDS
Sulfate as SO4 - Turbidimetric
Standing Water Level
Sodium
Redox Potential (Field)
Potassium
pH (Lab)
pH (Field)
Nickel
Manganese
Magnesium
Lead
Iron
Ionic Balance
Hardness as CaCO3
Fluoride
Electrical conductivity *(lab)
EC (field)
Dissolved Oxygen - % Saturation
Copper
Chloride
Cations Total
Calcium
Cadmium
Arsenic
Anions Total
Aluminium
Alkalinity (total) as CaCO3
Alkalinity (Hydroxide) as CaCO3
Alkalinity (Carbonate as CaCO3)
Alkalinity (Bicarbonate as CaCO3)
Chem Name
2017_Q1
2017_Q3
2018_Q1
2018_Q2
2018_Q3
2018_Q4
Quarter
Sampled?
No
Yes

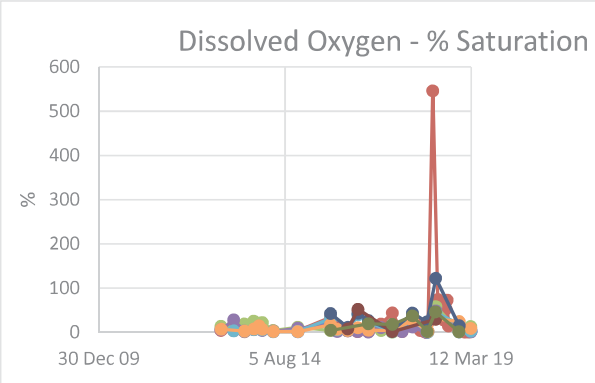

MB9D
Zinc
TSS
Temp (Field)
TDS
Sulfate as SO4 - Turbidimetric
Standing Water Level
Sodium
Redox Potential (Field)
Potassium
pH (Lab)
pH (Field)
Nickel
Manganese
Magnesium
Lead
Iron
Ionic Balance
Hardness as CaCO3
Fluoride
Electrical conductivity *(lab)
EC (field)
Dissolved Oxygen - % Saturation
Copper
Chloride
Cations Total
Calcium
Cadmium
Arsenic
Anions Total
Aluminium
Alkalinity (total) as CaCO3
Alkalinity (Hydroxide) as CaCO3
Alkalinity (Carbonate as CaCO3)
Alkalinity (Bicarbonate as CaCO3)
Chem Name
2017_Q1
2017_Q3
2018_Q1
2018_Q2
2018_Q3
2018_Q4
Quarter
Sampled?
No
Yes

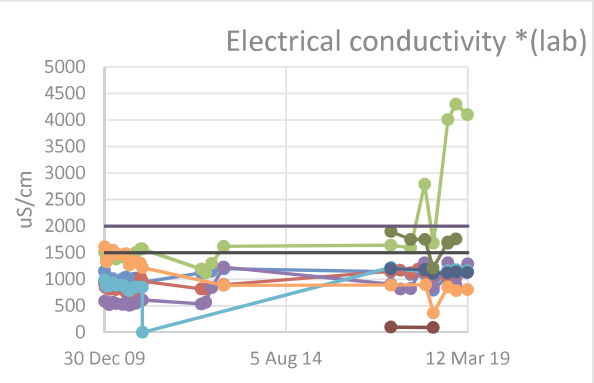

MB9S
Zinc
TSS
Temp (Field)
TDS
Sulfate as SO4 - Turbidimetric
Standing Water Level
Sodium
Redox Potential (Field)
Potassium
pH (Lab)
pH (Field)
Nickel
Manganese
Magnesium
Lead
Iron
Ionic Balance
Hardness as CaCO3
Fluoride
Electrical conductivity *(lab)
EC (field)
Dissolved Oxygen - % Saturation
Copper
Chloride
Cations Total
Calcium
Cadmium
Arsenic
Anions Total
Aluminium
Alkalinity (total) as CaCO3
Alkalinity (Hydroxide) as CaCO3
Alkalinity (Carbonate as CaCO3)
Alkalinity (Bicarbonate as CaCO3)
Chem Name
2017_Q1
2018_Q2
Quarter
Sampled?
No
Yes

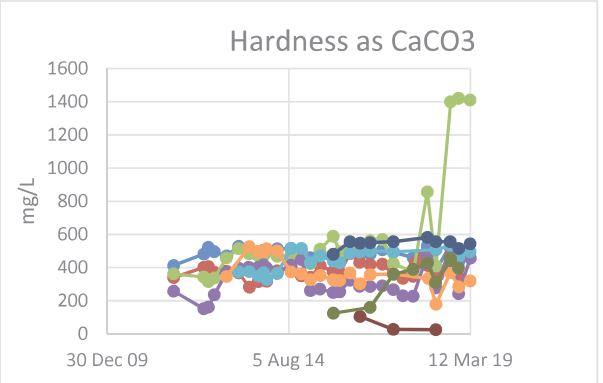
Appendix E Analytical Results (Total Concentrations)

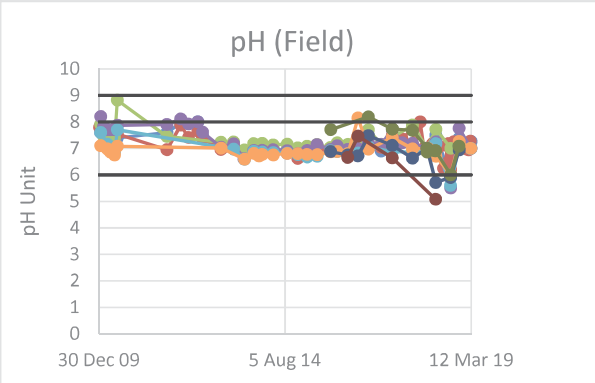
LocCode	WellCode	Sampled_Date-Time	Lab_Report_Number	Metals: Arsenic	Arsenic (Filtered)	Cadmium	Cadmium (Filtered)	Aluminium	Aluminium (Filtered)	Copper	Copper (Filtered)	Iron	Iron (Filtered)	Lead	Lead (Filtered)	Manganese	Manganese (Filtered)	Nickel	Nickel (Filtered)	Zinc	Zinc (Filtered)
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
EQL				0.001	0.001	0.0001	0.0001	0.01	0.01	0.001	0.001	0.05	0.05	0.001	0.001	0.001	0.001	0.001	0.001	0.005	0.005
ContamLimit-EA-MMG				0.5		0.01		5		1				0.1				1		20	
TriggerLevel-EA-MMG					0.013		0.0002		0.055		0.0014				0.0034		1.9		0.011		0.008
GWBFAB		27/04/2018	ET1801163	0.045	0.01	0.0076	0.003	1.58	<0.01	0.028	<0.001	5.27	0.2	0.617	0.008	0.239	0.197	0.006	0.001	4.49	1.31
MB1		30/03/2017	EB1706945	<0.001	<0.001	<0.0001	<0.0001	0.13	<0.01	0.002	<0.001	1.08	<0.05	0.006	<0.001	0.304	0.073	<0.001	<0.001	0.049	<0.005
MB1		29/09/2017	EB1720574	<0.001	<0.001	<0.0001	<0.0001	0.14	<0.01	0.037	<0.001	1.69	<0.05	<0.001	<0.001	0.128	0.047	<0.001	<0.001	0.011	<0.005
MB1		5/02/2018	EB1803858	<0.001	<0.001	<0.0001	<0.0001	0.1	<0.01	<0.001	<0.001	0.19	<0.05	<0.001	<0.001	0.035	0.028	0.003	0.004	0.05	<0.005
MB1		27/04/2018	ET1801163	0.001	0.001	<0.0001	<0.0001	0.07	<0.01	0.001	<0.001	0.17	<0.05	0.008	<0.001	0.068	0.045	<0.001	<0.001	0.061	0.038
MB1		8/09/2018	ET1802314	0.002	0.002	<0.0001	<0.0001	0.02	<0.01	<0.001	<0.001	0.1	<0.05	<0.001	<0.001	0.04	0.039	<0.001	<0.001	0.011	<0.005
MB1		23/11/2018	ET1803049	0.002	0.001	<0.0001	<0.0001	0.05	<0.01	0.001	<0.001	0.36	<0.05	0.007	<0.001	0.076	0.041	<0.001	<0.001	0.042	0.023
MB1		12/03/2019	ET1900886	0.001	0.001	0.0001	<0.0001	0.05	<0.01	<0.001	<0.001	0.12	0.06	<0.001	<0.001	0.049	0.042	<0.001	<0.001	<0.005	<0.005
MB10		28/04/2018	ET1801163	4.94	0.024	0.078	0.0009	0.53	<0.01	0.006	<0.001	624	2.73	0.038	<0.001	1.4	0.61	0.015	0.004	89.9	3.16
MB11		27/04/2018	ET1801163	1.4	1.23	9.45	9	21.1	17.8	2.8	2.76	440	390	2.92	2.35	13.9	12.7	0.653	0.62	469	465
MB1AB		29/09/2017	EB1720574	<0.001	<0.001	<0.0001	<0.0001	0.27	<0.01	0.013	<0.001	0.24	<0.05	<0.001	<0.001	0.042	<0.001	<0.001	<0.001	0.006	<0.005
MB1AB		6/02/2018	EB1803858	0.002	<0.001	0.0007	0.0002	2.93	<0.01	0.019	0.007	2.7	<0.05	0.042	<0.001	0.17	0.013	0.004	0.003	0.556	0.223
MB1AB		27/04/2018	ET1801163	<0.001	<0.001	<0.0001	<0.0001	0.36	<0.01	<0.001	<0.001	0.31	<0.05	0.006	<0.001	0.041	0.026	<0.001	<0.001	0.033	0.009
MB1AB		7/09/2018	ET1802314	0.001	<0.001	0.0003	<0.0001	0.6	<0.01	0.003	<0.001	0.71	<0.05	0.021	<0.001	0.155	0.071	0.001	<0.001	0.089	0.037
MB2		30/03/2017	EB1706945	<0.001	<0.001	<0.0001	<0.0001	0.04	<0.01	0.058	0.031	0.06	<0.05	0.003	<0.001	0.027	0.003	<0.001	<0.001	0.026	0.006
MB2		26/06/2017	EB1713282	<0.001	<0.001	<0.0001	<0.0001	0.02	<0.01	0.068	0.031	<0.05	<0.05	<0.001	<0.001	0.016	0.003	<0.001	<0.001	<0.005	0.007
MB2		29/09/2017	EB1720574	0.001	<0.001	<0.0001	<0.0001	0.06	<0.01	0.065	0.044	<0.05	<0.05	0.002	<0.001	0.016	0.002	<0.001	<0.001	0.009	0.01
MB2		3/02/2018	EB1803858	0.001	<0.001	<0.0001	<0.0001	<0.01	<0.01	0.037	0.036	<0.05	<0.05	<0.001	<0.001	0.03	0.031	<0.001	0.003	<0.005	<0.005
MB2		8/09/2018	ET1802314	<0.001	<0.001	0.0001	<0.0001	<0.01	<0.01	0.019	0.017	<0.05	<0.05	<0.001	<0.001	0.04	0.042	<0.001	<0.001	<0.005	<0.005
MB2		22/11/2018	ET1803049	<0.001	<0.001	<0.0001	<0.0001	<0.01	<0.01	0.027	0.025	<0.05	<0.05	<0.001	<0.001	0.088	0.101	<0.001	<0.001	<0.005	<0.005
MB2AB		29/09/2017	EB1720574	0.002	<0.001	0.0001	<0.0001	2.93	<0.01	0.025	0.003	3.22	<0.05	0.003	<0.001	0.099	0.006	0.006	<0.001	0.038	<0.005
MB2AB		8/02/2018	EB1803858	0.002	<0.001	<0.0001	<0.0001	3.34	<0.01	0.02	<0.001	3.61	<0.05	0.008	<0.001	0.159	0.068	0.006	0.002	0.07	<0.005
MB2AB		27/04/2018	ET1801163	0.001	<0.001	<0.0001	<0.0001	0.13	<0.01	0.001	<0.001	0.2	0.06	0.005	<0.001	0.149	0.142	<0.001	<0.001	0.046	0.021
MB2AB		8/09/2018	ET1802314	0.004	0.001	0.0009	0.0004	0.23	<0.01	0.005	<0.001	0.68	<0.05	0.062	0.002	0.055	0.002	<0.001	<0.001	0.31	0.168
MB3		30/03/2017	EB1706945	0.002	0.001	<0.0001	<0.0001	<0.01	<0.01	<0.001	<0.001	<0.05	<0.05	<0.001	<0.001	0.003	0.002	<0.001	<0.001	0.007	<0.005
MB3		29/09/2017	EB1720574	0.001	0.001	<0.0001	<0.0001	0.04	<0.01	0.004	<0.001	<0.05	<0.05	0.002	<0.001	0.01	<0.001	<0.001	<0.001	0.008	<0.005
MB3		6/02/2018	EB1803858	0.001	0.001	<0.0001	<0.0001	<0.01	<0.01	<0.001	0.001	<0.05	<0.05	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	0.007	<0.005
MB3		28/04/2018	ET1801163	0.007	0.001	0.0014	0.0011	0.03	<0.01	0.002	<0.001	0.69	<0.05	0.014	<0.001	0.01	0.006	0.001	<0.001	0.186	0.11
MB3		9/09/2018	ET1802314	0.001	0.001	<0.0001	<0.0001	<0.01	<0.01	<0.001	<0.001	<0.05	<0.05	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.005
MB3		22/11/2018	ET1803049	<0.001	0.001	<0.0001	<0.0001	<0.01	<0.01	<0.001	<0.001	<0.05	<0.05	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.005
MB3		9/03/2019	ET1900886	0.001	0.001	0.0001	<0.0001	<0.01	<0.01	0.002	0.002	<0.05	<0.05	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.005	0.006
MB3AB		29/09/2017	EB1720574	0.001	0.001	<0.0001	<0.0001	1.33	<0.01	0.006	<0.001	1.41	<0.05	<0.001	<0.001	0.191	0.004	0.001	<0.001	<0.005	<0.005
MB3AB		6/02/2018	EB1803858	0.002	0.001	<0.0001	<0.0001	5.88	<0.01	0.011	0.002	4.88	<0.05	0.006	<0.001	0.783	0.002	0.006	0.002	0.062	0.034
MB3AB		26/04/2018	ET1801163	0.001	<0.001	<0.0001	<0.0001	1.15	<0.01	0.005	0.002	0.79	<0.05	0.003	<0.001	0.111	0.002	0.002	<0.001	0.021	0.006
MB3AB		9/09/2018	ET1802314	0.005	0.001	0.0009	0.0001	4.34	<0.01	0.01	<0.001	3.56	<0.05	0.045	<0.001	0.283	0.006	0.003	<0.001	0.297	0.034
MB4		26/06/2017	EB1713282	<0.001	<0.001	<0.0001	<0.0001	0.26	<0.01	0.002	<0.001	0.38	<0.05	0.002	<0.001	0.161	0.119	<0.001	<0.001	0.021	0.007
MB4		30/03/2017	EB1706945	<0.001	<0.001	<0.0001	<0.0001	0.6	<0.01	0.003	<0.001	0.88	<0.05	0.017	<0.001	0.225	0.116	0.001	<0.001	0.044	0.012
MB4		29/09/2017	EB1720574	<0.001	<0.001	<0.0001	<0.0001	0.17	<0.01	0.005	<0.001	0.22	<0.05	0.002	<0.001	0.168	0.137	<0.001	<0.001	0.018	<0.005
MB4		4/02/2018	EB1803858	<0.001	<0.001	<0.0001	<0.0001	<0.01	<0.01	<0.001	<0.001	<0.05	<0.05	<0.001	<0.001	0.013	0.013	<0.001	0.003	0.006	<0.005
MB4		27/04/2018	ET1801163	<0.001	<0.001	0.0001	<0.0001	0.07	<0.01	0.001	<0.001	0.1	<0.05	0.007	<0.001	0.065	0.051	<0.001	<0.001	0.07	0.021
MB4		8/09/2018	ET1802314	<0.001	<0.001	<0.0001	<0.0001	<0.01	<0.01	<0.001	<0.001	<0.05	<0.05	<0.001	<0.001	0.009	0.009	<0.001	<0.001	<0.005	<0.005
MB4		23/11/2018	ET1803049	<0.001	<0.001	<0.0001	<0.0001	0.03	<0.01	0.001	0.002	0.07	<0.05	0.004	<0.001	0.028	0.015	<0.001	<0.001	0.051	0.028
MB4		11/03/2019	ET1900886	<0.001	<0.001	0.0001	<0.0001	<0.01	<0.01	<0.001	<0.001	<0.05	<0.05	<0.001	<0.001	0.015	0.016	<0.001	<0.001	<0.005	<0.005
MB4AB		29/09/2017	EB1720574	0.025	0.002	0.0004	<0.0001	154	<0.01	0.194	<0.001	207	0.21	0.034	<0.001	6.94	1.32	0.313	<0.001	0.195	<0.005
MB4AB		6/02/2018	EB1803858	0.004	0.003	<0.0001	<0.0001	5.59	<0.01	0.009	<0.001	9.9	0.19	0.005	<0.001	1.2	0.953	0.013	0.004	0.042	0.03
MB4AB		26/04/2018	ET1801163	0.004	0.002	<0.0001	<0.0001	2.48	<0.01	0.005	<0.001	4.56	0.28	0.006	<0.001	1.51	1.3	0.007	<0.001	0.052	0.008
MB5		30/03/2017	EB1706945	0.001	<0.001	<0.0001	<0.0001	0.23	<0.01	0.004	<0.001	0.71	<0.05	0.004	<0.001	2.67	0.686	0.001	<0.001	0.025	<0.005
MB5		28/04/2018	ET1801163	0.002	<0.001	0.0002	0.0002	0.06	<0.01	0.002	<0.001	0.2	<0.05	0.003	<0.001	0.522	0.21	<0.001	<0.001	0.067	0.046
MB5		6/09/2018	ET1802314	<0.001	<0.001	<0.0001	<0.0001	0.02	<0.01	0.001	<0.001	0.11	0.09	<0.001	<0.001	0.638	0.665	<0.001	<0.001	0.008	<0.005
MB5		24/11/2018	ET1803049	0.001	<0.001	0.0002	0.0002	0.05	<0.01	0.003	0.003	0.12	<0.05	0.01	0.001	0.711	0.616	<0.001	<0.001	0.116	0.099
MB5		9/03/2019	ET1900886	<0.001	<0.001	0.0001	<0.0001	<0.01	<0.01	<0.001	<0.001	0.19	0.18	<0.001	<0.001	0.667	0.676	<0.001	<0.001	<0.005	<0.005
MB6		30/03/2017	EB1706945	0.002	0.001	<0.0001	<0.0001	0.25	<0.01	0.006	<0.001	0.5	<0.05	0.004	<0.001	0.884	0.756	<0.001	<0.001	0.085	0.008
MB6		28/04/2018	ET1801163	0.006	0.002	0.0009	0.0005	0.1	<0.01	0.002	<0.001	0.48	<0.05	0.01	<0.001	0.595	0.495	<0.001	<0.001	0.581	0.485
MB6		7/09/2018	ET1802314	0.004	0.004	<0.0001	<0.0001	<0.01	<0.01	<0.001	<0.001	0.13	0.11	<0.001	<0.001	0.803	0.796	<0.001	<0.001	<0.005	<0.005
MB6		24/11/2018	ET1803049	0.006	0.005	0.0003	0.0001	0.1	0.02	0.005	0.002	0.22	0.06	0.014	0.003	0.481	0.549	<0.001	<0.001	0.217	0.086
MB6		9/03/2019	ET1900886	0.006	0.005	0.0001	<0.0001	0.21	<0.01	0.004	0.002	0.32	0.06	<0.001	<0.001	0.497	0.397	0.002	<0.001	0.056	0.035
MB9D		6/02/2018	EB1803858	0.001	<0.001	0.0002	<0.0001	0.2	<0.01	0.004	0.002	0.37	<0.05	0.012	<0.001	0.331	0.003	<0.001	0.003	0.094	0.048
MB9D		26/04/2018	ET1801163	0.001	<0.001	0.0003	<0.0001	1.14	<0.01	0.017	0.004	1.38	<0.05	0.014	<0.001	1.72	0.642	0.004	<0.001	0.119	0.04
MB9D		6/09/2018	ET1802314	0.011	<0.001	0.0017	0.0002	0.49	<0.01	0.008	<0.001	1.92	<0.05	0.125	<0.001	2.17	1.01	0.003	<0.001	0.492	0.029
MB9D		24/11/2018	ET1803049	0.006	<0.001	0.0008	0.0002	4.66	<0.01	0.042	<0.001	5	<0.05	0.068	<0.001	1.6	0.62	0.008	<0.001	0.275	0.03
MB9D		9/03/2019	ET1900886	0.008	<0.001	0.0013	0.0004	7.6	<0.01	0.063	0.005	11	<0.05	0.093	<0.001	1.14	0.47	0.019	0.003	0.492	0.1
MB9D		30/03/2017	EB1706945	0.001	<0.001	0.0004	<0.0001	0.21	<0.01	0.006	0.001	1.02	<0.05	0.006	<0.001	14.6	0.004	0.013	<0.001	0.072	0.009
MB9S		26/04/2018	ET1801163	0.002	<0.001	<0.0001	<0.0001	2.57	0.21	0.023	0.001	3.73	0.13	0.005	<0.001	0.098	0.028	0.004	<0.001	0.044	0.015
MB9S		30/03/2017	EB1706945	0.001	<0.001	<0.0001	<0.0001	3.4	0.04	0.028	<0.001	5.3	<0.05	0.003	<0.001	0.31	0.003	0.004	<0.001	0.015	<0.005
Saturday Bore		31/03/2017	EB1706945	0.001	<0.001	<0.0001	<0.0001	0.98	<0.01	0.013	<0.001	2.38	<0.05	0.008	<0.001	1.23	1.14	0.002	<0.001	0.106	<0.005
Saturday Bore		29/09/2017	EB1720574	<0.001	<0.001	<0.0001	<0.0001	0.09	<0.01	0.002	0.002	0.12	<0.05	<0.001	<0.001	1.64	1.45	<0.001	0.006	0.011	0.005
Saturday Bore		8/02/2018	EB1803858	0.001	0.001	<0.0001	<0.0001	<0.01	<0.01	<0.001	<0.001	0.13	0.08	<0.001	<0.001	0.675	0.595	0.003	0.003	0.008	<0.005
Saturday Bore		24/04/2018	ET1801163	0.002	0.001	<0.0001	<0.0001	0.13	<0.01	<0.001	<0.001	0.87	0.62	0.001	<0.001	1.81	1.62	0.003	<0.001	0.014	<0.005
Saturday Bore		8/09/2018	ET1802314	0.002	0.001	<0.0001	<0.0001	<0.01	<0.01	<0.001	<0.001	0.19	0.18	<0.001	<0.001	1.13	1.25	<0.001	<0.001	<0.005	<0.005
Saturday Bore		22/11/2018	ET1803049	0.001	<0.001	<0.0001	<0.0001	<0.01	<0.01	<0.001	<0.001	0.14	0.13	<0.001	<0.001	0.877	0.96	<0.001	<0.001	<0.005	<0.005
SHALL6AB		26/04/2018	ET1801163	0.001	<0.001	<0.0001	<0.0001	0.66	<0.01	0.005	<0.001	0.94	0.21	0.008	<0.001	0.161	0.097	0.003	<0.001	0.09	0.018

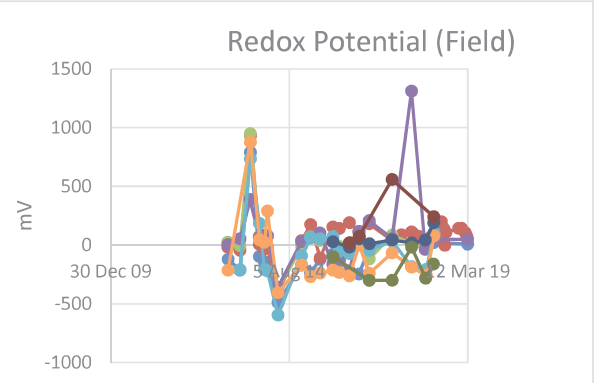
LocCode	Sampled_Date-Time	Field: pH (Field)	Redox Potential (Field)	EC (field)	Turbidity	Temp (Field)	Inorganics: Alkalinity (Hydroxide) as CaCO3	Alkalinity (total) as CaCO3	Electrical conductivity *(lab)	Sodium (Filtered)	TDS	Chloride	Sulfate as SO4 - Turbidimetric (Filtered)	Fluoride	Hardness as CaCO3 (Filtered)	TSS	Alkalinity (Bicarbonate as CaCO3)	Alkalinity (Carbonate as CaCO3)	Dissolved Oxygen - % Saturation	Calcium (Filtered)	Magnesium (Filtered)	Potassium (Filtered)
		pH Unit	mV	uS/cm	NTU	oC	µg/L	mg/L	uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	%	mg/L	mg/L	mg/L
EQL					0.1		1000	1	1	1	10	1	1	0.1	1	5	1	1		1	1	1
ContamLimit-EA-MMG		6 to 9		2000					2000				1000	2								
TriggerLevel-EA-MMG		6 to 8		1500					1500				150									
GWBFAB	27/04/2018	7.09	-5.1	1240	-	30.7	<1000	492	1030	93	642	38	83	1.3	407	124	492	<1	41.23	74	54	17
MB1	30/03/2017	7.36	63.3	1295	-	31	<1000	560	1140	65	635	40	22	1.6	493	15	560	<1	3.3	72	76	10
MB1	29/09/2017	7.11	-	1360	-	-	<1000	537	1090	63	643	48	32	1.8	460	39	537	<1	-	72	68	9
MB1	5/02/2018	7	-12.9	1325	-	32.2	<1000	541	1100	60	640	40	22	1.8	530	80	541	<1	15.3	72	85	11
MB1	27/04/2018	7.5	21.2	949	-	30.9	<1000	397	794	43	456	38	24	1.3	382	16	397	<1	48.17	54	60	8
MB1	8/09/2018	5.9	-	1445	-	32	<1000	536	1070	67	634	46	24	0.8	538	10	536	<1	-	77	84	11
MB1	23/11/2018	-	-	-	-	-	<1000	498	1090	59	620	95	18	0.9	435	28	498	<1	-	62	68	9
MB1	12/03/2019	-	-	-	0.5	-	<1000	532	1030	61	639	40	23	1.6	482	<5	532	<1	-	71	74	10
MB10	28/04/2018	6.8	-87.1	1627	-	29.8	<1000	455	1410	88	904	119	230	2.7	630	544	455	<1	92.19	107	88	22
MB11	27/04/2018	2.92	563	3325	-	28.5	<1000	<1	3020	6	3440	5	1180	3	114	40	<1	<1	220	29	10	10
MB1AB	29/09/2017	7.11	6	1447	-	33.9	<1000	630	1190	132	730	37	12	3.8	360	128	630	<1	23.9	47	59	14
MB1AB	6/02/2018	7	64.6	1475	-	30.5	<1000	657	1260	142	777	31	11	3.6	419	371	657	<1	16.5	49	72	16
MB1AB	27/04/2018	7.34	14.4	1165	-	31.6	<1000	508	966	112	552	40	13	3.2	332	40	508	<1	47.36	44	54	13
MB1AB	7/09/2018	6.2	-	1473	-	31	<1000	587	1150	140	678	37	15	1.6	391	372	587	<1	-	51	64	15
MB2	30/03/2017	7.48	39.9	1351	-	32.1	<1000	411	1150	116	646	59	109	2.2	361	6	411	<1	43.8	67	47	6
MB2	26/06/2017	7.36	88.1	1141	-	23	<1000	487	1170	118	723	68	129	2.2	335	<5	487	<1	1.66	60	45	7
MB2	29/09/2017	7.75	112.2	1310	-	29.8	<1000	400	1120	118	680	66	120	2.9	347	20	400	<1	29.5	63	46	6
MB2	3/02/2018	7	25.5	1345	-	31.1	<1000	362	1150	88	792	63	151	1.8	464	<5	362	<1	0.7	100	52	6
MB2	8/09/2018	6.2	-	1343	-	32	<1000	341	1030	83	686	60	149	0.6	476	<5	341	<1	-	108	50	5
MB2	22/11/2018	-	-	-	-	-	<1000	323	1030	81	630	54	147	1.2	346	<5	323	<1	-	76	38	5
MB2AB	29/09/2017	-	-	-	-	-	<1000	413	1140	68	712	67	118	1	470	270	413	<1	-	119	42	4
MB2AB	8/02/2018	7	-186.2	1264	-	30	<1000	362	1130	82	758	64	145	0.9	446	172	362	<1	12.4	111	41	4
MB2AB	27/04/2018	7.61	-98.1	1212	-	30.1	<1000	369	1030	101	658	69	126	1.2	387	14	369	<1	70.76	99	34	4
MB2AB	8/09/2018	6.85	-	1257	-	27.9	<1000	342	1030	102	686	61	143	0.5	434	36	342	<1	-	111	38	4
MB3	30/03/2017	7.41	86.2	1870	-	30.8	<1000	577	1640	207	1030	46	125	3	424	9	577	<1	0.13	43	77	11
MB3	29/09/2017	-	-	-	-	-	<1000	502	1590	216	1080	60	148	3.3	373	21	502	<1	-	19	79	12
MB3	6/02/2018	7	-32.6	3237	-	31.7	<1000	516	2790	307	2000	122	312	2.9	856	5	516	<1	0.7	87	155	16
MB3	28/04/2018	7.72	92.7	2018	-	31.8	<1000	535	1680	247	1080	59	146	2.9	409	8	535	<1	58.15	37	77	12
MB3	9/09/2018	7	-	5905	-	37.5	<1000	445	4010	394	3220	154	501	1.2	1400	<5	445	<1	-	150	250	20
MB3	22/11/2018	-	-	-	-	-	<1000	433	4300	376	3220	169	601	1.4	1420	<5	433	<1	-	150	253	23
MB3	9/03/2019	-	-	-	<0.1	-	<1000	446	4100	393	3400	162	698	2.4	1410	<5	446	<1	-	153	249	20
MB3AB	29/09/2017	-	-	-	-	-	<1000	481	1430	200	1010	34	137	3.5	329	52	481	<1	-	36	58	12
MB3AB	6/02/2018	7	30.5	2008	-	29.6	<1000	714	1750	297	1120	46	97	3.3	360	143	714	<1	20.4	37	65	14
MB3AB	26/04/2018	7.53	60.5	1632	-	31.5	<1000	480	1370	201	908	42	141	3.2	346	42	480	<1	94.86	38	61	12
MB3AB	9/09/2018	7.7	-	1370	-	30.1	<1000	604	1560	274	1060	47	129	1.5	350	74	604	<1	-	38	62	14
MB4	26/06/2017	7.21	-	968	-	30.2	<1000	295	816	90	538	68	80	0.8	230	19	295	<1	1.6	54	23	4
MB4	30/03/2017	7.72	56.2	1037	-	29.1	<1000	273	907	88	516	74	82	0.8	267	37	273	<1	4.22	64	26	5
MB4	29/09/2017	-	-	-	-	-	<1000	259	822	85	559	70	74	0.9	227	16	259	<1	-	53	23	4
MB4	4/02/2018	7	-36.8	1535	-	31.2	<1000	508	1310	128	801	76	96	1.5	474	<5	508	<1	0	94	58	6
MB4	27/04/2018	7.24	49.5	1001	-	30.5	<1000	319	855	91	518	71	77	1	278	12	319	<1	48.24	62	30	5
MB4	8/09/2018	5.5	-	1751	-	31.7	<1000	538	1310	152	810	80	96	0.7	520	<5	538	<1	-	106	62	6
MB4	23/11/2018	-	-	-	-	-	<1000	272	879	86	508	61	71	0.4	243	6	272	<1	-	51	28	5
MB4	11/03/2019	-	-	-	0.2	-	<1000	523	1290	127	766	77	103	1.4	457	<5	523	<1	-	94	54	6
MB4AB	29/09/2017	-	-	-	-	-	<1000	563	2660	370	1910	302	580	1.4	684	6890	563	<1	-	160	69	6
MB4AB	6/02/2018	7	-74.8	2719	-	31.4	<1000	518	2370	327	1530	237	464	1.2	604	271	518	<1	17.2	138	63	6
MB4AB	26/04/2018	5.86	-8.5	278.5	-	31.1	<1000	571	2300	330	1600	214	542	1.4	684	118	571	<1	185.8	160	69	6
MB5	30/03/2017	6.87	34.8	1426	-	33.2	<1000	438	1220	68	687	91	98	0.4	495	27	438	<1	1.33	81	71	11
MB5	28/04/2018	7.18	107.1	1335	-	31.4	<1000	425	1110	69	632	95	94	0.4	507	12	425	<1	44.1	81	74	11
MB5	6/09/2018	5.6	-	1585	-	33	<1000	446	1160	78	676	90	98	0.2	535	<5	446	<1	-	89	76	12
MB5	24/11/2018	-	-	-	-	-	<1000	408	1180	65	682	85	98	0.2	466	102	408	<1	-	78	66	11
MB5	9/03/2019	-	-	-	1	-	<1000	428	1160	69	668	85	103	0.4	495	<5	428	<1	-	81	71	10
MB6	30/03/2017	7.41	-66.7	1026	-	32.9	<1000	445	889	53	509	19	1	1.1	361	40	445	<1	3.86	95	30	10
MB6	28/04/2018	6.7	77.8	438.3	-	31.7	<1000	187	365	10	204	6	3	0.2	179	<5	187	<1	30.39	60	7	3
MB6	7/09/2018	6	-	1155	-	32	<1000	447	855	58	526	28	6	0.5	370	<5	447	<1	-	97	31	9
MB6	24/11/2018	-	-	-	-	-	<1000	381	786	46	444	26	8	0.5	284	38	381	<1	-	71	26	10
MB6	9/03/2019	-	-	-	3.1	-	<1000	420	806	44	454	23	6	1	319	12	420	<1	-	85	26	8
MB9D	6/02/2018	7	43	1378	-	31.5	<1000	424	1180	36	670	113	44	0.5	582	22	424	<1	23.5	88	88	15
MB9D	26/04/2018	5.71	190.4	1309	-	31.1	<1000	412	1110	33	614	123	48	0.5	556	104	412	<1	122.1	84	84	14
MB9D	6/09/2018	5.9	-	1491	-	30.5	<1000	421	1120	37	660	120	47	0.2	556	36	421	<1	-	86	83	13
MB9D	24/11/2018	-	-	-	-	-	<1000	396	1140	32	646	113	40	0.2	515	264	396	<1	-	81	76	13
MB9D	9/03/2019	-	-	-	664	-	<1000	418	1130	36	662	116	52	0.5	543	784	418	<1	-	84	81	13
MB9D	30/03/2017	7.11	44	791	-	32.7	<1000	423	1200	34	660	112	50	0.5	556	40	423	<1	4.3	84	84	13
MB9S	26/04/2018	5.08	242.3	108.9	-	32	<1000	33	92	6	92	6	4	0.1	25	126	33	<1	29.55	5	3	5
MB9S	30/03/2017	6.64	559	117.7	-	32.8	<1000	40	99	6	158	4	2	<0.1	27	68	40	<1	1.49	6	3	4
Saturday Bore	31/03/2017	7.73	-299	1911	-	25.4	<1000	646	1900	215	943	147	117	1.7	360	82	646	<1	17.8	65	48	10
Saturday Bore	29/09/2017	-	-	-	-	-	<1000	590	1750	241	1110	182	132	2.1	389	6	590	<1	-	70	52	5
Saturday Bore	8/02/2018	6.86	-282.3	2128	-	30.1	<1000	559	1750	246	1040	169	155	1.9	427	<5	559	<1	1.6	77	57	5
Saturday Bore	24/04/2018	6.91	-161.6	1516	-	33.6	<1000	452	1210	166	734	113	82	1.2	310	8	452	<1	46.38	60	39	4
Saturday Bore	8/09/2018	6	-	2193	-	30.6	<1000	559	1700	276	1020	161	149	0.8	442	<5	559	<1	-	83	57	4
Saturday Bore	22/11/2018	-	-	-	-	-	<1000	510	1760	198	1070	175	175	0.9	397	<5	510	<1	-	75	51	4
SHALL6AB	26/04/2018	7.12	-81.6	1971	-	32.1	<1000	934	1580	90	892	53	<1	2.5	833	60	934	<1	56.12	73	158	35

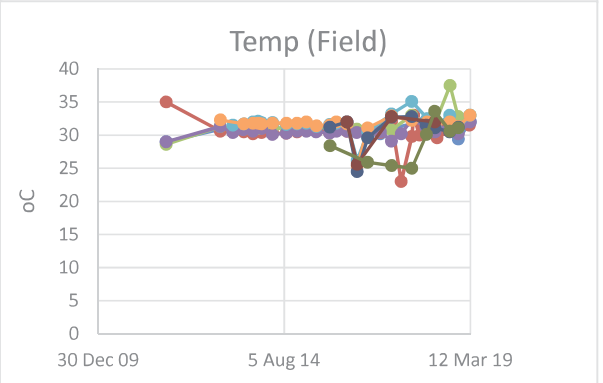

Dissolved Oxygen - % Saturation
%
600
500
400
300
200
100
0
30 Dec 09
5 Aug 14
12 Mar 19

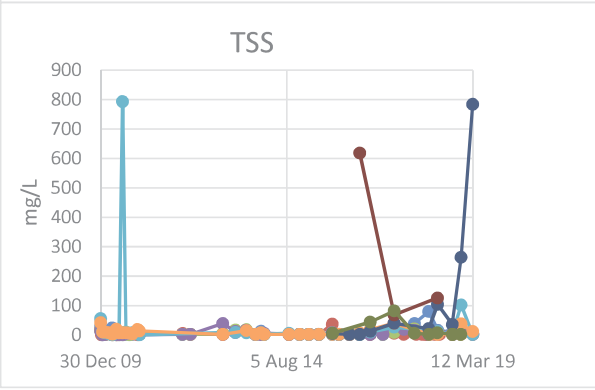

Electrical conductivity *(lab)
uS/cm
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
30 Dec 09
5 Aug 14
12 Mar 19

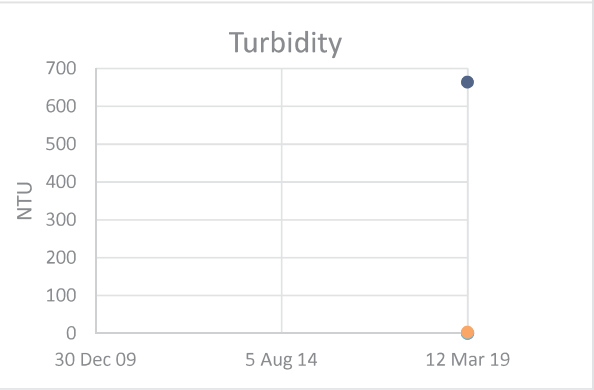

Hardness as CaCO3
mg/L
1600
1400
1200
1000
800
600
400
200
0
30 Dec 09
5 Aug 14
12 Mar 19


pH (Field)
pH Unit
10
9
8
7
6
5
4
3
2
1
0
30 Dec 09
5 Aug 14
12 Mar 19

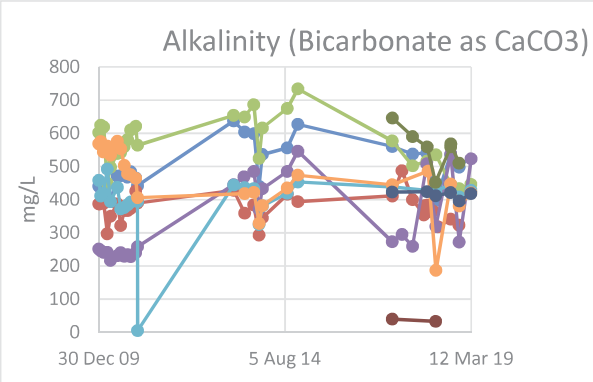

Redox Potential (Field)
mV
1500
1000
500
0
-500
-1000
30 Dec 09
12 Mar 19

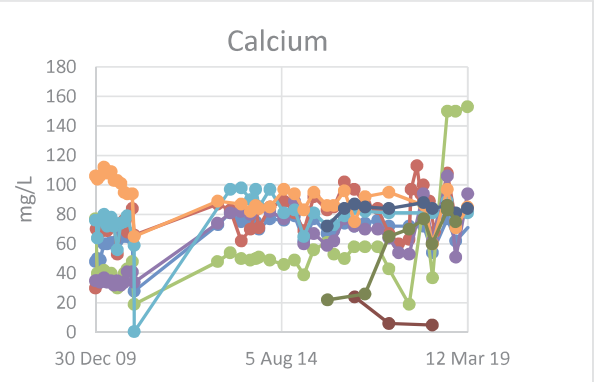

Temp (Field)
oC
40
35
30
25
20
15
10
5
0
30 Dec 09
5 Aug 14
12 Mar 19

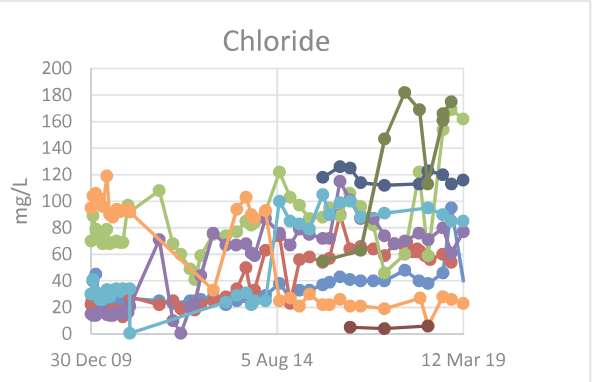

TSS
mg/L
900
800
700
600
500
400
300
200
100
0
30 Dec 09
5 Aug 14
12 Mar 19

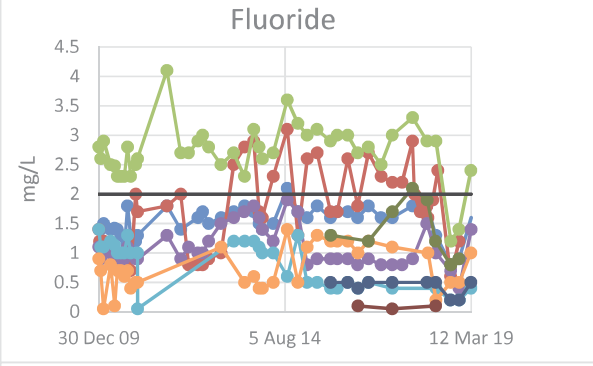

Turbidity
NTU
700
600
500
400
300
200
100
0
30 Dec 09
5 Aug 14
12 Mar 19

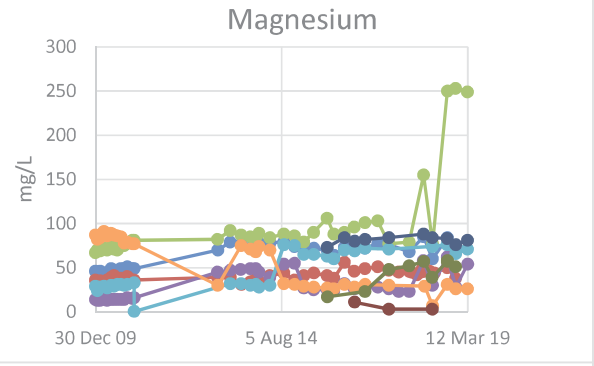

MB1
MB2
MB3
MB4
MB5
MB6
MB9D
MB9S
Saturday Bore

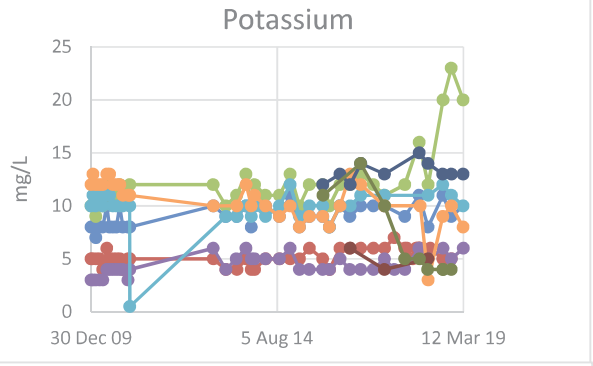

Alkalinity (Bicarbonate as CaCO3)
mg/L
800
700
600
500
400
300
200
100
0
30 Dec 09
5 Aug 14
12 Mar 19

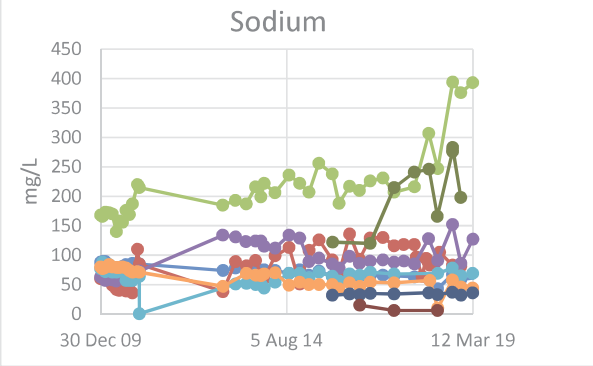

Calcium
mg/L
180
160
140
120
100
80
60
40
20
0
30 Dec 09
5 Aug 14
12 Mar 19

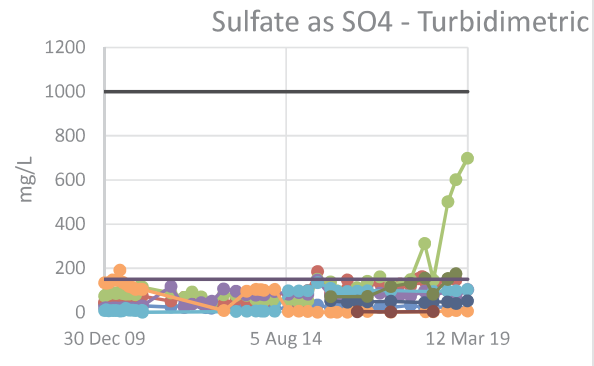

Chloride
mg/L
200
180
160
140
120
100
80
60
40
20
0
30 Dec 09
5 Aug 14
12 Mar 19

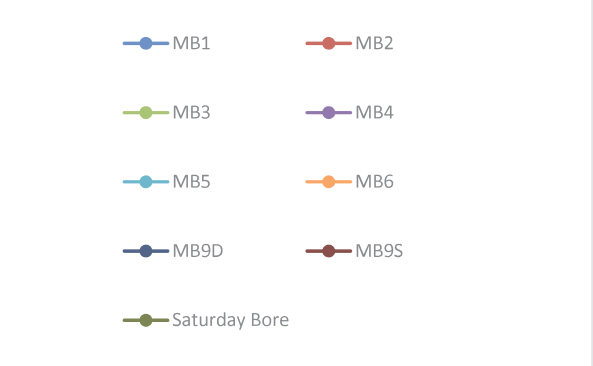

Fluoride
mg/L
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
30 Dec 09
5 Aug 14
12 Mar 19

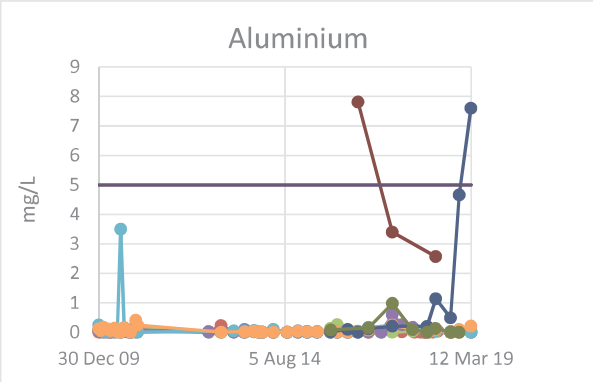

Magnesium
mg/L
300
250
200
150
100
50
0
30 Dec 09
5 Aug 14
12 Mar 19

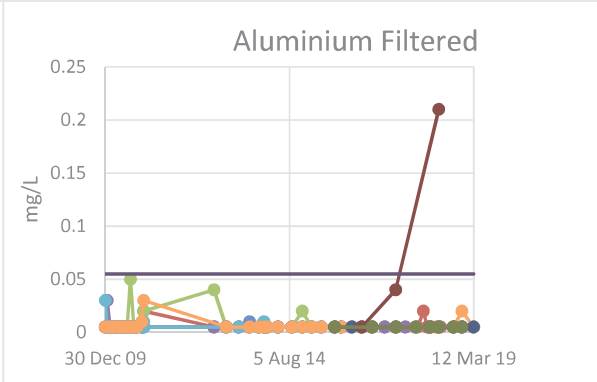

Potassium
mg/L
25
20
15
10
5
0
30 Dec 09
5 Aug 14
12 Mar 19

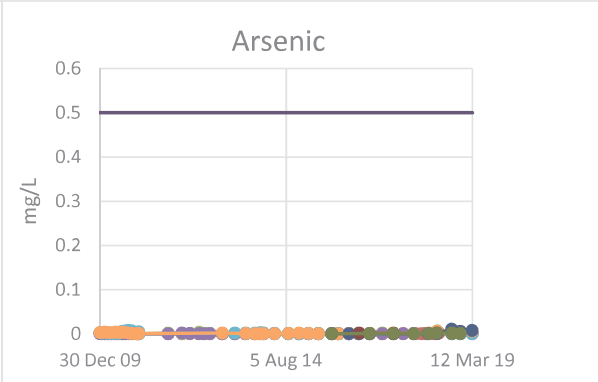

Sodium
mg/L
450
400
350
300
250
200
150
100
50
0
30 Dec 09
5 Aug 14
12 Mar 19

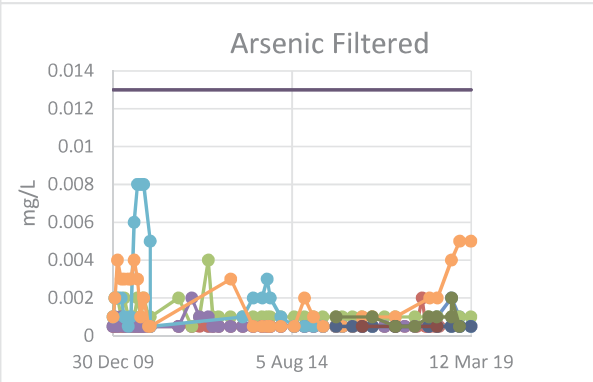

Sulfate as SO4 - Turbidimetric
mg/L
1200
1000
800
600
400
200
0
30 Dec 09
5 Aug 14
12 Mar 19

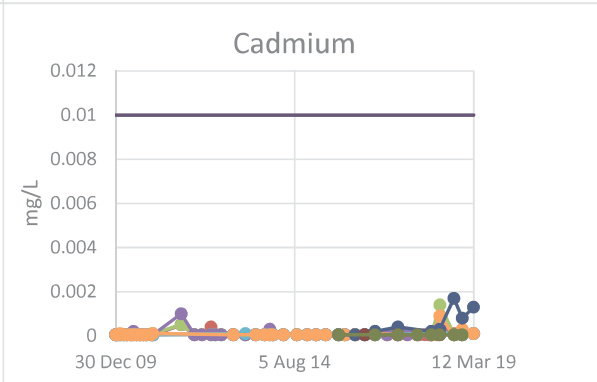

MB1
MB2
MB3
MB4
MB5
MB6
MB9D
MB9S
Saturday Bore

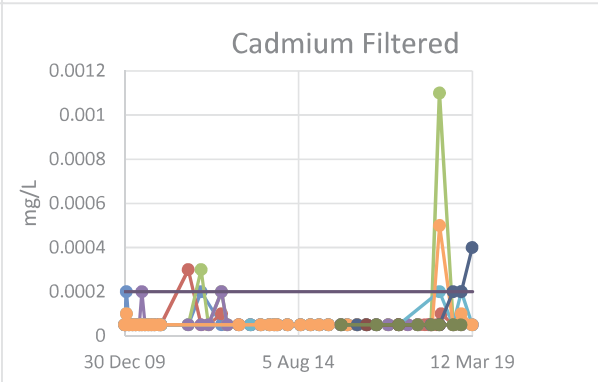

Aluminium
mg/L
9
8
7
6
5
4
3
2
1
0
30 Dec 09
5 Aug 14
12 Mar 19

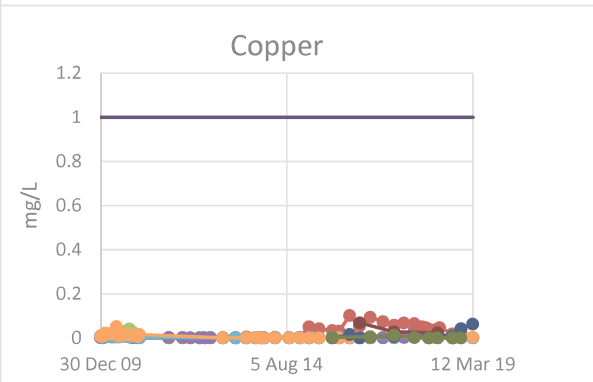

Aluminium Filtered
mg/L
0.25
0.2
0.15
0.1
0.05
0
30 Dec 09
5 Aug 14
12 Mar 19

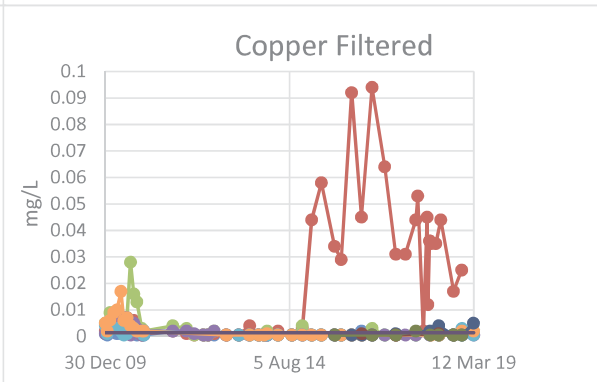

Arsenic
mg/L
0.6
0.5
0.4
0.3
0.2
0.1
0
30 Dec 09
5 Aug 14
12 Mar 19


Arsenic Filtered
mg/L
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
30 Dec 09
5 Aug 14
12 Mar 19

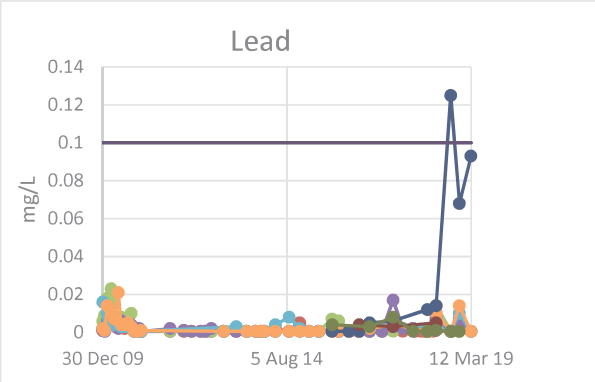

Cadmium
mg/L
0.012
0.01
0.008
0.006
0.004
0.002
0
30 Dec 09
5 Aug 14
12 Mar 19

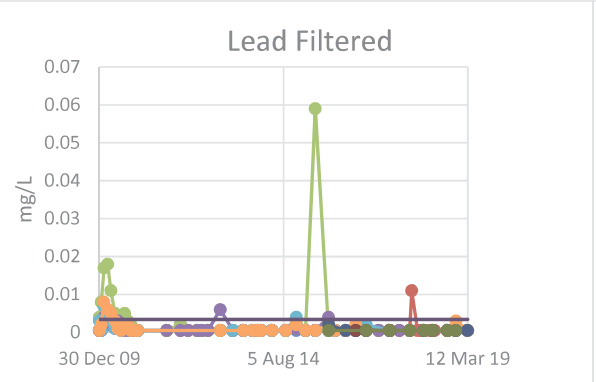

Cadmium Filtered
mg/L
0.0012
0.001
0.0008
0.0006
0.0004
0.0002
0
30 Dec 09
5 Aug 14
12 Mar 19

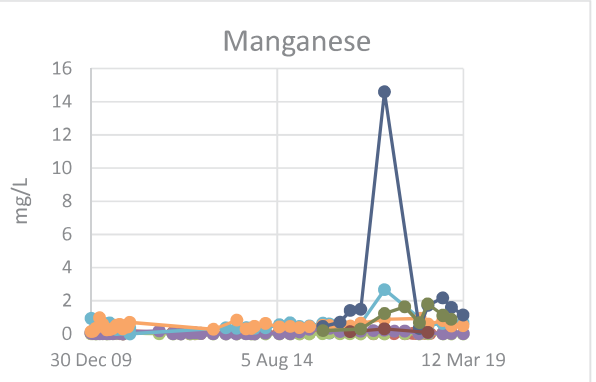

Copper
mg/L
1.2
1
0.8
0.6
0.4
0.2
0
30 Dec 09
5 Aug 14
12 Mar 19

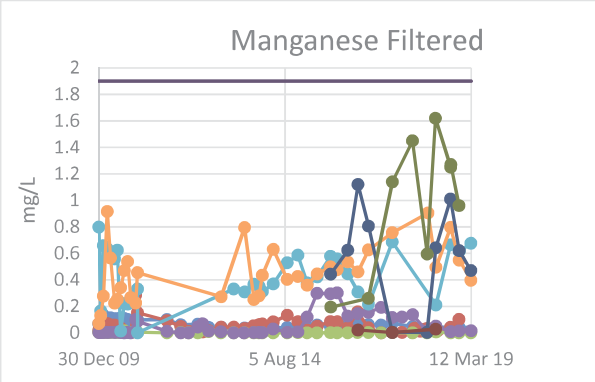

Copper Filtered
mg/L
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
30 Dec 09
5 Aug 14
12 Mar 19

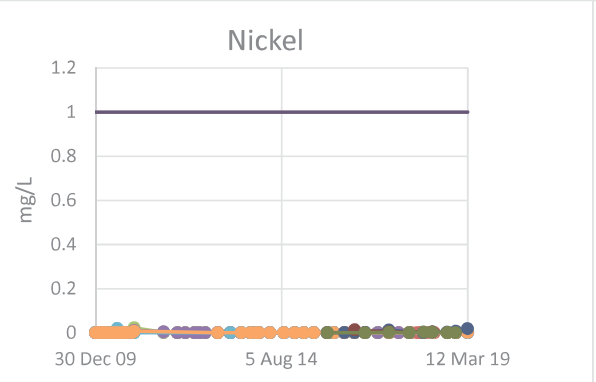

MB1
MB2
MB3
MB4
MB5
MB6
MB9D
MB9S
Saturday Bore

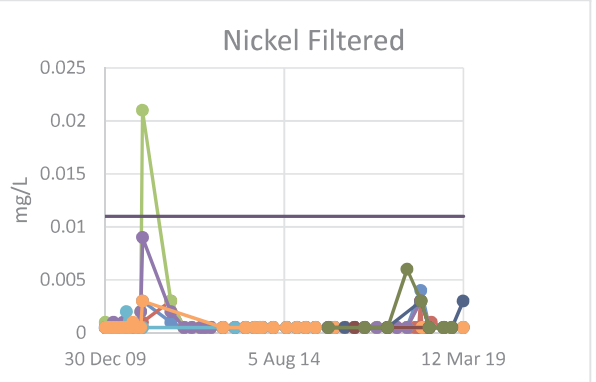

Lead
mg/L
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
30 Dec 09
5 Aug 14
12 Mar 19

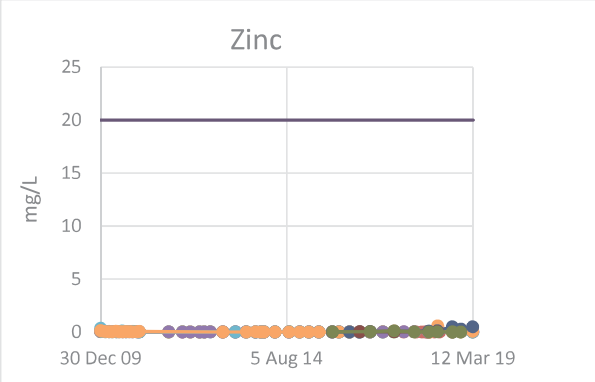

Lead Filtered
mg/L
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
30 Dec 09
5 Aug 14
12 Mar 19

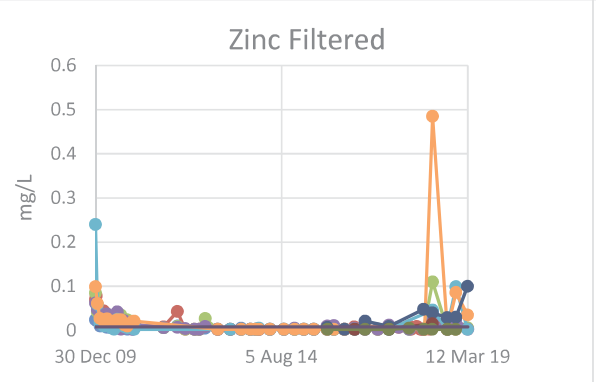

Manganese
mg/L
16
14
12
10
8
6
4
2
0
30 Dec 09
5 Aug 14
12 Mar 19

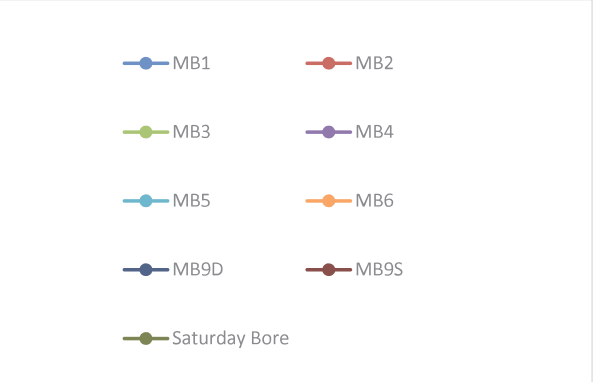

Manganese Filtered
mg/L
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
30 Dec 09
5 Aug 14
12 Mar 19


Nickel
mg/L
1.2
1
0.8
0.6
0.4
0.2
0
30 Dec 09
5 Aug 14
12 Mar 19


Nickel Filtered
mg/L
0.025
0.02
0.015
0.01
0.005
0
30 Dec 09
5 Aug 14
12 Mar 19


Zinc
mg/L
25
20
15
10
5
0
30 Dec 09
5 Aug 14
12 Mar 19


Zinc Filtered
mg/L
0.6
0.5
0.4
0.3
0.2
0.1
0
30 Dec 09
5 Aug 14
12 Mar 19


MB1
MB2
MB3
MB4
MB5
MB6
MB9D
MB9S
Saturday Bore

Appendix F Analytical Results (QA/QC)

Field Duplicates (WATER)
Filter: Lab_Report_Nu

Lab Report Number	ET1802314	ET1802314	
Field ID	Saturday Bore	GW Duplicate	**RPD**
Sampled Date/Time	8/09/2018 10:15	8/09/2018 10:15	

Chem_Gro	ChemNam	Units	EQL			
	Sulfate as	mg/l	1	149.0	153.0	3
pH	pH (Lab)	pH Unit	0.01	7.61	7.51	1
Metals/Met	Arsenic (Fi	mg/l	0.001	0.001	0.002	67
	Arsenic	mg/l	0.001	0.002	0.001	67
	Cadmium (	mg/l	0.0001	<0.0001	<0.0001	0
	Cadmium	mg/l	0.0001	<0.0001	<0.0001	0
	Copper (Fi	mg/l	0.001	<0.001	<0.001	0
	Copper	mg/l	0.001	<0.001	<0.001	0
	Iron (Filtere	mg/l	0.05	0.18	0.17	6
	Iron	mg/l	0.05	0.19	0.16	17
	Lead (Filte	mg/l	0.001	<0.001	<0.001	0
	Lead	mg/l	0.001	<0.001	<0.001	0
	Manganese	mg/l	0.001	1.25	1.27	2
	Manganese	mg/l	0.001	1.13	1.09	4
	Nickel (Filt	mg/l	0.001	<0.001	<0.001	0
	Nickel	mg/l	0.001	<0.001	0.001	0
	Zinc (Filter	mg/l	0.005	<0.005	<0.005	0
	Zinc	mg/l	0.005	<0.005	<0.005	0
alloids						
Inorganics	Chloride	mg/l	1	161.0	166.0	3
	Fluoride	mg/l	0.1	0.8	0.8	0
(other)						
Inorganics	Alkalinity (H	µg/l	1000	<1000.0	<1000.0	0
	Alkalinity (t	mg/l	1	559.0	568.0	2
	Anions Tot	meq/L	0.01	18.8	19.2	2
	Cations To	meq/L	0.01	20.9	21.5	3
	Electrical c	uS/cm	1	1700.0	1680.0	1
	Ionic Balan	%	0.01	5.35	5.55	4
	Sodium (Fi	mg/l	1	276.0	283.0	3
	TDS	mg/l	10	1020.0	1080.0	6
	Hardness a	mg/l	1	442.0	454.0	3
	TSS	mg/l	5	<5.0	<5.0	0
	Alkalinity (B	mg/l	1	559.0	568.0	2
	Alkalinity (C	mg/l	1	<1.0	<1.0	0
Metals	Aluminium	mg/l	0.01	<0.01	<0.01	0
	Aluminium	mg/l	0.01	<0.01	0.01	0
	Calcium (F	mg/l	1	83.0	86.0	4
	Magnesium	mg/l	1	57.0	58.0	2
	Potassium	mg/l	1	4.0	4.0	0

*RPDs have only been considered where a concentration is greater than 1 times the EQL.
**High RPDs are in bold (Acceptable RPDs for each EQL multiplier range are: 80 (1-10 x EQL); 50 (10
***Interlab Duplicates are matched on a per compound basis as methods vary between laboratories. A

Filter: Lab_Report_Number
in('ET1900886','ET1803049','ET1802314','ET1801163','EB1803858','EB1720574','EB1713282','EB1706945')

Field Blanks (WATER)
Filter: Lab_Report_Number in('ET1900886','ET1803049','ET18023

Lab Report Number	ET1802314
Field ID	GW Blank
Sampled_Date/Time	9/09/2018 17:04
Sample Type	Field_B

Chem_Group	ChemName	Units	EQL	
	Sulfate as SO4 - Turbidimetric (Filtered)	mg/l	1	<1
	Standing Water Level	m AHD		
Acid Sulfate Soils	pH (Field)	pH Unit		
Field	Redox Potential (Field)	mV		
	EC (field)	uS/cm		
	Turbidity	NTU	0.1	
	Temp (Field)	oC		
Inorganics	Alkalinity (Hydroxide) as CaCO3	µg/l	1000	<1000
	Alkalinity (total) as CaCO3	mg/l	1	**8**
	Anions Total	meq/L	0.01	**0.19**
	Cations Total	meq/L	0.01	**0.04**
	Electrical conductivity *(lab)	uS/cm	1	**6**
	Ionic Balance	%	0.01	
	Sodium (Filtered)	mg/l	1	**1**
	TDS	mg/l	10	<10
	Hardness as CaCO3 (Filtered)	mg/l	1	<1
	TSS	mg/l	5	<5
	Alkalinity (Bicarbonate as CaCO3)	mg/l	1	**8**
	Alkalinity (Carbonate as CaCO3)	mg/l	1	<1
	Dissolved Oxygen - % Saturation	%		
Inorganics (other)	Chloride	mg/l	1	**1**
	Fluoride	mg/l	0.1	<0.1
Metals	Aluminium	mg/l	0.01	<0.01
	Aluminium (Filtered)	mg/l	0.01	<0.01
	Calcium (Filtered)	mg/l	1	<1
	Magnesium (Filtered)	mg/l	1	<1
	Potassium (Filtered)	mg/l	1	<1
Metals/Metalloids	Arsenic	mg/l	0.001	<0.001
	Arsenic (Filtered)	mg/l	0.001	<0.001
	Cadmium	mg/l	0.0001	<0.0001
	Cadmium (Filtered)	mg/l	0.0001	<0.0001
	Copper	mg/l	0.001	<0.001
	Copper (Filtered)	mg/l	0.001	<0.001
	Iron	mg/l	0.05	<0.05
	Iron (Filtered)	mg/l	0.05	<0.05
	Lead	mg/l	0.001	<0.001
	Lead (Filtered)	mg/l	0.001	<0.001
	Manganese	mg/l	0.001	<0.001
	Manganese (Filtered)	mg/l	0.001	<0.001
	Nickel	mg/l	0.001	<0.001
	Nickel (Filtered)	mg/l	0.001	<0.001
	Zinc	mg/l	0.005	<0.005
	Zinc (Filtered)	mg/l	0.005	<0.005
pH	pH (Lab)	pH Unit	0.01	**7.2**

Filter: Lab_Report_Number
in('ET1900886','ET1803049','ET1802314','ET1801163','EB1803858','EB1720574','EB1713282','EB1706945')

Appendix G Certificate of Analysis

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB1706945**	Page	: 1 of 6
Client	: **MMGROUP LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR JONATHAN EDEN	Contact	: Joy Morgan
Address	: PO BOX 69 CLONCURRY QLD, AUSTRALIA 4824	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61-7-3243 7222
Project	: Sample Analysis	Date Samples Received	: 06-Apr-2017 10:00
Order number	: 4400092876	Date Analysis Commenced	: 06-Apr-2017
C-O-C number	: ----	Issue Date	: 13-Apr-2017 13:41
Sampler	: ANDREW DORGE		
Site	: ----		
Quote number	: BN/753/14 v5		
No. of samples received	: 10		
No. of samples analysed	: 10		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Andrew Epps	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Greg Vogel	Laboratory Manager	Brisbane Inorganics, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, the sampling date will be assumed by the laboratory and displayed in brackets without a time component.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- TDS by method EA-015 may bias high due to the presence of fine particulate matter, which may pass through the prescribed GF/C paper.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	MB 02	MB06	MD09D	MD09S	MB01
				Client sampling date / time	30-Mar-2017 16:30	30-Mar-2017 15:25	30-Mar-2017 14:00	30-Mar-2017 14:20	30-Mar-2017 11:15
Compound	CAS Number	LOR	Unit		EB1706945-001	EB1706945-002	EB1706945-003	EB1706945-004	EB1706945-005
					Result	Result	Result	Result	Result
EA005P: pH by PC Titrator									
pH Value	----	0.01	pH Unit		7.53	7.35	7.33	6.36	7.58
EA010P: Conductivity by PC Titrator									
Electrical Conductivity @ 25°C	----	1	µS/cm		1150	889	1200	99	1140
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		646	509	660	158	635
EA025: Total Suspended Solids dried at 104 ± 2°C									
Suspended Solids (SS)	----	5	mg/L		6	40	40	68	15
ED037P: Alkalinity by PC Titrator									
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L		<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L		<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L		411	445	423	40	560
Total Alkalinity as CaCO3	----	1	mg/L		411	445	423	40	560
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		109	1	50	2	22
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L		59	19	112	4	40
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		67	95	84	6	72
Magnesium	7439-95-4	1	mg/L		47	30	84	3	76
Sodium	7440-23-5	1	mg/L		116	53	34	6	65
Potassium	7440-09-7	1	mg/L		6	10	13	4	10
ED093F: SAR and Hardness Calculations									
Total Hardness as CaCO3	----	1	mg/L		361	361	556	27	493
EG020F: Dissolved Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		<0.01	<0.01	<0.01	0.04	<0.01
Arsenic	7440-38-2	0.001	mg/L		<0.001	0.001	<0.001	<0.001	<0.001
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Copper	7440-50-8	0.001	mg/L		0.031	<0.001	0.001	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	7439-96-5	0.001	mg/L		0.003	0.756	0.004	0.003	0.073
Nickel	7440-02-0	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L		0.006	0.008	0.009	<0.005	<0.005
Iron	7439-89-6	0.05	mg/L		<0.05	<0.05	<0.05	<0.05	<0.05

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	Client sample ID	MB 02	MB06	MD09D	MD09S	MB01
				Client sampling date / time	30-Mar-2017 16:30	30-Mar-2017 15:25	30-Mar-2017 14:00	30-Mar-2017 14:20	30-Mar-2017 11:15
					EB1706945-001	EB1706945-002	EB1706945-003	EB1706945-004	EB1706945-005
					Result	Result	Result	Result	Result
EG020T: Total Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		**0.04**	**0.25**	**0.21**	**3.40**	**0.13**
Arsenic	7440-38-2	0.001	mg/L		<0.001	**0.002**	**0.001**	**0.001**	<0.001
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	<0.0001	**0.0004**	<0.0001	<0.0001
Copper	7440-50-8	0.001	mg/L		**0.058**	**0.006**	**0.006**	**0.028**	**0.002**
Lead	7439-92-1	0.001	mg/L		**0.003**	**0.004**	**0.006**	**0.003**	**0.006**
Manganese	7439-96-5	0.001	mg/L		**0.027**	**0.884**	**14.6**	**0.310**	**0.304**
Nickel	7440-02-0	0.001	mg/L		<0.001	<0.001	**0.013**	**0.004**	<0.001
Zinc	7440-66-6	0.005	mg/L		**0.026**	**0.085**	**0.072**	**0.015**	**0.049**
Iron	7439-89-6	0.05	mg/L		**0.06**	**0.50**	**1.02**	**5.30**	**1.08**
EK040P: Fluoride by PC Titrator									
Fluoride	16984-48-8	0.1	mg/L		**2.2**	**1.1**	**0.5**	<0.1	**1.6**
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		**12.1**	**9.45**	**12.6**	**0.95**	**12.8**
Total Cations	----	0.01	meq/L		**12.4**	**9.77**	**12.9**	**0.91**	**12.9**
Ionic Balance	----	0.01	%		**1.08**	**1.68**	**1.04**	**----**	**0.61**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	MB04	MB03	MB05	FBU08	Saturday Bore
				Client sampling date / time	30-Mar-2017 09:30	30-Mar-2017 08:45	30-Mar-2017 15:00	30-Mar-2017 09:00	31-Mar-2017 07:30
Compound	CAS Number	LOR	Unit		EB1706945-006	EB1706945-007	EB1706945-008	EB1706945-009	EB1706945-010
					Result	Result	Result	Result	Result
EA005P: pH by PC Titrator									
pH Value	----	0.01	pH Unit		7.53	7.55	7.30	----	7.61
EA010P: Conductivity by PC Titrator									
Electrical Conductivity @ 25°C	----	1	µS/cm		907	1640	1220	----	1900
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		516	1030	687	----	943
EA025: Total Suspended Solids dried at 104 ± 2°C									
Suspended Solids (SS)	----	5	mg/L		37	9	27	----	82
ED037P: Alkalinity by PC Titrator									
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L		<1	<1	<1	----	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L		<1	<1	<1	----	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L		273	577	438	----	646
Total Alkalinity as CaCO3	----	1	mg/L		273	577	438	----	646
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		82	125	98	----	117
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L		74	46	91	----	147
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		64	43	81	<1	65
Magnesium	7439-95-4	1	mg/L		26	77	71	<1	48
Sodium	7440-23-5	1	mg/L		88	207	68	<1	215
Potassium	7440-09-7	1	mg/L		5	11	11	<1	10
ED093F: SAR and Hardness Calculations									
Total Hardness as CaCO3	----	1	mg/L		267	424	495	----	360
EG020F: Dissolved Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
Arsenic	7440-38-2	0.001	mg/L		<0.001	0.001	<0.001	<0.001	<0.001
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Copper	7440-50-8	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	7439-96-5	0.001	mg/L		0.116	0.002	0.686	<0.001	1.14
Nickel	7440-02-0	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L		0.012	<0.005	<0.005	<0.005	<0.005
Iron	7439-89-6	0.05	mg/L		<0.05	<0.05	<0.05	<0.05	<0.05

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	MB04	MB03	MB05	FBU08	Saturday Bore
				Client sampling date / time	30-Mar-2017 09:30	30-Mar-2017 08:45	30-Mar-2017 15:00	30-Mar-2017 09:00	31-Mar-2017 07:30
Compound	CAS Number	LOR	Unit		EB1706945-006	EB1706945-007	EB1706945-008	EB1706945-009	EB1706945-010
					Result	Result	Result	Result	Result
EG020T: Total Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		**0.60**	<0.01	**0.23**	<0.01	**0.98**
Arsenic	7440-38-2	0.001	mg/L		<0.001	**0.002**	**0.001**	<0.001	**0.001**
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Copper	7440-50-8	0.001	mg/L		**0.003**	<0.001	**0.004**	<0.001	**0.013**
Lead	7439-92-1	0.001	mg/L		**0.017**	<0.001	**0.004**	<0.001	**0.008**
Manganese	7439-96-5	0.001	mg/L		**0.225**	**0.003**	**2.67**	<0.001	**1.23**
Nickel	7440-02-0	0.001	mg/L		**0.001**	<0.001	**0.001**	<0.001	**0.002**
Zinc	7440-66-6	0.005	mg/L		**0.044**	**0.007**	**0.025**	<0.005	**0.106**
Iron	7439-89-6	0.05	mg/L		**0.88**	<0.05	**0.71**	<0.05	**2.38**
EK040P: Fluoride by PC Titrator									
Fluoride	16984-48-8	0.1	mg/L		**0.8**	**3.0**	**0.4**	**----**	**1.7**
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		**9.25**	**15.4**	**13.4**	**----**	**19.5**
Total Cations	----	0.01	meq/L		**9.29**	**17.8**	**13.1**	**----**	**16.8**
Ionic Balance	----	0.01	%		**0.22**	**7.05**	**0.88**	**----**	**7.41**

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB1713282**	Page	: 1 of 4
Client	: **MMGROUP LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR JONATHAN EDEN	Contact	: Joy Morgan
Address	: PO BOX 69 CLONCURRY QLD, AUSTRALIA 4824	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61-7-3243 7222
Project	: Sample Analysis	Date Samples Received	: 29-Jun-2017 09:00
Order number	: 4400092876	Date Analysis Commenced	: 29-Jun-2017
C-O-C number	: ----	Issue Date	: 04-Jul-2017 16:17
Sampler	: ANDREW DORGE		
Site	: ----		
Quote number	: BN/753/14 v5		
No. of samples received	: 4		
No. of samples analysed	: 4		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

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Signatories	*Position*	*Accreditation Category*
Andrew Epps	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

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When no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, the sampling date will be assumed by the laboratory and displayed in brackets without a time component.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- It is recognised that EG020T (Total Metals) is less than EG020F (Dissolved Metals) for some samples. However, the difference is within experimental variation of the methods.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	MB 02	MB 04	FBU08	CBU	----
				Client sampling date / time	26-Jun-2017 08:45	26-Jun-2017 12:00	26-Jun-2017 07:30	26-Jun-2017 12:30	----
Compound	CAS Number	LOR	Unit		EB1713282-001	EB1713282-002	EB1713282-003	EB1713282-004	--------
					Result	Result	Result	Result	----
EA005P: pH by PC Titrator									
pH Value	----	0.01	pH Unit		7.28	7.63	6.38	----	----
EA010P: Conductivity by PC Titrator									
Electrical Conductivity @ 25°C	----	1	µS/cm		1170	816	6	----	----
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		----	----	<10	----	----
Total Dissolved Solids @180°C	----	10	mg/L		723	538	----	----	----
EA025: Total Suspended Solids dried at 104 ± 2°C									
Suspended Solids (SS)	----	5	mg/L		<5	19	<5	----	----
ED037P: Alkalinity by PC Titrator									
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L		<1	<1	<1	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L		<1	<1	<1	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L		487	295	2	----	----
Total Alkalinity as CaCO3	----	1	mg/L		487	295	2	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		129	80	<1	----	----
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L		68	68	2	----	----
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		60	54	<1	----	----
Magnesium	7439-95-4	1	mg/L		45	23	<1	----	----
Sodium	7440-23-5	1	mg/L		118	90	3	----	----
Potassium	7440-09-7	1	mg/L		7	4	<1	----	----
ED093F: SAR and Hardness Calculations									
Total Hardness as CaCO3	----	1	mg/L		335	230	<1	----	----
EG020F: Dissolved Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		<0.01	<0.01	<0.01	----	----
Arsenic	7440-38-2	0.001	mg/L		<0.001	<0.001	<0.001	----	----
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	<0.0001	<0.0001	----	----
Copper	7440-50-8	0.001	mg/L		0.031	<0.001	<0.001	----	----
Lead	7439-92-1	0.001	mg/L		<0.001	<0.001	<0.001	----	----
Manganese	7439-96-5	0.001	mg/L		0.003	0.119	<0.001	----	----
Nickel	7440-02-0	0.001	mg/L		<0.001	<0.001	<0.001	----	----
Zinc	7440-66-6	0.005	mg/L		0.007	0.007	<0.005	----	----
Iron	7439-89-6	0.05	mg/L		<0.05	<0.05	<0.05	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	MB 02	MB 04	FBU08	CBU	----
				Client sampling date / time	26-Jun-2017 08:45	26-Jun-2017 12:00	26-Jun-2017 07:30	26-Jun-2017 12:30	----
Compound	CAS Number	LOR	Unit		EB1713282-001	EB1713282-002	EB1713282-003	EB1713282-004	--------
					Result	Result	Result	Result	----
EG020T: Total Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		**0.02**	**0.26**	<0.01	<0.01	----
Arsenic	7440-38-2	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	----
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	----
Copper	7440-50-8	0.001	mg/L		**0.068**	**0.002**	<0.001	<0.001	----
Lead	7439-92-1	0.001	mg/L		<0.001	**0.002**	<0.001	<0.001	----
Manganese	7439-96-5	0.001	mg/L		**0.016**	**0.161**	<0.001	<0.001	----
Nickel	7440-02-0	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	----
Zinc	7440-66-6	0.005	mg/L		<0.005	**0.021**	<0.005	<0.005	----
Iron	7439-89-6	0.05	mg/L		<0.05	**0.38**	<0.05	<0.05	----
EK040P: Fluoride by PC Titrator									
Fluoride	16984-48-8	0.1	mg/L		**2.2**	**0.8**	<0.1	----	----
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		**14.3**	**9.48**	**0.10**	----	----
Total Cations	----	0.01	meq/L		**12.0**	**8.60**	**0.13**	----	----
Ionic Balance	----	0.01	%		**8.82**	**4.83**	----	----	----

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB1720574**	Page	: 1 of 6
Client	: **MMGROUP LTD**	Laboratory	: Environmental Division Brisbane
Contact	: LORELLE GALLAGHER	Contact	: Joy Morgan
Address	: PO BOX 69 CLONCURRY QLD, AUSTRALIA 4824	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61-7-3243 7222
Project	: Sample Analysis	Date Samples Received	: 06-Oct-2017 11:25
Order number	: 4400092876	Date Analysis Commenced	: 09-Oct-2017
C-O-C number	: ----	Issue Date	: 13-Oct-2017 09:18
Sampler	: ANDREW DORGE		
Site	: ----		
Quote number	: BN/753/14 v6		
No. of samples received	: 13		
No. of samples analysed	: 10		

Accreditation No. 825
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Signatories	*Position*	*Accreditation Category*
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD

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LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- It is recognised that EG020-T (Total Metals by ICP-MS) is less than EG020-F (Dissolved Metals by ICP-MS) for some samples. However, the difference is within experimental variation of the methods.

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	Client sample ID	MB1	MB1 ab	MB2	MB2 ab	MB3
				Client sampling date / time	29-Sep-2017 10:50	29-Sep-2017 10:50	29-Sep-2017 08:25	29-Sep-2017 08:55	29-Sep-2017 16:05
					EB1720574-001	EB1720574-002	EB1720574-003	EB1720574-004	EB1720574-005
					Result	Result	Result	Result	Result
EA005P: pH by PC Titrator									
pH Value	----	0.01	pH Unit		**7.80**	**7.69**	**7.77**	**7.48**	**8.17**
EA010P: Conductivity by PC Titrator									
Electrical Conductivity @ 25°C	----	1	µS/cm		**1090**	**1190**	**1120**	**1140**	**1590**
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		**643**	**730**	**680**	**712**	**1080**
EA025: Total Suspended Solids dried at 104 ± 2°C									
Suspended Solids (SS)	----	5	mg/L		**39**	**128**	**20**	**270**	**21**
ED037P: Alkalinity by PC Titrator									
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L		<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L		<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L		**537**	**630**	**400**	**413**	**502**
Total Alkalinity as CaCO3	----	1	mg/L		**537**	**630**	**400**	**413**	**502**
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		**32**	**12**	**120**	**118**	**148**
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L		**48**	**37**	**66**	**67**	**60**
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		**72**	**47**	**63**	**119**	**19**
Magnesium	7439-95-4	1	mg/L		**68**	**59**	**46**	**42**	**79**
Sodium	7440-23-5	1	mg/L		**63**	**132**	**118**	**68**	**216**
Potassium	7440-09-7	1	mg/L		**9**	**14**	**6**	**4**	**12**
ED093F: SAR and Hardness Calculations									
Total Hardness as CaCO3	----	1	mg/L		**460**	**360**	**347**	**470**	**373**
EG020F: Dissolved Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
Arsenic	7440-38-2	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	**0.001**
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Copper	7440-50-8	0.001	mg/L		<0.001	<0.001	**0.044**	**0.003**	<0.001
Lead	7439-92-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	7439-96-5	0.001	mg/L		**0.047**	<0.001	**0.002**	**0.006**	<0.001
Nickel	7440-02-0	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L		<0.005	<0.005	**0.010**	<0.005	<0.005
Iron	7439-89-6	0.05	mg/L		<0.05	<0.05	<0.05	<0.05	<0.05

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	Client sample ID	MB1	MB1 ab	MB2	MB2 ab	MB3
				Client sampling date / time	29-Sep-2017 10:50	29-Sep-2017 10:50	29-Sep-2017 08:25	29-Sep-2017 08:55	29-Sep-2017 16:05
					EB1720574-001	EB1720574-002	EB1720574-003	EB1720574-004	EB1720574-005
					Result	Result	Result	Result	Result
EG020T: Total Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		**0.14**	**0.27**	**0.06**	**2.93**	**0.04**
Arsenic	7440-38-2	0.001	mg/L		<0.001	<0.001	**0.001**	**0.002**	**0.001**
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	<0.0001	<0.0001	**0.0001**	<0.0001
Copper	7440-50-8	0.001	mg/L		**0.037**	**0.013**	**0.065**	**0.025**	**0.004**
Lead	7439-92-1	0.001	mg/L		<0.001	<0.001	**0.002**	**0.003**	**0.002**
Manganese	7439-96-5	0.001	mg/L		**0.128**	**0.042**	**0.016**	**0.099**	**0.010**
Nickel	7440-02-0	0.001	mg/L		<0.001	<0.001	<0.001	**0.006**	<0.001
Zinc	7440-66-6	0.005	mg/L		**0.011**	**0.006**	**0.009**	**0.038**	**0.008**
Iron	7439-89-6	0.05	mg/L		**1.69**	**0.24**	<0.05	**3.22**	<0.05
EK040P: Fluoride by PC Titrator									
Fluoride	16984-48-8	0.1	mg/L		**1.8**	**3.8**	**2.9**	**1.0**	**3.3**
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		**12.7**	**13.9**	**12.4**	**12.6**	**14.8**
Total Cations	----	0.01	meq/L		**12.2**	**13.3**	**12.2**	**12.4**	**17.2**
Ionic Balance	----	0.01	%		**2.37**	**2.13**	**0.56**	**0.57**	**7.35**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	MB4	MB3 ab	MB4 ab	Saturday Bore	FBUB
				Client sampling date / time	29-Sep-2017 15:00	29-Sep-2017 16:35	29-Sep-2017 15:20	29-Sep-2017 07:45	29-Sep-2017 17:15
Compound	CAS Number	LOR	Unit		EB1720574-006	EB1720574-008	EB1720574-009	EB1720574-011	EB1720574-012
					Result	Result	Result	Result	Result
EA005P: pH by PC Titrator									
pH Value	----	0.01	pH Unit		7.68	7.73	7.14	7.80	6.39
EA010P: Conductivity by PC Titrator									
Electrical Conductivity @ 25°C	----	1	µS/cm		822	1430	2660	1750	6
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		559	1010	1910	1110	<10
EA025: Total Suspended Solids dried at 104 ± 2°C									
Suspended Solids (SS)	----	5	mg/L		16	52	6890	6	<5
ED037P: Alkalinity by PC Titrator									
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L		<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L		<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L		259	481	563	590	4
Total Alkalinity as CaCO3	----	1	mg/L		259	481	563	590	4
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		74	137	580	132	<1
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L		70	34	302	182	2
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		53	36	160	70	<1
Magnesium	7439-95-4	1	mg/L		23	58	69	52	<1
Sodium	7440-23-5	1	mg/L		85	200	370	241	1
Potassium	7440-09-7	1	mg/L		4	12	6	5	<1
ED093F: SAR and Hardness Calculations									
Total Hardness as CaCO3	----	1	mg/L		227	329	684	389	<1
EG020F: Dissolved Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
Arsenic	7440-38-2	0.001	mg/L		<0.001	0.001	0.002	<0.001	<0.001
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Copper	7440-50-8	0.001	mg/L		<0.001	<0.001	<0.001	0.002	<0.001
Lead	7439-92-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	7439-96-5	0.001	mg/L		0.137	0.004	1.32	1.45	<0.001
Nickel	7440-02-0	0.001	mg/L		<0.001	<0.001	<0.001	0.006	<0.001
Zinc	7440-66-6	0.005	mg/L		<0.005	<0.005	<0.005	0.005	<0.005
Iron	7439-89-6	0.05	mg/L		<0.05	<0.05	0.21	<0.05	<0.05

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	MB4	MB3 ab	MB4 ab	Saturday Bore	FBUB
				Client sampling date / time	29-Sep-2017 15:00	29-Sep-2017 16:35	29-Sep-2017 15:20	29-Sep-2017 07:45	29-Sep-2017 17:15
Compound	CAS Number	LOR	Unit		EB1720574-006	EB1720574-008	EB1720574-009	EB1720574-011	EB1720574-012
					Result	Result	Result	Result	Result
EG020T: Total Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		**0.17**	**1.33**	**154**	**0.09**	<0.01
Arsenic	7440-38-2	0.001	mg/L		<0.001	**0.001**	**0.025**	<0.001	<0.001
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	<0.0001	**0.0004**	<0.0001	<0.0001
Copper	7440-50-8	0.001	mg/L		**0.005**	**0.006**	**0.194**	**0.002**	<0.001
Lead	7439-92-1	0.001	mg/L		**0.002**	<0.001	**0.034**	<0.001	<0.001
Manganese	7439-96-5	0.001	mg/L		**0.168**	**0.191**	**6.94**	**1.64**	<0.001
Nickel	7440-02-0	0.001	mg/L		<0.001	**0.001**	**0.313**	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L		**0.018**	<0.005	**0.195**	**0.011**	<0.005
Iron	7439-89-6	0.05	mg/L		**0.22**	**1.41**	**207**	**0.12**	<0.05
EK040P: Fluoride by PC Titrator									
Fluoride	16984-48-8	0.1	mg/L		**0.9**	**3.5**	**1.4**	**2.1**	<0.1
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		**8.69**	**13.4**	**31.8**	**19.7**	**0.14**
Total Cations	----	0.01	meq/L		**8.34**	**15.6**	**29.9**	**18.4**	**0.04**
Ionic Balance	----	0.01	%		**2.07**	**7.43**	**3.13**	**3.38**	**----**

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB1803858**	Page	: 1 of 6
Client	: **MMGROUP LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MS LORELLE GALLAGHER	Contact	: Joy Morgan
Address	: PO BOX 69 CLONCURRY QLD, AUSTRALIA 4824	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: ----	Telephone	: +61-7-3243 7222
Project	: Quarterly Groundwater Feb	Date Samples Received	: 09-Feb-2018 13:50
Order number	: 4400209992	Date Analysis Commenced	: 10-Feb-2018
C-O-C number	: ----	Issue Date	: 15-Feb-2018 16:22
Sampler	: TOBIAS MORGAN		
Site	: ----		
Quote number	: BN/753/14 v6		
No. of samples received	: 11		
No. of samples analysed	: 10		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Andrew Epps	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Greg Vogel	Laboratory Manager	Brisbane Inorganics, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Tom Maloney	Nutrients Section Supervisor	Brisbane Inorganics, Stafford, QLD

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- It is recognised that EG020T (Total Metals) is less than EG020F (Dissolved Metals) for some samples. However, the difference is within experimental variation of the methods.
- Ionic Balance out of acceptable limits for some samples due to analytes not quantified in this report.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	MB2	MB4	MB1	MB9D	MB4AB
				Client sampling date / time	03-Feb-2018 10:50	04-Feb-2018 13:10	05-Feb-2018 12:20	06-Feb-2018 16:35	06-Feb-2018 14:10
Compound	CAS Number	LOR	Unit		EB1803858-001	EB1803858-002	EB1803858-003	EB1803858-004	EB1803858-005
					Result	Result	Result	Result	Result
EA005P: pH by PC Titrator									
pH Value	----	0.01	pH Unit		7.64	7.61	7.86	7.57	7.58
EA010P: Conductivity by PC Titrator									
Electrical Conductivity @ 25°C	----	1	µS/cm		1150	1310	1100	1180	2370
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		792	801	640	670	1530
EA025: Total Suspended Solids dried at 104 ± 2°C									
Suspended Solids (SS)	----	5	mg/L		<5	<5	80	22	271
ED037P: Alkalinity by PC Titrator									
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L		<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L		<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L		362	508	541	424	518
Total Alkalinity as CaCO3	----	1	mg/L		362	508	541	424	518
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		151	96	22	44	464
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L		63	76	40	113	237
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		100	94	72	88	138
Magnesium	7439-95-4	1	mg/L		52	58	85	88	63
Sodium	7440-23-5	1	mg/L		88	128	60	36	327
Potassium	7440-09-7	1	mg/L		6	6	11	15	6
ED093F: SAR and Hardness Calculations									
Total Hardness as CaCO3	----	1	mg/L		464	474	530	582	604
EG020F: Dissolved Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
Arsenic	7440-38-2	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	0.003
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Copper	7440-50-8	0.001	mg/L		0.036	<0.001	<0.001	0.002	<0.001
Lead	7439-92-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	7439-96-5	0.001	mg/L		0.031	0.013	0.028	0.003	0.953
Nickel	7440-02-0	0.001	mg/L		0.003	0.003	0.004	0.003	0.004
Zinc	7440-66-6	0.005	mg/L		<0.005	<0.005	<0.005	0.048	0.030
Iron	7439-89-6	0.05	mg/L		<0.05	<0.05	<0.05	<0.05	0.19

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	Client sample ID	MB2	MB4	MB1	MB9D	MB4AB
				Client sampling date / time	03-Feb-2018 10:50	04-Feb-2018 13:10	05-Feb-2018 12:20	06-Feb-2018 16:35	06-Feb-2018 14:10
					EB1803858-001	EB1803858-002	EB1803858-003	EB1803858-004	EB1803858-005
					Result	Result	Result	Result	Result
EG020T: Total Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		<0.01	<0.01	**0.10**	**0.20**	**5.59**
Arsenic	7440-38-2	0.001	mg/L		**0.001**	<0.001	<0.001	**0.001**	**0.004**
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	<0.0001	<0.0001	**0.0002**	<0.0001
Copper	7440-50-8	0.001	mg/L		**0.037**	<0.001	<0.001	**0.004**	**0.009**
Lead	7439-92-1	0.001	mg/L		<0.001	<0.001	<0.001	**0.012**	**0.005**
Manganese	7439-96-5	0.001	mg/L		**0.030**	**0.013**	**0.035**	**0.331**	**1.20**
Nickel	7440-02-0	0.001	mg/L		<0.001	<0.001	**0.003**	<0.001	**0.013**
Zinc	7440-66-6	0.005	mg/L		<0.005	**0.006**	**0.050**	**0.094**	**0.042**
Iron	7439-89-6	0.05	mg/L		<0.05	<0.05	**0.19**	**0.37**	**9.90**
EK040P: Fluoride by PC Titrator									
Fluoride	16984-48-8	0.1	mg/L		**1.8**	**1.5**	**1.8**	**0.5**	**1.2**
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		**12.2**	**14.3**	**12.4**	**12.6**	**26.7**
Total Cations	----	0.01	meq/L		**13.2**	**15.2**	**13.5**	**13.6**	**26.4**
Ionic Balance	----	0.01	%		**4.32**	**3.03**	**4.19**	**3.85**	**0.46**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	MB3	MB3AB	MB1AB	MB2AB	Saturday Bore
				Client sampling date / time	06-Feb-2018 11:30	06-Feb-2018 11:50	06-Feb-2018 10:00	08-Feb-2018 10:00	08-Feb-2018 13:00
Compound	CAS Number	LOR	Unit		EB1803858-006	EB1803858-007	EB1803858-008	EB1803858-009	EB1803858-010
					Result	Result	Result	Result	Result
EA005P: pH by PC Titrator									
pH Value	----	0.01	pH Unit		7.81	8.03	7.88	7.69	7.74
EA010P: Conductivity by PC Titrator									
Electrical Conductivity @ 25°C	----	1	µS/cm		2790	1750	1260	1130	1750
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		2000	1120	777	758	1040
EA025: Total Suspended Solids dried at 104 ± 2°C									
Suspended Solids (SS)	----	5	mg/L		5	143	371	172	<5
ED037P: Alkalinity by PC Titrator									
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L		<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L		<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L		516	714	657	362	559
Total Alkalinity as CaCO3	----	1	mg/L		516	714	657	362	559
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		312	97	11	145	155
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L		122	46	31	64	169
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		87	37	49	111	77
Magnesium	7439-95-4	1	mg/L		155	65	72	41	57
Sodium	7440-23-5	1	mg/L		307	297	142	82	246
Potassium	7440-09-7	1	mg/L		16	14	16	4	5
ED093F: SAR and Hardness Calculations									
Total Hardness as CaCO3	----	1	mg/L		856	360	419	446	427
EG020F: Dissolved Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
Arsenic	7440-38-2	0.001	mg/L		0.001	0.001	<0.001	<0.001	0.001
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	<0.0001	0.0002	<0.0001	<0.0001
Copper	7440-50-8	0.001	mg/L		0.001	0.002	0.007	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	7439-96-5	0.001	mg/L		<0.001	0.002	0.013	0.068	0.595
Nickel	7440-02-0	0.001	mg/L		0.003	0.002	0.003	0.002	0.003
Zinc	7440-66-6	0.005	mg/L		<0.005	0.034	0.223	<0.005	<0.005
Iron	7439-89-6	0.05	mg/L		<0.05	<0.05	<0.05	<0.05	0.08

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	Client sample ID	MB3	MB3AB	MB1AB	MB2AB	Saturday Bore
				Client sampling date / time	06-Feb-2018 11:30	06-Feb-2018 11:50	06-Feb-2018 10:00	08-Feb-2018 10:00	08-Feb-2018 13:00
					EB1803858-006	EB1803858-007	EB1803858-008	EB1803858-009	EB1803858-010
					Result	Result	Result	Result	Result
EG020T: Total Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		<0.01	**5.88**	**2.93**	**3.34**	<0.01
Arsenic	7440-38-2	0.001	mg/L		**0.001**	**0.002**	**0.002**	**0.002**	**0.001**
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	<0.0001	**0.0007**	<0.0001	<0.0001
Copper	7440-50-8	0.001	mg/L		<0.001	**0.011**	**0.019**	**0.020**	<0.001
Lead	7439-92-1	0.001	mg/L		<0.001	**0.006**	**0.042**	**0.008**	<0.001
Manganese	7439-96-5	0.001	mg/L		<0.001	**0.783**	**0.170**	**0.159**	**0.675**
Nickel	7440-02-0	0.001	mg/L		<0.001	**0.006**	**0.004**	**0.006**	**0.003**
Zinc	7440-66-6	0.005	mg/L		**0.007**	**0.062**	**0.556**	**0.070**	**0.008**
Iron	7439-89-6	0.05	mg/L		<0.05	**4.88**	**2.70**	**3.61**	**0.13**
EK040P: Fluoride by PC Titrator									
Fluoride	16984-48-8	0.1	mg/L		**2.9**	**3.3**	**3.6**	**0.9**	**1.9**
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		**20.2**	**17.6**	**14.2**	**12.0**	**19.2**
Total Cations	----	0.01	meq/L		**30.9**	**20.5**	**15.0**	**12.6**	**19.4**
Ionic Balance	----	0.01	%		**20.8**	**7.59**	**2.49**	**2.13**	**0.52**

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **ET1803049**	Page	: 1 of 6
Amendment	: **1**		
Client	: **MMG GROUP LTD**	Laboratory	: Environmental Division Townsville
Contact	: MS ALISON STERNES	Contact	: Joy Morgan
Address	: PO BOX 69 CLONCURRY QLD, AUSTRALIA 4824	Address	: 13 Carlton Street, Kirwan Townsville QLD Australia 4814
Telephone	: ----	Telephone	: +61 7 4773 0030
Project	: GWM_181123_0000	Date Samples Received	: 29-Nov-2018 11:00
Order number	: 4400209992	Date Analysis Commenced	: 29-Nov-2018
C-O-C number	: ----	Issue Date	: 02-Jan-2019 11:22
Sampler	: ALISON STERNES		
Site	: ----		
Quote number	: BN/753/14 v10		
No. of samples received	: 9		
No. of samples analysed	: 9		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Dilani Fernando	Senior Inorganic Chemist	Melbourne Inorganics, Springvale, VIC
Greg Vogel		Townsville Inorganics, Townsville, QLD
Kim McCabe		Townsville Inorganics, Townsville, QLD

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- ED093F: ET1803049 #4, the results for Cations have been confirmed by re-preparation and re-analysis.
- It is recognised that total metals are less than dissolved metals for samples #1, 2, 3, 4, 6 and 9. However, the difference is within experimental variation of the methods.
- EG020T: ET1803049#7 results for total Manganese have been confirmed by re-digestion and re-analysis.
- All remaining analysis conducted by ALS Townsville, NATA accreditation no. 825, (Site no. 23313)
- EN055-PG, ED093F, EG020F, EG020T conducted by ALS Melbourne, NATA accreditation no. 825, site no 13778
- Ionic Balance out of acceptable limits for sample #4 due to analytes not quantified in this report. cations and aniona have been confirmed by re-analysis
- Amendment (2/01/2019): This report has been amended to alter project reference code as requested by the client. All analysis results are as per the previous report.
- Ionic balances were calculated using: major anions - chloride, alkalinity and sulfate; and major cations - calcium, magnesium, potassium and sodium.
- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	Saturday Bore	MB2	DSU-08	MB3	MB1
				Client sampling date / time	22-Nov-2018 00:00	22-Nov-2018 00:00	22-Nov-2018 00:00	22-Nov-2018 00:00	23-Nov-2018 00:00
Compound	CAS Number	LOR	Unit		ET1803049-001	ET1803049-002	ET1803049-003	ET1803049-004	ET1803049-005
					Result	Result	Result	Result	Result
EA005P: pH by PC Titrator									
pH Value	----	0.01	pH Unit		7.43	7.53	7.67	7.50	7.77
EA010P: Conductivity by PC Titrator									
Electrical Conductivity @ 25°C	----	1	µS/cm		1760	1030	1030	4300	1090
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		1070	630	664	3220	620
EA025: Total Suspended Solids dried at 104 ± 2°C									
Suspended Solids (SS)	----	5	mg/L		<5	<5	<5	<5	28
ED037P: Alkalinity by PC Titrator									
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L		<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L		<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L		510	323	328	433	498
Total Alkalinity as CaCO3	----	1	mg/L		510	323	328	433	498
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		175	147	152	601	18
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L		175	54	55	169	95
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		75	76	74	150	62
Magnesium	7439-95-4	1	mg/L		51	38	37	253	68
Sodium	7440-23-5	1	mg/L		198	81	79	376	59
Potassium	7440-09-7	1	mg/L		4	5	5	23	9
ED093F: SAR and Hardness Calculations									
Total Hardness as CaCO3	----	1	mg/L		397	346	337	1420	435
EG020F: Dissolved Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
Arsenic	7440-38-2	0.001	mg/L		<0.001	<0.001	<0.001	0.001	0.001
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Copper	7440-50-8	0.001	mg/L		<0.001	0.025	0.026	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	7439-96-5	0.001	mg/L		0.960	0.101	0.101	<0.001	0.041
Nickel	7440-02-0	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L		<0.005	<0.005	<0.005	<0.005	0.023
Iron	7439-89-6	0.05	mg/L		0.13	<0.05	<0.05	<0.05	<0.05

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	Saturday Bore	MB2	DSU-08	MB3	MB1
				Client sampling date / time	22-Nov-2018 00:00	22-Nov-2018 00:00	22-Nov-2018 00:00	22-Nov-2018 00:00	23-Nov-2018 00:00
Compound	CAS Number	LOR	Unit		ET1803049-001	ET1803049-002	ET1803049-003	ET1803049-004	ET1803049-005
					Result	Result	Result	Result	Result
EG020T: Total Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	**0.05**
Arsenic	7440-38-2	0.001	mg/L		**0.001**	<0.001	<0.001	<0.001	**0.002**
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Copper	7440-50-8	0.001	mg/L		<0.001	**0.027**	**0.027**	<0.001	**0.001**
Lead	7439-92-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	**0.007**
Manganese	7439-96-5	0.001	mg/L		**0.877**	**0.088**	**0.087**	<0.001	**0.076**
Nickel	7440-02-0	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L		<0.005	<0.005	<0.005	<0.005	**0.042**
Iron	7439-89-6	0.05	mg/L		**0.14**	<0.05	<0.05	<0.05	**0.36**
EK040P: Fluoride by PC Titrator									
Fluoride	16984-48-8	0.1	mg/L		**0.9**	**1.2**	**1.2**	**1.4**	**0.9**
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		**18.8**	**11.0**	**11.3**	**25.9**	**13.0**
Total Cations	----	0.01	meq/L		**16.6**	**10.6**	**10.3**	**45.2**	**11.5**
Ionic Balance	----	0.01	%		**5.97**	**2.16**	**4.48**	**27.1**	**6.20**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	MB4	MB9D	MB5	MB6	----
				Client sampling date / time	23-Nov-2018 00:00	24-Nov-2018 00:00	24-Nov-2018 00:00	24-Nov-2018 00:00	----
Compound	CAS Number	LOR	Unit		ET1803049-006	ET1803049-007	ET1803049-008	ET1803049-009	--------
					Result	Result	Result	Result	----
EA005P: pH by PC Titrator									
pH Value	----	0.01	pH Unit		7.71	7.33	7.56	7.42	----
EA010P: Conductivity by PC Titrator									
Electrical Conductivity @ 25°C	----	1	µS/cm		879	1140	1180	786	----
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		508	646	682	444	----
EA025: Total Suspended Solids dried at 104 ± 2°C									
Suspended Solids (SS)	----	5	mg/L		6	264	102	38	----
ED037P: Alkalinity by PC Titrator									
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L		<1	<1	<1	<1	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L		<1	<1	<1	<1	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L		272	396	408	381	----
Total Alkalinity as CaCO3	----	1	mg/L		272	396	408	381	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		71	40	98	8	----
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L		61	113	85	26	----
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		51	81	78	71	----
Magnesium	7439-95-4	1	mg/L		28	76	66	26	----
Sodium	7440-23-5	1	mg/L		86	32	65	46	----
Potassium	7440-09-7	1	mg/L		5	13	11	10	----
ED093F: SAR and Hardness Calculations									
Total Hardness as CaCO3	----	1	mg/L		243	515	466	284	----
EG020F: Dissolved Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		<0.01	<0.01	<0.01	0.02	----
Arsenic	7440-38-2	0.001	mg/L		<0.001	<0.001	<0.001	0.005	----
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	0.0002	0.0002	0.0001	----
Copper	7440-50-8	0.001	mg/L		0.002	<0.001	0.003	0.002	----
Lead	7439-92-1	0.001	mg/L		<0.001	<0.001	0.001	0.003	----
Manganese	7439-96-5	0.001	mg/L		0.015	0.620	0.616	0.549	----
Nickel	7440-02-0	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	----
Zinc	7440-66-6	0.005	mg/L		0.028	0.030	0.099	0.086	----
Iron	7439-89-6	0.05	mg/L		<0.05	<0.05	<0.05	0.06	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	MB4	MB9D	MB5	MB6	----
				Client sampling date / time	23-Nov-2018 00:00	24-Nov-2018 00:00	24-Nov-2018 00:00	24-Nov-2018 00:00	----
Compound	CAS Number	LOR	Unit		ET1803049-006	ET1803049-007	ET1803049-008	ET1803049-009	--------
					Result	Result	Result	Result	----
EG020T: Total Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		**0.03**	**4.66**	**0.05**	**0.10**	**----**
Arsenic	7440-38-2	0.001	mg/L		<0.001	**0.006**	**0.001**	**0.006**	**----**
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	**0.0008**	**0.0002**	**0.0003**	**----**
Copper	7440-50-8	0.001	mg/L		**0.001**	**0.042**	**0.003**	**0.005**	**----**
Lead	7439-92-1	0.001	mg/L		**0.004**	**0.068**	**0.010**	**0.014**	**----**
Manganese	7439-96-5	0.001	mg/L		**0.028**	**1.60**	**0.711**	**0.481**	**----**
Nickel	7440-02-0	0.001	mg/L		<0.001	**0.008**	<0.001	<0.001	**----**
Zinc	7440-66-6	0.005	mg/L		**0.051**	**0.275**	**0.116**	**0.217**	**----**
Iron	7439-89-6	0.05	mg/L		**0.07**	**5.00**	**0.12**	**0.22**	**----**
EK040P: Fluoride by PC Titrator									
Fluoride	16984-48-8	0.1	mg/L		**0.4**	**0.2**	**0.2**	**0.5**	**----**
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		**8.63**	**11.9**	**12.6**	**8.51**	**----**
Total Cations	----	0.01	meq/L		**8.72**	**12.0**	**12.4**	**7.94**	**----**
Ionic Balance	----	0.01	%		**0.49**	**0.37**	**0.63**	**3.48**	**----**

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **ET1900886**	Page	: 1 of 6
Client	: **MMG GROUP LTD**	Laboratory	: Environmental Division Townsville
Contact	: CARL RIECK	Contact	: Joy Morgan
Address	: PO BOX 69 CLONCURRY QLD, AUSTRALIA 4824	Address	: 13 Carlton Street, Kirwan Townsville QLD Australia 4814
Telephone	: ----	Telephone	: +61 7 4773 0030
Project	: GWM_190312_0000	Date Samples Received	: 14-Mar-2019 10:30
Order number	: 4200001897	Date Analysis Commenced	: 14-Mar-2019
C-O-C number	: ----	Issue Date	: 27-Mar-2019 11:23
Sampler	: CARL RIECK		
Site	: ----		
Quote number	: BN/753/14 v10		
No. of samples received	: 6		
No. of samples analysed	: 6		

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Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Kim McCabe		Townsville Inorganics, Townsville, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Narelle Drummond	Analyst	Townsville Inorganics, Townsville, QLD

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- TSS by EA-025 may bias low due to fine particulate matter passing through the prescribed filter.
- TDS by method EA-015 may bias high due to the presence of fine particulate matter, which may pass through the prescribed GF/C paper.
- TDS by method EA-015 result confirmed.
- All remaining analysis conducted by ALS Townsville, NATA accreditation no. 825, (Site no. 23313)
- Ionic Balance out of acceptable limits for sample MB3 due to analytes not quantified in this report.
- It is recognised that EG020-T (Total Metals by ICP-MS) is less than EG020-F (Dissolved Metals by ICP-MS) for some samples. However, the difference is within experimental variation of the methods.
- Sodium Adsorption Ratio (where reported): Where results for Na, Ca or Mg are <LOR, a concentration at half the reported LOR is incorporated into the SAR calculation. This represents a conservative approach for Na relative to the assumption that <LOR = zero concentration and a conservative approach for Ca & Mg relative to the assumption that <LOR is equivalent to the LOR concentration.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	MB1 142472	MB3 142473	MB4 142474	MB5 142475	MB6 142476
				Client sampling date / time	12-Mar-2019 08:00	09-Mar-2019 12:30	11-Mar-2019 16:00	09-Mar-2019 15:40	09-Mar-2019 14:30
Compound	CAS Number	LOR	Unit		ET1900886-001	ET1900886-002	ET1900886-003	ET1900886-004	ET1900886-005
					Result	Result	Result	Result	Result
EA005P: pH by PC Titrator									
pH Value	----	0.01	pH Unit		7.31	7.25	7.14	7.09	7.16
EA010P: Conductivity by PC Titrator									
Electrical Conductivity @ 25°C	----	1	µS/cm		1030	4100	1290	1160	806
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		639	3400	766	668	454
EA025: Total Suspended Solids dried at 104 ± 2°C									
Suspended Solids (SS)	----	5	mg/L		<5	<5	<5	<5	12
EA045: Turbidity									
Turbidity	----	0.1	NTU		0.5	<0.1	0.2	1.0	3.1
ED037P: Alkalinity by PC Titrator									
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L		<1	<1	<1	<1	<1
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L		<1	<1	<1	<1	<1
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L		532	446	523	428	420
Total Alkalinity as CaCO3	----	1	mg/L		532	446	523	428	420
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		23	698	103	103	6
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L		40	162	77	85	23
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		71	153	94	81	85
Magnesium	7439-95-4	1	mg/L		74	249	54	71	26
Sodium	7440-23-5	1	mg/L		61	393	127	69	44
Potassium	7440-09-7	1	mg/L		10	20	6	10	8
ED093F: SAR and Hardness Calculations									
Total Hardness as CaCO3	----	1	mg/L		482	1410	457	495	319
EG020F: Dissolved Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		<0.01	<0.01	<0.01	<0.01	<0.01
Arsenic	7440-38-2	0.001	mg/L		0.001	0.001	<0.001	<0.001	0.005
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Copper	7440-50-8	0.001	mg/L		<0.001	0.002	<0.001	<0.001	0.002
Lead	7439-92-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	7439-96-5	0.001	mg/L		0.042	<0.001	0.016	0.676	0.397
Nickel	7440-02-0	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001

Analytical Results

Sub-Matrix: **WATER**
(Matrix: **WATER**)

Compound	CAS Number	LOR	Unit	Client sample ID	MB1 142472	MB3 142473	MB4 142474	MB5 142475	MB6 142476
				Client sampling date / time	12-Mar-2019 08:00	09-Mar-2019 12:30	11-Mar-2019 16:00	09-Mar-2019 15:40	09-Mar-2019 14:30
					ET1900886-001	ET1900886-002	ET1900886-003	ET1900886-004	ET1900886-005
					Result	Result	Result	Result	Result
EG020F: Dissolved Metals by ICP-MS - Continued									
Zinc	7440-66-6	0.005	mg/L		<0.005	**0.006**	<0.005	<0.005	**0.035**
Iron	7439-89-6	0.05	mg/L		**0.06**	<0.05	<0.05	**0.18**	**0.06**
EG020T: Total Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		**0.05**	<0.01	<0.01	<0.01	**0.21**
Arsenic	7440-38-2	0.001	mg/L		**0.001**	**0.001**	<0.001	<0.001	**0.006**
Cadmium	7440-43-9	0.0001	mg/L		**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0001**
Copper	7440-50-8	0.001	mg/L		<0.001	**0.002**	<0.001	<0.001	**0.004**
Lead	7439-92-1	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	<0.001
Manganese	7439-96-5	0.001	mg/L		**0.049**	<0.001	**0.015**	**0.667**	**0.497**
Nickel	7440-02-0	0.001	mg/L		<0.001	<0.001	<0.001	<0.001	**0.002**
Zinc	7440-66-6	0.005	mg/L		<0.005	<0.005	<0.005	<0.005	**0.056**
Iron	7439-89-6	0.05	mg/L		**0.12**	<0.05	<0.05	**0.19**	**0.32**
EK040P: Fluoride by PC Titrator									
Fluoride	16984-48-8	0.1	mg/L		**1.6**	**2.4**	**1.4**	**0.4**	**1.0**
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		**12.2**	**28.0**	**14.8**	**13.1**	**9.16**
Total Cations	----	0.01	meq/L		**12.5**	**45.7**	**14.8**	**13.1**	**8.50**
Ionic Balance	----	0.01	%		**1.23**	**24.0**	**0.16**	**0.19**	**3.77**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	MB9D 142477	----	----	----	----
				Client sampling date / time	09-Mar-2019 17:00	----	----	----	----
Compound	CAS Number	LOR	Unit		ET1900886-006	--------	--------	--------	--------
					Result	----	----	----	----
EA005P: pH by PC Titrator									
pH Value	----	0.01	pH Unit		**7.18**	----	----	----	----
EA010P: Conductivity by PC Titrator									
Electrical Conductivity @ 25°C	----	1	µS/cm		**1130**	----	----	----	----
EA015: Total Dissolved Solids dried at 180 ± 5 °C									
Total Dissolved Solids @180°C	----	10	mg/L		**662**	----	----	----	----
EA025: Total Suspended Solids dried at 104 ± 2°C									
Suspended Solids (SS)	----	5	mg/L		**784**	----	----	----	----
EA045: Turbidity									
Turbidity	----	0.1	NTU		**664**	----	----	----	----
ED037P: Alkalinity by PC Titrator									
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L		<1	----	----	----	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L		<1	----	----	----	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L		**418**	----	----	----	----
Total Alkalinity as CaCO3	----	1	mg/L		**418**	----	----	----	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA									
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L		**52**	----	----	----	----
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	1	mg/L		**116**	----	----	----	----
ED093F: Dissolved Major Cations									
Calcium	7440-70-2	1	mg/L		**84**	----	----	----	----
Magnesium	7439-95-4	1	mg/L		**81**	----	----	----	----
Sodium	7440-23-5	1	mg/L		**36**	----	----	----	----
Potassium	7440-09-7	1	mg/L		**13**	----	----	----	----
ED093F: SAR and Hardness Calculations									
Total Hardness as CaCO3	----	1	mg/L		**543**	----	----	----	----
EG020F: Dissolved Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		<0.01	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L		<0.001	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L		**0.0004**	----	----	----	----
Copper	7440-50-8	0.001	mg/L		**0.005**	----	----	----	----
Lead	7439-92-1	0.001	mg/L		<0.001	----	----	----	----
Manganese	7439-96-5	0.001	mg/L		**0.470**	----	----	----	----
Nickel	7440-02-0	0.001	mg/L		**0.003**	----	----	----	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	MB9D 142477	----	----	----	----
				Client sampling date / time	09-Mar-2019 17:00	----	----	----	----
Compound	CAS Number	LOR	Unit		ET1900886-006	--------	--------	--------	--------
					Result	----	----	----	----
EG020F: Dissolved Metals by ICP-MS - Continued									
Zinc	7440-66-6	0.005	mg/L		**0.100**	----	----	----	----
Iron	7439-89-6	0.05	mg/L		<0.05	----	----	----	----
EG020T: Total Metals by ICP-MS									
Aluminium	7429-90-5	0.01	mg/L		**7.60**	----	----	----	----
Arsenic	7440-38-2	0.001	mg/L		**0.008**	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L		**0.0013**	----	----	----	----
Copper	7440-50-8	0.001	mg/L		**0.063**	----	----	----	----
Lead	7439-92-1	0.001	mg/L		**0.093**	----	----	----	----
Manganese	7439-96-5	0.001	mg/L		**1.14**	----	----	----	----
Nickel	7440-02-0	0.001	mg/L		**0.019**	----	----	----	----
Zinc	7440-66-6	0.005	mg/L		**0.492**	----	----	----	----
Iron	7439-89-6	0.05	mg/L		**11.0**	----	----	----	----
EK040P: Fluoride by PC Titrator									
Fluoride	16984-48-8	0.1	mg/L		**0.5**	----	----	----	----
EN055: Ionic Balance									
Total Anions	----	0.01	meq/L		**12.7**	----	----	----	----
Total Cations	----	0.01	meq/L		**12.8**	----	----	----	----
Ionic Balance	----	0.01	%		**0.20**	----	----	----	----

Appendix C

Memorandum Surface Subsidence Geotechnical Risk Review



MEMORANDUM

To	Jonathon Crosbie, Martin Brownlee
Cc	Charles Smith, Adam Barton, Tim Akroyd
From	Madeline Merrett
Date	19/05/2020
Subject	**DRM SURFACE SUBSIDENCE RISK**

MEMORANDUM SURFACE SUBSIDENCE GEOTECHNICAL RISK REVIEW

BACKGROUND

As part of the DRM Progressive Closure and Rehabilitation Plan (PRCP), the surface and underground subsidence risk needs to be reviewed to ensure long term stability. As part of the Department of Environment and Science progressive rehab and closure guidelines a geotechnical study must be completed on surface subsidence risk and should include the following:

- Post closure stabilisation of underground workings (Geotechnical assessment of the stability of the underground openings, assessment of ground water conditions and ground water impacts on the design)
- Sealing off surface openings to underground workings (Geotechnical assessment of bulkhead materials, competency and stability of the ground containing the bulkhead, the need for additional ground support and reinforcement)
- Extent of post closure residual subsidence of underground workings (Geotechnical assessment of the stability of the underground openings and over burden, surface and ground water conditions and ground water impacts on subsidence)

INTRODUCTION

The Dugald Rive Mine crown pillar and mine extraction method has been designed to ensure long term stability and prevent surface and underground subsidence. The primary purpose of the crown pillar is to protect surface land users, the mine, and all those who work within the mine. It is vital that the surface pillar remains stable throughout the life of the mine and remain stable beyond this time. Dugald River mine has adopted a sub level open stope mine method with backfill to increase the long-term stability of the mine and ensure consolidation of voids. The crown pillar has been designed to prevent surface subsidence and underground stope design guidelines are in place to prevent cave like failure underground.

All geotechnical risk on site at Dugald River Mine are captured in the ground control risk bowtie and the Ground Control Management Plan (GCMP). Previous work has been completed by consultants on the stability and design of the crown pillar and the influence of ground water on the stability of the mine which all form a part of the GCMP.

WEATHERING

Weathering varies across the Dugald River deposit from gossan to a shallow weathering profile. The gossan marks the outcropping line of lode and extends along the crest of a low ridge for >2 km and at a width of up to 10 m. Weathering is a critical component of the rock mass characterisation and will have a significant impact on the overall crown pillar stability.

The DRM weathering and leaching depths are estimated in the following table:

Table 1: DRM Weathering Depths (AMC 2011)

	Hanging wall	Dugald Lode	Footwall
Base of complete Oxidation	12m	Variable	1m
Base of Leaching	31.5m	Variable	5m

Weathering to significantly greater depths is likely down sheared or faulted zones that intersect the surface particularly along the contact of the Dugald lode with the hangingwall and footwall slates.

The following assumptions have been made regarding the weathering profile for the crown pillar design (AMC 2011)

- Within the hangingwall, extremely to partially weathered rock can extend to depths of approximately 30m. Rock that is slightly weathered or weathered only on fractures, may extend to a depth in the order of 40m.
- Within the Dugald Lode and Footwall sequence, the weathering profile is shallow. In the absence of significant shears or fault zones, extremely to partially weathered rock may extend to depths of approximately 1m. Beyond 5m depth, weathering is only expected on fractures.

To ensure long term stability the crown pillar has been designed in fresh rock, below the level of significant weathering (Figure 1)

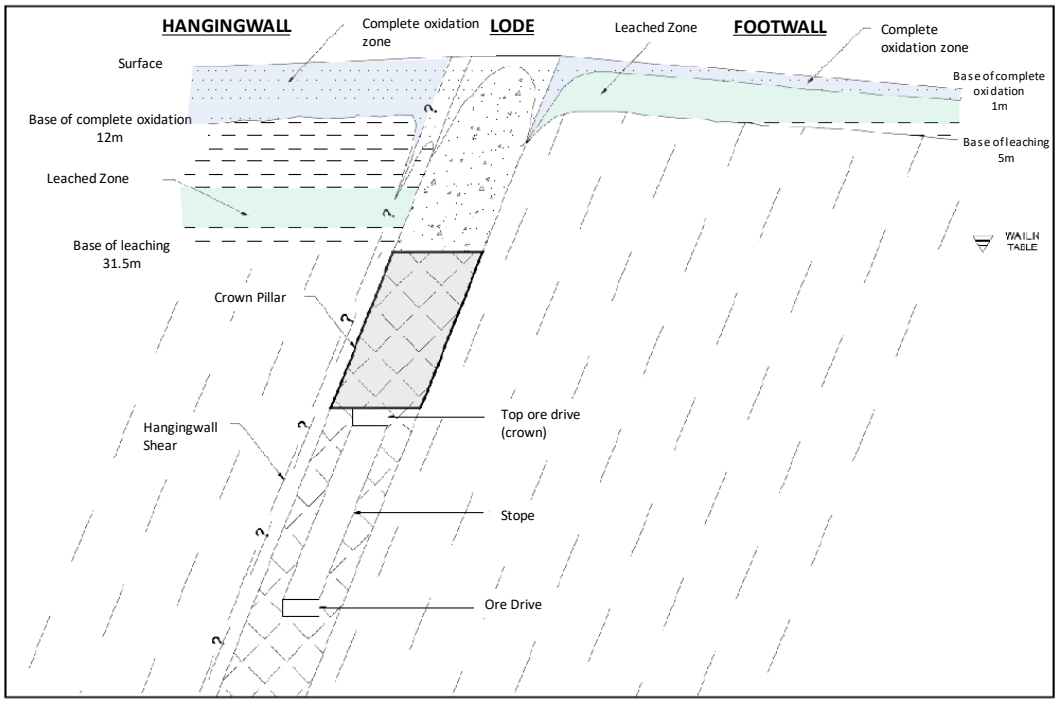


Figure 1 DRM Depth of Weathering

GROUND WATER

The Dugald River hydrogeological conditions have been summarised in the document MMG Dugald River Mine Groundwater Monitoring Program (Big Dog Hydrogeology, September 2014) and in the Environmental Impact Statement (Rob Lait & Associates, 2010).

The following observations were outlined:

- Ground water depths, in bores around the project, range from 10.1m to 230m depth, with a median depth of 31.5m.

- Flows range from 0.13L/s to 9.3L/s, with a median value of 0.98L/s, with groundwater flows in excess of 2L/s being the exception
- The geological units around the Dugald River Project are not highly productive and the majority of the ground water occurs at shallow depths
- Very minor supplies of groundwater occur in the Dugald River Slates, which form the immediate hanging wall and footwall of the Dugald Lode.
- The gradient of the potentiometric surface is 0.009, which is typical of low bulk permeability.
- Ground water flow occurs predominantly in zones of fracturing close to the base of weathering in metasediments.
- Overall, the mining observations to date indicate low to moderate permeability for fracture zones within the Dugald River slate, with limited ground water storage.

Groundwater samples have been taken underground from STH-175 Level, STH Stock Pile _1 and NTH Stock Pile 3. Generally, water flow into development at Dugald River Mine can be classified between wet and dripping.

Table 2 Ground Water Testing

Location	Electrical Conductivity (EC) µS/cm	TDS Mg/L ppm	pH	Temperature	Redox mV	Dissolved Oxygen % Sat
STH_175	1722	682	7.5	31.2	-108.7	10.4
STH_SP1	1545	612	6.06	30.5	-55.8	5.2
NTH_SP3	2055	814	7.34	30.2	-29.2	13.1

An assessment of the corrosivity of the ground water (MMG Internal File Note, December 2013) identified that the following:

- Groundwater intersected in development is associated with faults.
- Given the dissolved oxygen reading a corrosion rate of 0.12 (wet) to 0.20 mm/yr (dripping) can be expected.

CROWN PILLAR STABILITY (SURFACE SUBSIDENCE)

AMC Consultants completed a study in March 2011 to investigate the geotechnical conditions of the crown surface pillar for the Dugald River Project (Dugald River Crown Pillar Assessment – AMC 111005 March 2011). As part of this study AMC assessed the weathering profile, depth of the water table and crown pillar stability and size.

Standard empirical assessment techniques based on ground conditions and Lode Geometry was used to determine the appropriate crown pillar size and thickness along the length of the orebody. Rock mass Quality Q (after Barton et al, 1974) was used to assess the rock mass and the scaled crown span concept and Critical span limits developed by Carter (1992) was used to assess the stability of the crown pillar.

It is assumed that any crown pillar instability at Dugald River mine will be the result of a significant geological feature such as faults or shears. The Dugald River rock mass data indicates that the overall rock mass quality of the Dugald Lode is better than the host slate material.

To ensure long term stability the crown pillar has been designed in fresh rock, below the level of significant weathering. The top-level stopes beneath the crown must also be backfilled, as tight as practically possible, to minimise the change of hangingwall unravelling in the long term.

Only shallow depths of ground water is expected to be encountered and ground water is only expected to occur above the base of weathering. The mine crown regional pillar has been designed beneath the base of weathering zone and hence this shallow ground water will not impact the stability of the crown and henceforth affect surface subsidence.

The results of the assessment indicate that the crown pillar is likely to be stable at the design strike of 25m between dip pillars for the widths proposed in the current mine design and the dimensions. (Figure 2 and Table 3)

Table 3: DRM Crown Pillar Size (AMC 2011)

Mining Area	Maximum Design Width	Minimum Crown Pillar Thickness in Unweathered Rock	Thickness of Weathered Rock	Minimum Distance to Surface (Ultimate Surface Crown Pillar)
North	3.4m	5.5m	31.5m	37m
South	9.8m	19m	31.5m	50.5m

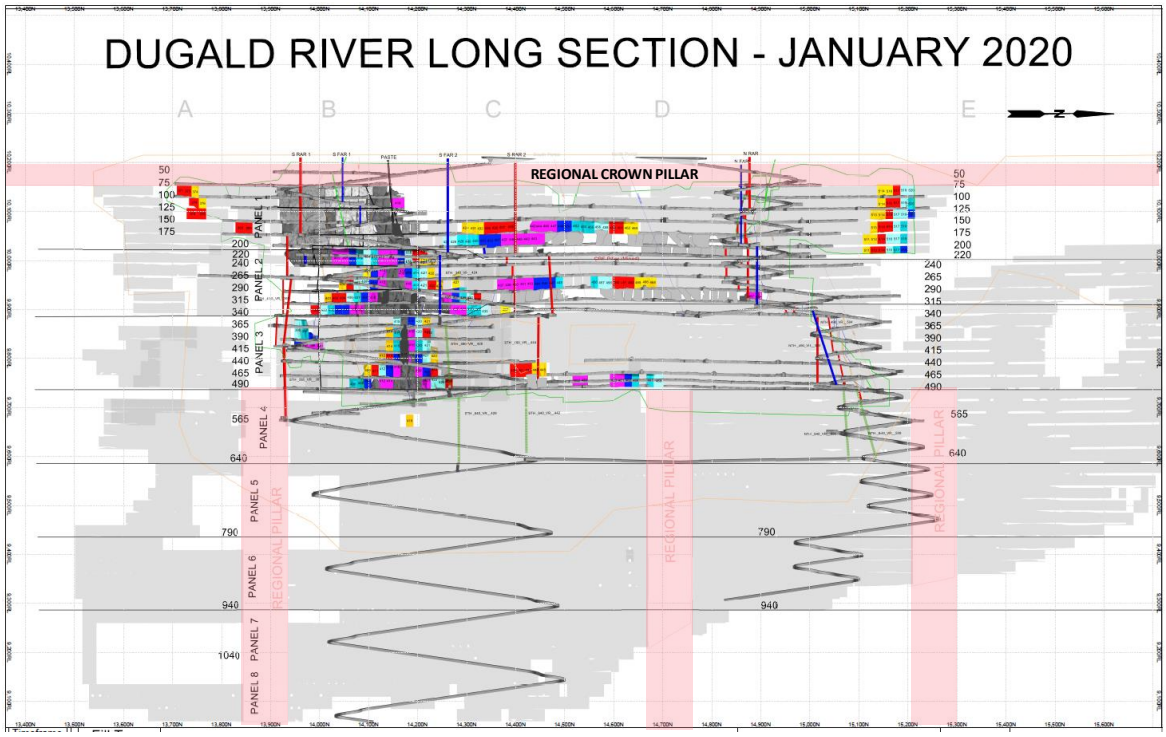


Figure 2 DRM Life of Mine Regional Pillar Locations

UNDERGROUND OPENING STABILITY (UNDERGROUND SUBSIDENCE)

Dugald River mine extraction method is a Sub Level Open Stope operation with both Cemented and rockfill backfill methods.

All design requirements and stability assessment for underground excavations are covered in the GCMP Section 11 – Geotechnical Mine Design. The empirical modified Mathews Stability Graph (Mathews et al. 1981) is used to determine stable dimensions for open stopes. Stope span limited are determined using the geotechnical classification values developed from core logging, underground mapping and structural data available. All stopes underground are backfilled to eliminate the potential for subsidence underground. Backfill design methods are presented in the DRM Backfill Design Work Quality Requirement 15811530. A void register is in place to manage backfill type and potential voids underground in order to manage consolidation of voids underground.

All underground stope excavations have a short life span and are completely backfilled. All stopes are assessed based on local ground conditions experienced and there is minimal influence of ground water on stope stability long term.

The Modified Stability Graph Method has been used to determine the stability of the top stope back and hangingwall spans (AMC 2011). If any failure initiates in the top stope hangingwall material, it has potential to destabilise the stope backs, effectively increase the crown span and failure may occur. In order to prevent crown pillar failure throughout stoping the top stope back, maximum stope spans have been determined to prevent failure before backfilling. The stopes below the crown pillar spans are to be kept at 14m for black slate hangingwall and 22m for Dugald Lode hangingwall. These stopes must be tight filled.

The main cause of instability in the crown pillar is likely to be via collapse and progressive unravelling of the hangingwall and weathered material. This is prevented in the short term by using appropriate stope spans and cable bolts and in the long term by tight filling of the stope voids to provide confinement.

There is potential for ground water to permeate along fractured zones due to faulting and zones of weak rock mass. It has been recommended that rib pillars be left at all locations where E-W off-setting structures are identified. The rock mass in these fault zones are expected to have poorer rock mass which will enable ingress of water and increased weathering. The probability of unravelling, block, or chimney failure mechanisms will be higher in these localised areas.

SEALING OFF SURFACE OPENINGS TO UNDERGROUND

There has been no design work completed on bulkhead design to seal off the underground mine for mine closure. At this stage due to the mine method and completely tight filling voids underground there is minimal risk of significant build-up of water in the underground workings and this assessment has not been deemed necessary.

CURRENT SURFACE SUBSIDENCE CONTROLS IN PLACE

The following recommendations are for the exclusion zones and regional Crown pillars as per the GCMP:

- No extraction to occur above 10150RL (75 level) for both the South and North Mine. The crown pillar located above this RL is considered a primary pillar and cannot be mined for the Life of Mine (LOM).
- For stopes near the crown pillar, unravelling to be prevented by appropriate stope spans and cable bolts. Long-term stopes are required to be tight-filled to the floor of the drill drive as a minimum.
- No permanent civil infrastructure should be constructed over the crown pillar zones, or within 90m on the hanging wall side of the crown pillar.
- Commence regular surface subsidence monitoring by Permanent Survey Marks or other means during mining of the top stopes beneath the crown pillar. Focus on the Potentially Acid Forming (PAF) runoff dams and surface fault expression. Monitoring should continue for at least 6 months after tight filling is completed
- No water storage or settling ponds are to be located on the crown pillar zone, where water may infiltrate the ground surface and into the rock mass, owing to surface subsidence.
- crown pillar has been designed in fresh rock, below the level of significant weathering.
- All excavated voids underground are backfilled and managed in a void register

Crown pillar failure or uncontrolled failure underground can impact surface infrastructure, stockpiles, roads and dams. As an additional control the critical mill infrastructure is located to the east of all workings and the surface dams located to the west. In the event of an uncontrolled failure underground no critical infrastructure is likely to be affected.
Figure 3 shows the location of the surface infrastructure with relation to the underground workings.

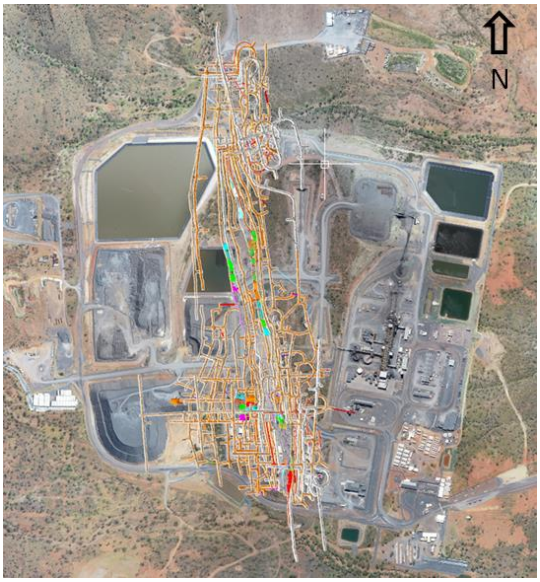


Figure 3 Plan view showing the surface of Dugald River mine with the as-built development and design stopes from Panel 1 and Panel 2

NOTE: Panel 1 stopes closest to the surface are located to the east. The red coloured stopes are the crown stopes for panel 2 located 215m below surface.

CONCLUSION

From the geotechnical stability assessments completed based on weathering and ground water profiles and controls in place at Dugald river, post-mine closure underground stability and surface subsidence risk is low. Dugald river mine has a shallow weathering profile and shallow ground water therefore there is minimal influence of ground water on the underground stability and crown pillar stability.

All stopes extracted underground have limited stope strikes and are cable bolted to increase the short-term stability and are all backfilled with either waste rock or cemented backfill to ensure long term stability and confinement of voids to prevent long term subsidence.

SUPPORTING REFERENCES

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Appendix D
Community Engagement Plan



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SOLUTIONS
FOR COMPLEX
PROJECTS

Dugald River Draft Community Engagement Plan

Prepared for MMG by
Nation Partners

24 May 2019



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Date
May 2019

Prepared by
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Dugald River Community Engagement Plan

1. Introduction

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

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

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

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

2. Purpose and Objectives

2.1 The CEP

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

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

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

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

2.2 Community and stakeholder engagement

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

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

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

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

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

3. Approach

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

The engagement process will aim to be:

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

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

Table 1 IAP2 Public Participation Spectrum

IAP2 Public Participation Spectrum

Developed by the International Association for Public Participation

INCREASING LEVEL OF PUBLIC IMPACT

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

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

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

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

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

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

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

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

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

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

4. Resources

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

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

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

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

5. Stakeholder and issues identification

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

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

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

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

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

Table 2 Criteria for ranking stakeholders by Project influence/interest

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

Table 3 Potential key stakeholder by social issues/ impact areas

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

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

6. Information requirements from stakeholders

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

Table 4 Information needs from community and stakeholder engagement

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

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

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

7. Proposed methodology

Step 1: MMG review stakeholder list and engagement approach

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

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

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

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

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

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

Step 4: Make initial contact with potential key stakeholders

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

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

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

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

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

Step 5: Undertake round 1 phone interviews

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

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

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

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

Step 7: Draft summary report and integrate feedback into reporting

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

Step 8: Undertake round 2 phone interviews

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

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

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

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

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

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

8. Engagement schedule

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

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

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SOLUTIONS FOR
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Appendices

Appendix A - Issues Scoping

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

Table 1 Key social impact areas

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

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

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

Appendix B – Proposed Stakeholder engagement method

Table 2 Stakeholder contact details and anticipated method of engagement

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

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

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

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

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

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

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

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

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

Dear <insert name here>,

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

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

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

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

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

We look forward to speaking to you soon.

Kind regards,

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

Dear <inset name here>,

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

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

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

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

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

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

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

We look forward to speaking to you soon.

Kind regards,

Appendix E
Surface Water Assessment



DUGALD RIVER PROJECT
SURFACE WATER ASSESSMENT

Minerals and Metals Group
December 2010

www.wrmwater.com.au

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REPORT TITLE: Dugald River Project, Surface Water Assessment
CLIENT: Minerals and Metals Group
REPORT NUMBER: 0435-02-B

Revision Number	Report Date	Report Author	Reviewer
DRAFT	13 August 2010	RAC	SM
0	3 September 2010	RAC	SM
1	15 September 2010	RAC	SM
2	3 December 2010	RAC	SM

For and on behalf of
WRM Water & Environment Pty Ltd



Sharmil Markar
Director

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EXECUTIVE SUMMARY

Project Site

The Dugald River Project site has undulating topography with a dominant ridgeline (Knapdales) running in a north-south direction through the central portion of the site and separating the catchments of Dugald River and Cabbage Tree Creek. There are no major watercourses through the Project Site. However, there are several minor tributaries of Dugald River and Cabbage Tree Creek that run through the Project Site. Watercourses on the eastern side of the Project Site generally drain into Dugald River. Watercourses on the western side of the Project Site generally drain into Cabbage Tree Creek.

The local watercourses are ephemeral, generally flowing for short periods after significant rainfall events or protracted wet periods. Baseflows in these watercourses are insignificant.

The predominant land use on the Project Site and the local catchments is exploration and historic mining activities. The area is also used for some low intensity grazing.

With respect to the mining operations and infrastructure layout on the Project Site, the following is of note:

- Most of the mining infrastructure is located within the catchment of Silvermine Creek between Silvermine Creek and Silvermine Creek Tributary A;
- The Tailings Storage Facility (TSF) is located within a minor unnamed tributary of Cabbage Tree Creek;
- The accommodation camp is located within the catchments of Vieuex Rose Creek (a tributary of Cabbage Tree Creek) and Silvermine Creek;
- The main access road from the Burke Developmental Road crosses the Dugald River, Silvermine Creek and an unnamed minor tributary of Dugald River;
- The road between the mine operational area and the accommodation camp crosses Silvermine Creek Tributary A and Tributary B, and several minor unnamed tributaries of Silvermine Creek;
- The water pipeline route (off the Ernest Henry/Lake Julius Pipeline) crosses Silvermine Creek Tributary A and two minor unnamed tributaries of Dugald River.

Potential Constraints to Proposed Mining Activities

Based on available information, there are minimal constraints to the proposed Dugald River Project with respect to surface water management. The areas of disturbance caused by the Project are small and can be readily managed with minimal impact on the existing surface drainage systems.

Surface Water Impacts

With appropriate controls in place, the impact of the Project on flows and water quality in downstream drainage systems would be insignificant. The Project Site covers an area of 33.7 km^2. Of this, 16.4 km^2 is within the Dugald River catchment and the remaining 17.3 km^2 is within the Cabbage Tree Creek catchment. Of the total Project Site, only about 2.5 km^2 (7.4%) is disturbed by mining activities. The areas of disturbance within the local and regional catchments caused by the Dugald River Project are minimal.

- Mining operations and infrastructure would disturb about 125 ha within the Silvermine Creek catchment. This is about 9.5% of the Silvermine Creek catchment area (total of 13.2 km^2), and about 0.2% of the Dugald River catchment area (total of 620 km^2) at the confluence with Silvermine Creek;
- The TSF occupies an area of about 90 ha. This represents only about 0.3% of the Cabbage Tree Creek catchment area to the confluence with Vieuex Rose Creek (250 km^2);
- The area disturbed by the accommodation camp is approximately 20 ha, approximately 50% of which is located in the Blackard Creek catchment area. The remaining portion of the accommodation camp area drains to Silvermine Creek (37.5%) and Cabbage Tree Creek (12.5%). The area disturbed by the accommodation camp represents less than 5% of the Blackard Creek catchment (3.7 km^2), 0.5% of the Silvermine Creek catchment (13.2 km^2) and less than 0.01% of the Cabbage Tree Creek catchment.
- The areas disturbed by the water pipeline and the access roads are not significant.

Flood Impacts

Although the main access road to the Project Site is susceptible to flooding from the Dugald River the Project Site itself is not susceptible to flooding from the Dugald River. However, parts of the Project Site, access roads and the water pipeline route are susceptible to flooding from tributaries of the Dugald River, including Silvermine Creek.

A flood study of the Dugald River, Silvermine Creek and other key tributary creeks of interest through the Project Site shows that all the mining operations and infrastructure are above 100 year Average Recurrence Interval (ARI) flood levels.

The main access road crossings have been designed as low level (causeway) crossings with minimum loss of waterway area and floodplain storage to minimise any potential impacts on the waterways. This would result in these crossings being overtopped whenever a significant runoff event occurs in the above catchments. During major flood events, the Dugald River crossing would be overtopped intermittently for periods varying from a few hours up to about 2 weeks. The Silvermine Creek and other minor tributary floods would overtop their respective road crossings for periods varying from a few hours up to 1 or 2 days depending on the magnitude and duration of the flood event.

The major and minor creek crossings along the road connecting the mine operations area to the accommodation camp area have been designed to provide flood immunity up to the 100 Year Average Recurrence Interval (ARI) flood event. The impact of these crossings on flooding behaviour in these waterways would be minimal.

The water supply pipeline route crosses Silvermine Creek Tributary A and two unnamed minor tributaries of Dugald River. The pipeline would cross these creeks above the 100 Year ARI flood level and would have minimal impact on flooding behaviour in these waterways.

Surface Water Management Objectives

The general principles adopted for the construction and mining phases of the Dugald River Project to manage surface water are as follows.

- The fullest separation possible of ‘clean’, ‘dirty’ and ‘contaminated’ water runoff.
- Minimise the area of disturbance, thus minimising the volume of dirty or contaminated runoff.

- Contain all 'dirty' (non-toxic) water on site (via sediment ponds) whenever possible. If not, release it in a controlled manner in compliance with adopted water quality criteria.
- Contain all 'dirty' (low toxicity) water on site (via low hazard dams). If necessary pump this water to the TSF via the process plant without releasing it to the natural watercourses. This water will only be released downstream during an extreme rainfall event and after notification to the Queensland Department of Environment and Resource Management.
- Segregate, collect and contain all potentially contaminated ('Toxic' and 'sub-lethal') water on site (via significant and high hazard dams). If necessary pump this water to the TSF via the process plant without releasing it to the natural watercourses. This water will only be released downstream during an extreme rainfall event and after notification to the Queensland Department of Environment and Resource Management.

Proposed Surface Water Management System

The proposed water management system can be described as follows:

- Clean runoff is diverted away from disturbed catchment areas by diversion banks and drains.
- Sediment laden runoff that will contain no potential contaminants will be captured by sediment ponds. Proposed sediment ponds have sufficient capacity to capture runoff from a 10 year 24 hour duration storm event.
- Dirty (low-toxicity) runoff will be captured by containment ponds, classified as low hazard storages by DME (1995).
- Sub-lethal contaminated runoff will be captured by containment ponds, classified as significant hazard storages by DME (1995).
- Toxic contaminated runoff will be captured by containment ponds, classified as high hazard storages by DME (1995).
- No significant reuse of captured runoff in on-site processing is proposed, and no water will be transferred between storages. In effect, each storage will operate as an individual evaporation basin.
- There is potential to transfer water from high and significant hazard dams to the TSF via the process plant, however this would only occur as an emergency measure to ensure DSA volumes are available, or prevent an MRL exceedance.
- Both high and significant hazard storages have been sized as 'no-spill' storages, and will be operated such that the appropriate DSA volume is available in each storage on 1st November each year.

Based on a 120 year period of simulation, the water balance modelling undertaken to investigate the long-term behaviour of the minesite storages indicates the following:

- No contaminated water is predicted to be released from high and significant hazard dams at the project site, although periodic releases of dirty water from sediment ponds and low hazard dams would occur. Any release of dirty water from the sediment ponds and low hazard dams is likely to only occur during significant flow events in Silvermine Creek and its tributaries. Further these release volumes would be insignificant when compared to expected flow volumes in Silvermine Creek during such flow events.
- The appropriate DSA is predicted to be available on 1st November in all high and significant hazard storages for at least 101 years out of the 120 year simulation period. DSA volumes in the low hazard storages are predicted to be available for at least 89 years out of the 120 year simulation. It should be noted that there will be infrastructure

in place to transfer water from high and significant hazard storages to the TSF via the process plant in order to ensure the DSA is available on the 1st November, however this would only be utilised as an ***emergency management option***.

Based on the results of the water balance modelling it is considered that the potential for contaminated water overflowing into Silvermine Creek or its tributaries is very low. Due to the low-toxic nature of the sediment pond and low hazard catchments and the potential for significant dilution of any overflows from these storages, the periodic release of dirty water is not considered likely to have any significant impact on Silvermine Creek and its tributaries.

The water balance modelling results indicate that the proposed water management system is robust and has more than adequate storage capacity for managing surface water runoff within the Project Site. As such there may be a case for potentially reducing the size of high hazard dams, for which the adopted FSL volume currently exceeds both the calculated DSA and the maximum storage volume predicted by the water balance model for each dam.

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1 INTRODUCTION

The Dugald River Project ('Project') is located approximately 85 km north-east of Mt Isa and 65 km north-west of Cloncurry in north-western Queensland. Minerals and Metals Group (MMG) proposes to develop a zinc/lead/silver and copper underground mining operation on the project site to extract initially 2, but expanding to 3 Million tonnes per annum (Mtpa) of Run-of-Mine (ROM) ore, and produce 450,000 tonnes per annum (tpa) of zinc/lead/silver concentrate and 75,000 tpa of Copper concentrate. The Project Site is located adjacent to the proposed Roseby Copper Project. A locality plan of the Project Site is shown in Figure 1.1.

Full details of the project background, and proposed mining operations are contained in the Environmental Impact Statement (EIS) (AARC, 2010a).

As part of the EIS for the proposed mine, AustralAsian Resource Consultants (on behalf of MMG) requested WRM Water & Environment Pty Ltd (WRM) to undertake a surface water assessment for the Project Site. This report has been prepared in response to that request.

This report is structured as follows.

- Section 2 describes the regional and local catchment and drainage characteristics in and around the Project Site.
- Section 3 describes the available climate (temperature, relative humidity and wind speed), rainfall, evaporation, runoff and flooding data for the Project Site.
- Section 4 describes the objectives of the surface water management strategy at the Project Site. The potential constraints to the proposed mining activities with respect to surface water management are also discussed.
- Section 5 presents the proposed surface water management controls for the Project Site to minimise or mitigate potential impacts of mining.
- Section 6 presents details of the water balance modelling undertaken for the Project Site.
- Section 7 presents an assessment of the potential impacts of flooding on Project Site infrastructure, access roads and the water supply pipeline.
- Section 8 presents an assessment of the potential impacts of mining activities on downstream surface water quantity and quality.
- Section 9 presents the conclusions of the study.
- Section 10 is a list of references.



Figure 1.1 Locality Plan, Dugald River Project Site

2 PROJECT SITE CATCHMENT CHARACTERISTICS

2.1 REGIONAL CATCHMENTS

Figure 2.1 shows the regional drainage network in the area of the proposed Dugald River Project Site. Three major ephemeral drainage systems drain through the Project Site and access areas:

- The southern and eastern sections of the Project Site are located in the Dugald River catchment and within a number of its tributary catchments, including Silvermine Creek;
- The western and northern sections of the Project Site are located in the Cabbage Tree Creek catchment and within a number of its tributary catchments, including Blackard Creek and Vieuex Rose Creek; and
- A significant portion of the mine access road from the Burke Developmental Road is located within the Cattle Creek catchment.

Dugald River runs in a north-easterly direction to the east of the Project Site. Cattle Creek, which also runs in a north-easterly direction further east of the Project Site, drains into Corella River. Both Dugald River and Corella River are tributaries of the Cloncurry River, which in turn is a tributary of the Flinders River. Flinders River flows into the Gulf of Carpentaria about 450 km north-east of the Project Site.

The Dugald River catchment extends about 45 km to the south-west of the Project Site and rises to elevations of over 500 mAHD. The catchment commands an area of about 620 km^2 upstream of the Project Site. Some of Dugald River's major tributaries upstream of the Project Site include Cleanskin, Lady Clayre and Clayton creeks. Silvermine Creek and its tributaries, which drain the eastern section of the Project Site, join Dugald River about 500 m downstream of the Clayton Creek confluence. The closest Dugald River stream gauging station to the Project Site is located at the Railway Crossing (see Figure 2.1), approximately 1.4 km upstream of where it is crossed by the Burke Developmental Road. The Dugald River catchment area to this gauging station is about 660 km^2.

The Knapdale Range, which rises in steep, deeply dissected escarpments, forms the drainage divide between the Dugald River and Cabbage Tree Creek within the Project Site.

Cabbage Tree Creek, which runs in a northerly direction to the west of the Project Site, joins Pinnacle Creek and then drains into the Leichhardt River, which flows into the Gulf of Carpentaria about 400 km north-west of the Project Site. The Cabbage Tree Creek extends about 25 km to the south-west of the Project Site and rises to elevations over 300 mAHD. It commands a catchment area of about 250 km^2 upstream of the Project Site. There are no stream gauging stations along Cabbage Tree Creek.

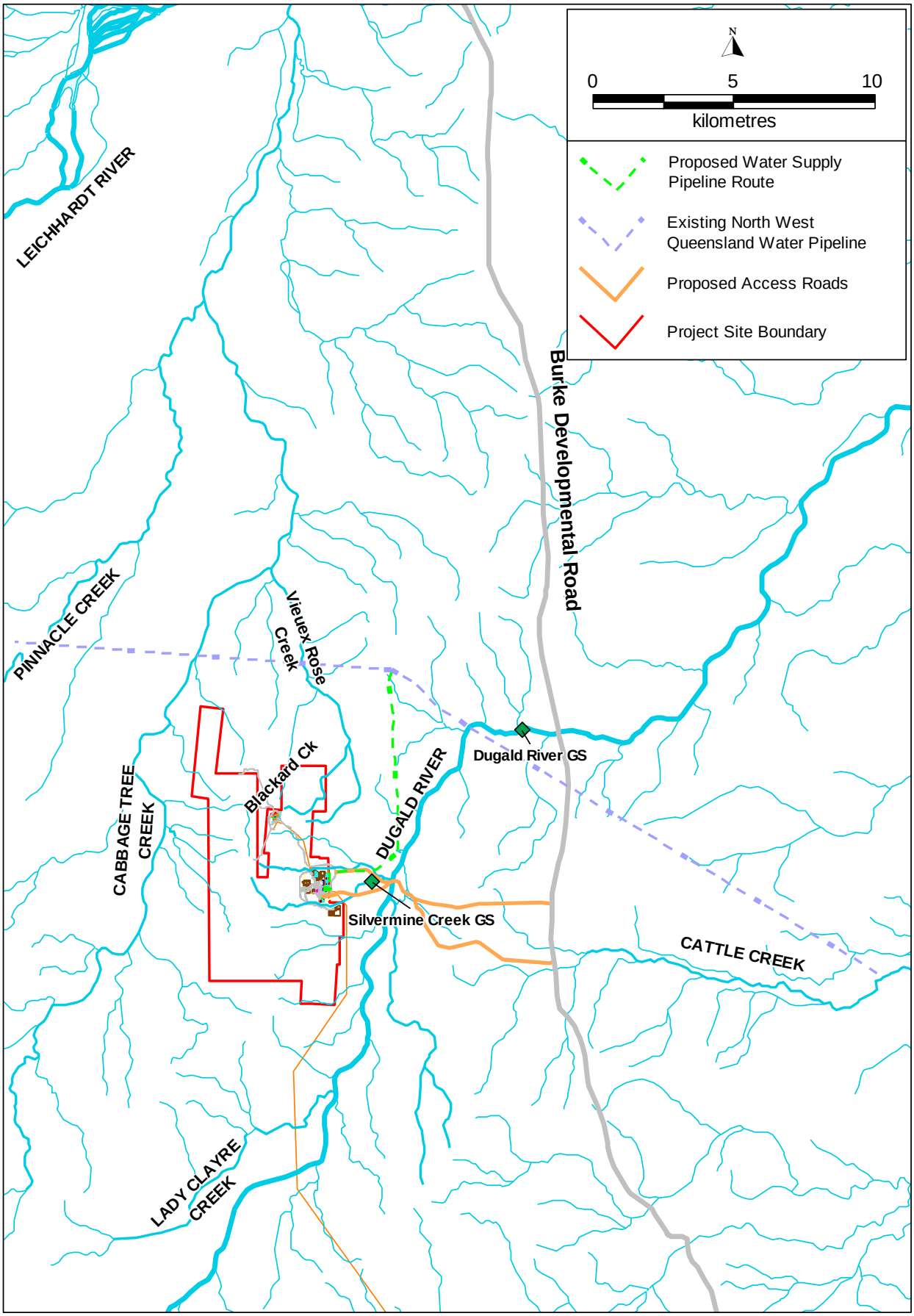


Figure 2.1 Regional Drainage Network in the Vicinity of the Project Site

Vieuex Rose Creek and Blackard Creek, two major tributaries of Cabbage Tree Creek, drain the north-eastern section of the Project Site. In addition, several minor tributaries of cabbage Tree Creek drain the western section of the Project Site.

Rivers and Creeks in the vicinity of the Dugald River Project Site normally flow only during, and for brief periods following the wet season, generally between November and April. Isolated pools along these river and creek beds can persist through the dry season.

2.2 LOCAL CATCHMENTS

Figure 2.2 shows the local drainage network in and adjacent to the Project Site. Figure 2.3 shows the drainage network and sub-catchments immediately adjacent to the mine operations area, access road and water supply pipeline. The topography of the Project site is undulating with a dominant ridgeline (Knapdales) running in a north-south direction through the central portion of the site and separating the catchments of Dugald River and Cabbage Tree Creek. There are no major watercourses through the Project Site. However, there are several minor tributaries of Dugald River and Cabbage Tree Creek that run through the Project Site. Watercourses on the eastern side of the Project Site generally drain into Dugald River. Watercourses on the western side of the Project Site generally drain into Cabbage Tree Creek.

The local watercourses are ephemeral, generally flowing for short periods after significant rainfall events or protracted wet periods. Baseflows in these watercourses are insignificant.

The local catchments through the Project Site are generally steep and stony, and therefore respond quickly to rainfall. In addition, the flow velocities along these watercourses are likely to be high.

The predominant land use on the Project Site and the local catchments is exploration and historic mining activities. The area is also used for some low intensity grazing.

Figure 2.2 and Figure 2.3 also show the conceptual mining operational and infrastructure layout on the Project Site, including the water pipeline and access road routes. The following is of note:

- Most of the mining infrastructure is located within the catchment of Silvermine Creek between Silvermine Creek and Silvermine Creek Tributary A;
- The Tailings Storage Facility (TSF) is located within a minor unnamed tributary of Cabbage Tree Creek;
- The accommodation camp is located within the catchments of Vieuex Rose Creek (a tributary of Cabbage Tree Creek) and Silvermine Creek;
- The main access road from the Burke Developmental Road crosses the Dugald River, Silvermine Creek and an unnamed minor tributary of Dugald River;
- The road between the mine operational area and the accommodation camp crosses Silvermine Creek Tributary A and Tributary B and other unnamed tributaries of Silvermine Creek; and
- The water pipeline route (off the Ernest Henry/Lake Julius Pipeline) crosses Silvermine Creek Tributary A, and two minor unnamed tributaries of the Dugald River

It is understood that the mine access road route to the west of Dugald River may have to be changed if Universal Resources Limited decides to mine their proposed 'Longumundi' Pit. Should this happen, the potential alternative route is shown in Figures 2.2 and 2.3.

The Project Site covers an area of 33.7 km^2. Of this, 16.4 km^2 is within the Dugald River catchment and the remaining 17.3 km^2 is within the Cabbage Tree Creek catchment. Of the total Project Site, only about 2.3 km^2 (6.8%) is disturbed by mining activities. The areas of disturbance within the local and regional catchments caused by the Dugald River Project are minimal.

- Mining operations and infrastructure would disturb about 125ha within the Silvermine Creek catchment. This is about 9.5% of the Silvermine Creek catchment area (13.2 km^2), and about 0.2% of the Dugald River catchment area (620 km^2) at the confluence with Silvermine Creek;
- The TSF occupies an area of about 90 ha. This represents only about 0.3% of the Cabbage Tree Creek catchment area to the confluence with Vieuex Rose Creek (250 km^2);
- The area disturbed by the accommodation camp is approximately 20 ha, approximately 50% of which is located in the Blackard Creek catchment area. The remaining portion of the accommodation camp area drains to Silvermine Creek (37.5%) and Cabbage Tree Creek (12.5%). The area disturbed by the accommodation camp represents less than 5% of the Blackard Creek catchment (3.7 km^2), 0.5% of the Silvermine Creek catchment (13.2 km^2) and less than 0.01% of the Cabbage Tree Creek catchment.
- The areas disturbed by the water pipeline and the access roads are not significant.

2.3 LOCAL WATER USE

There are no towns in the vicinity of the Project Site. Further, there are no significant water storages or water users in the locality of the Project Site. The only local water use in the vicinity of the Project Site appears to be for stock watering. It is understood that Roseby homestead uses groundwater for potable and household supply.

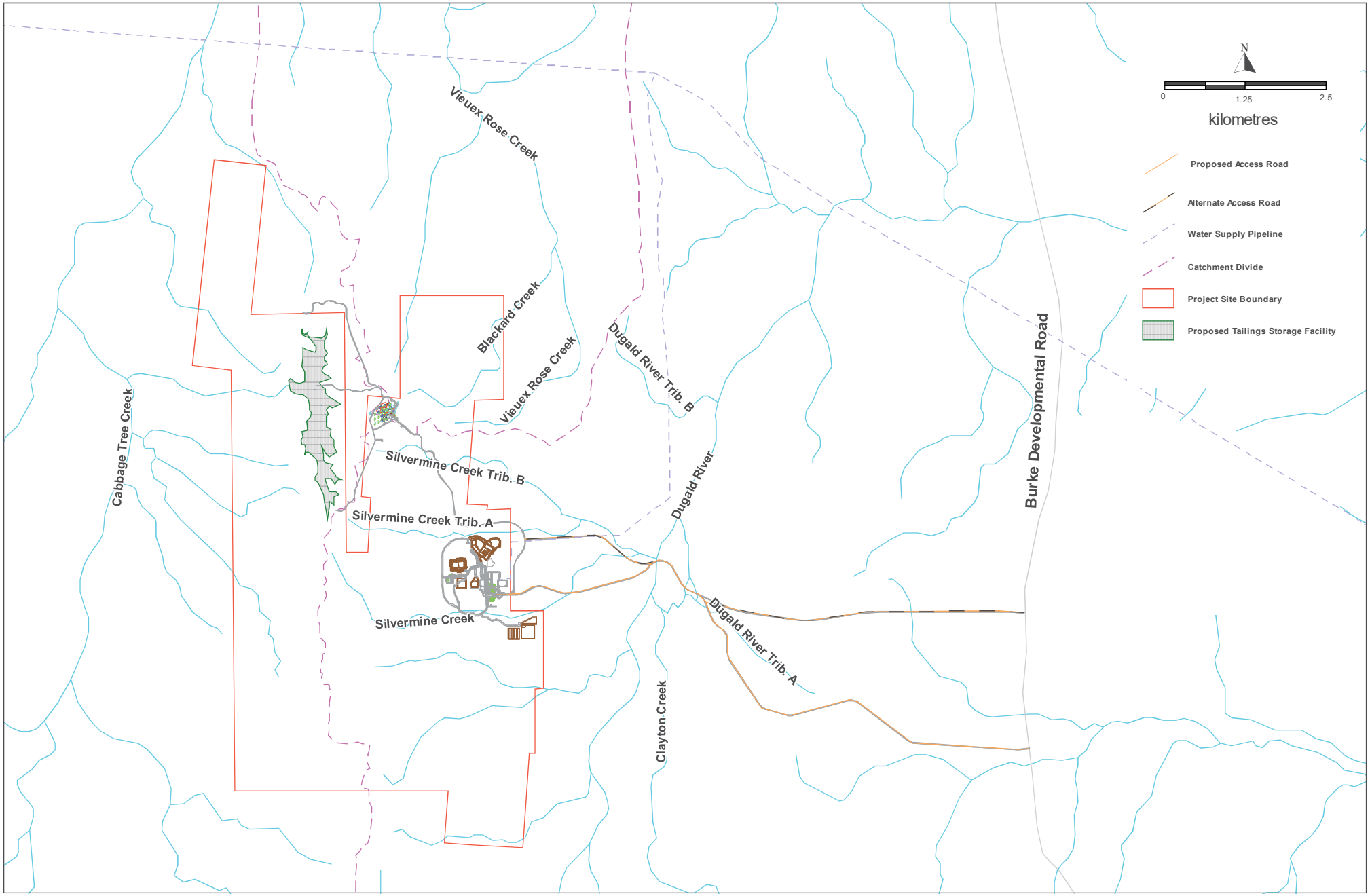


Figure 2.2 Local Catchments and Drainage Networks in the Project Area

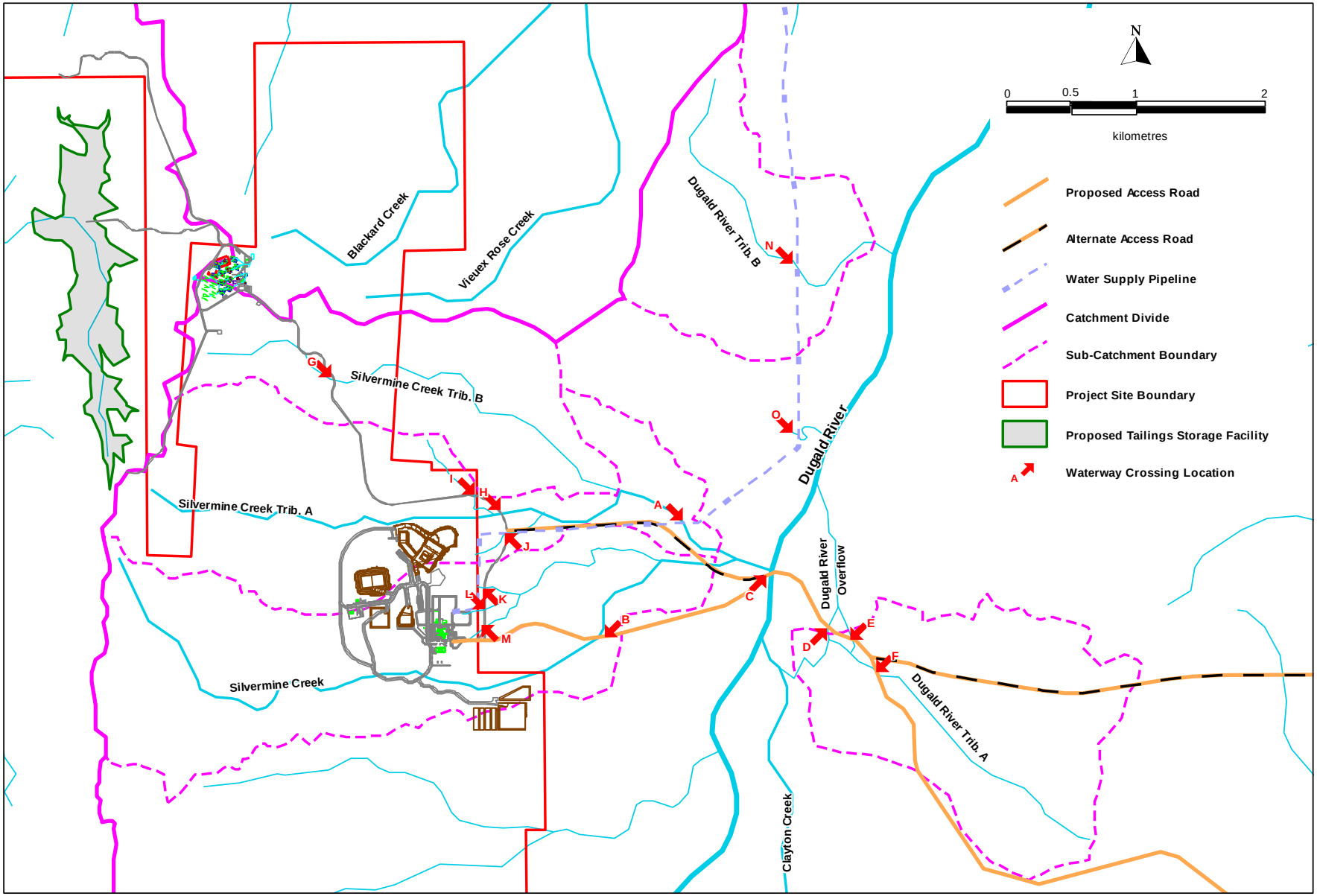


Figure 2.3 Local Catchments and Drainage Networks Affected by Mine Operations Area, Access Roads and Water Supply Pipeline

3 AVAILABLE DATA

3.1 CLIMATE

The nearest long-term climatic station to the Project Site is at Cloncurry and is located approximately 60 km south-west of the Project site. The Cloncurry Aero station (No. 029009) operated from 1939 to 1978 until it was replaced by the Cloncurry Airport station (No. 029141) in 1978. Both stations are Commonwealth Bureau of Meteorology (BOM) stations and have recorded a range of climatic parameters and rainfall since 1939.

Some climate data have been recorded at the Project Site from time to time between 1998 and 2010, however the available data has too many gaps to undertake any meaningful long-term analysis of the data.

Table 3.1 summarises average monthly and annual temperature, relative humidity and wind speed for the Project Site, based on 68 years of combined data (1939 – 2008) at Cloncurry Aero and Airport stations.

Table 3.1 Summary Climate Data, Cloncurry Aero (Station No. 029009) and Cloncurry Airport (Station No. 029141), 1939-2008

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Ave. Daily Max. Temp (°C)	37.2	35.9	35.1	32.7	28.5	25.7	25.5	28.0	31.9	35.6	37.7	38.3	32.7
Ave. Daily Min. Temp (°C)	24.6	24.2	22.5	19.4	15.0	11.3	10.3	11.9	15.9	20.0	22.7	24.3	18.5
Ave. 9am Daily Temp (°C)	29.3	28.3	27.3	24.7	20.1	16.5	15.7	18.3	23.1	27.5	29.8	30.5	24.3
Ave. 9am Rel. Humidity (%)	53.6	59.4	50.8	43.5	44.9	48.1	43.8	36.4	30.0	28.1	31.8	39.8	42.7
Ave. 9am Wind Speed (km/h)	13.4	12.5	13.4	15.1	14.9	13.6	14.0	15.1	17.6	18.4	17.4	15.2	15.1

The following is of note regarding the climate at the Dugald River Project site.

- Seasonal temperature fluctuations shown in Table 3.1 are typical for the region with the highest maximum daily temperatures being recorded during the months November to January (37.2^{0}C to 38.3^{0}C) and the lowest maximum daily temperatures being recorded during the months June to August (10.3^{0}C to 11.9^{0}C);
- The average relative humidity recorded at 9am varies between 28.1% and 59.4% throughout the year. The relative humidity is highest during the months of January through to March and lowest during the months September through to November; and

- The wind speed follows similar seasonal patterns to relative humidity with the highest values recorded in the months September through to November and the lowest values recorded during the months January through to March.

3.2 RAINFALL AND EVAPORATION

Table 3.2 shows the long-term seasonal variation in average monthly and annual rainfall and potential evaporation for the Project Site from two sources:

- Nearest long-term BOM stations: Long-term rainfall data for the Project Site were obtained by combining the data available from BOM's Cloncurry Aero (1939-1978) and Cloncurry Airport (1978-2010) stations. Long-term potential evaporation data for the Project Site was obtained from BOM's Mt Isa station (No. 029127), based on 41 years of data collected between 1966 and 2008. There are no other long-term potential evaporation recording stations closer to the Project Site.
- DERM's SILO Data Drill: DERM's SILO Data Drill for the project site for the period 1889 - 2010. These data are derived by interpolation of recorded data between stations as described by Jeffreys et al (2001). Data from the SILO Data is corrected for missing data and accumulated totals. Hence this data is more reliable and is considered more representative of rainfall and evaporation at the Project Site.

Table 3.2 Average Monthly and Annual Rainfall and Potential Evaporation, Dugald River Project Site

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Composite Record from Cloncurry & Mt Isa BOM Stations													
Ave. Monthly Rainfall (mm)	136.8	118.7	75.5	20.3	14.7	7.1	4.4	4.5	6.2	16.3	25.6	64.1	486.8
Max. Monthly Rainfall (mm)	686.2	408.9	513.6	199.0	129.2	46.2	47.6	88.1	45.3	114.2	97.9	346.8	1175.4
Min. Monthly Rainfall (mm)	10.4	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	3.8	117.4
No. Rain Days	9.9	9.6	6.0	2.2	1.5	1.1	0.9	0.9	1.6	3.1	4.6	6.9	48.2
Ave. Monthly Potential Evap (mm)	297.6	248.6	275.9	252	198.4	162	170.5	213.9	267	328.6	333	334.8	3068.1
SILO Data Drill Dugald River Project Site													
Ave. Monthly Rainfall (mm)	139.9	122.9	78.1	15.7	12.3	11.1	5.9	2.4	5.7	15.4	32.9	72.0	514.3
Max. Monthly Rainfall (mm)	1061.3	449.2	468.4	131.5	209.2	171.6	92.6	59.9	89.7	127.3	170.7	421.9	1410.8
Min. Monthly Rainfall (mm)	2.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	160.0
No. Rain Days	13.3	12.1	7.9	2.6	1.9	1.5	1.1	0.6	1.8	4.2	7.0	10.8	64.0
Ave. Monthly Potential Evap (mm)	304.4	255.0	279.5	253.8	205.3	168.9	184.9	232.2	280.6	337.1	341.8	338.5	3182.0

The following is of note regarding the rainfall and evaporation averages at the Dugald River Project site estimated using the SILO Data Drill. Based on data from the SILO Data Drill:

- The average annual rainfall at the Project Site is estimated at 514.3 mm. The annual rainfalls on the Project Site can vary considerably from year to year. Based on the synthesised 121 years of record, the minimum and maximum annual rainfalls at the Project Site are 160.0 mm and 1410.8 mm respectively.
- A comparison between the average annual rainfall totals obtained from the Cloncurry BOM station and the SILO Data Drill indicate that the Project Site receives slightly more rainfall than Cloncurry.
- The average monthly rainfalls at the Project Site exhibit distinct wet (November to April) and dry (May to October) seasons during the year, with a dry season low of 2.4 mm in August to a wet season high of 139.9 mm in January. The wet season average monthly rainfalls (72.0 mm to 139.9 mm) are significantly higher than the equivalent dry season monthly rainfalls (2.4 mm to 15.4 mm). The average number of 'rain days' in each month also follow a pattern similar to the average monthly rainfalls. There is little or no rainfall occurring at the Project Site during the dry season months.
- The average annual potential evaporation at the Project Site is estimated at 3182 mm. The values in Table 3.2 indicate that the average annual potential evaporation at the Project Site is about 6.2 times the average annual rainfall. Evaporation rate varies seasonally, with high evaporation rates occurring in the months between October and March. Further, the potential evaporation rates during the hotter months are about twice the evaporation rate during the cooler months. In addition, average potential evaporation significantly exceeds average rainfall for all months of the year. The potential evaporation rates during the cooler months are significantly greater (up to 25 - 50 times) than the equivalent average monthly rainfalls.

An automatic weather station installed in October 1998 has recorded rainfall at the Project Site for 33 complete months in the period between December 1998 and March 2010. This data is a better representation of local rainfall at the Project Site, but unfortunately the available record is discontinuous and too short to accurately assess long-term rainfall characteristics at the Project Site. Table 3.3 compares the average monthly rainfalls recorded at the Project Site with the equivalent rainfalls at Cloncurry and those obtained from the SILO Data Drill for the common period of available record.

Table 3.3 Comparison of SILO Data Drill Rainfall, Rainfalls Recorded at the Project Site and BOM Cloncurry Station, December 1998 to March 2010

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
No of Site Record Data Months	3	4	4	2	1	1	3	4	4	2	2	3
Ave. Monthly Project Site Rainfall (mm)	382.2	173.8	88.6	0.7	0.0	0.0	0.0	3.6	1.6	44.2	74.3	72.1
Ave. Monthly SILO Project Site Rainfall (mm)	439.1	186.8	72.9	0.3	5.9	0.0	0.0	2.1	2.5	45.0	86.6	77.2
Ave. Monthly Cloncurry Rainfall (mm)	304.4	102.4	73.2	1.3	19.4	0.0	0.1	6.1	0.8	61.8	58.9	118.5

The following is of note regarding the comparison of recorded site rainfall data with SILO Data Drill rainfall and recorded Cloncurry rainfall:

- It appears that the Project Site experiences more rainfall than at Cloncurry, particularly in January and February.
- The SILO rainfall correlates reasonably well with recorded site rainfalls for the coincident period of record.

For the reasons given above, the SILO rainfall record has been adopted for use in long term water balance modelling of the project site.

3.3 RUNOFF / STREAMFLOWS

3.3.1 Silvermine Creek

There is a stream gauging station located within the Project Site in Silvermine Creek. The location of this station is shown in Figure 2.1. Although water level data have been collected at this station for several periods between October 1998 and February 2009 the available water levels cannot be converted to runoff volumes because a rating curve is unavailable for this gauging station. Figure 3.1 to 3.3 show plots of recorded Silvermine Creek rainfall and water levels for the 1998/1999, 1999/2000 and 2008/2009 wet seasons. The following observations can be made regarding the runoff behaviour of Silvermine Creek based on available rainfall and water level data.

- Some runoff is generally produced when a rainfall event exceeds about 20 mm;
- Runoff response to rainfall is quite quick. Runoff occurs quickly after rainfall and normally peaks within a few hours of rainfall; and
- Runoff events do not last very long, generally a few hours to a few days depending on the duration of the rainfall event.
- During major flow events in the Dugald River (such as January/February 2009) Silvermine Creek water levels at the stream gauging station are affected by Dugald River backwater.

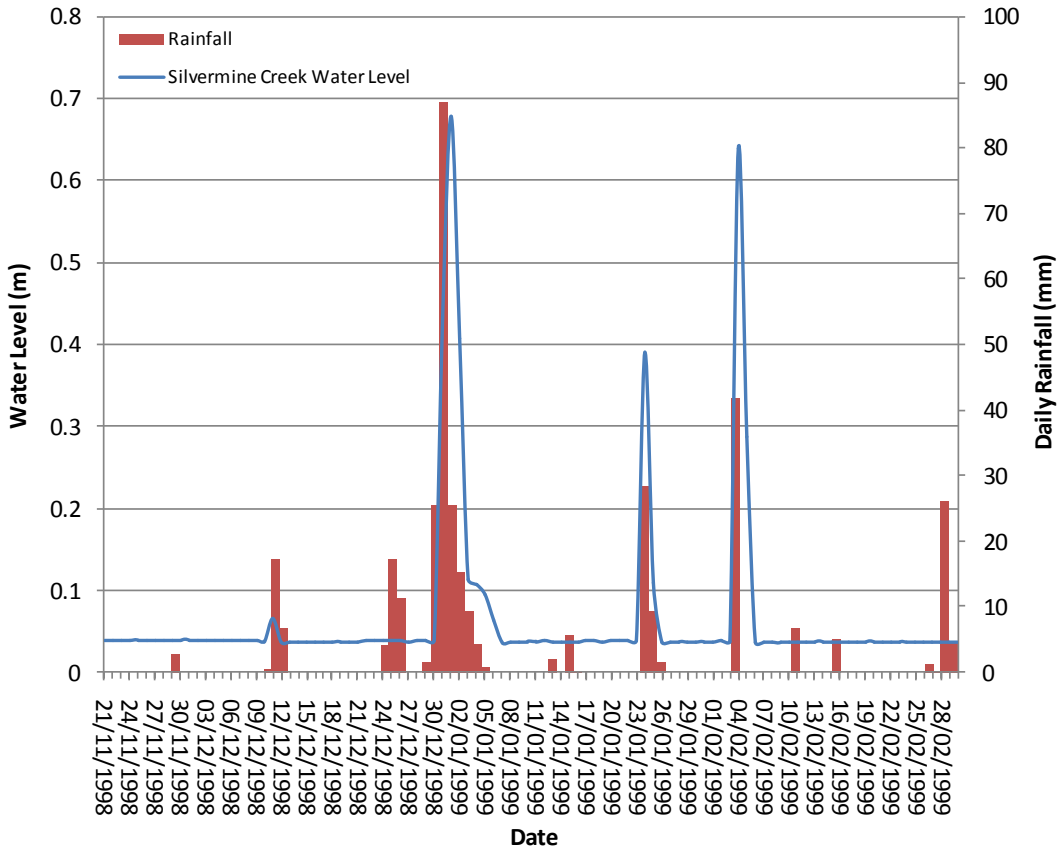


Figure 3.1 Silvermine Creek Recorded Rainfalls and Water Levels, Nov 1998 to Feb 1999

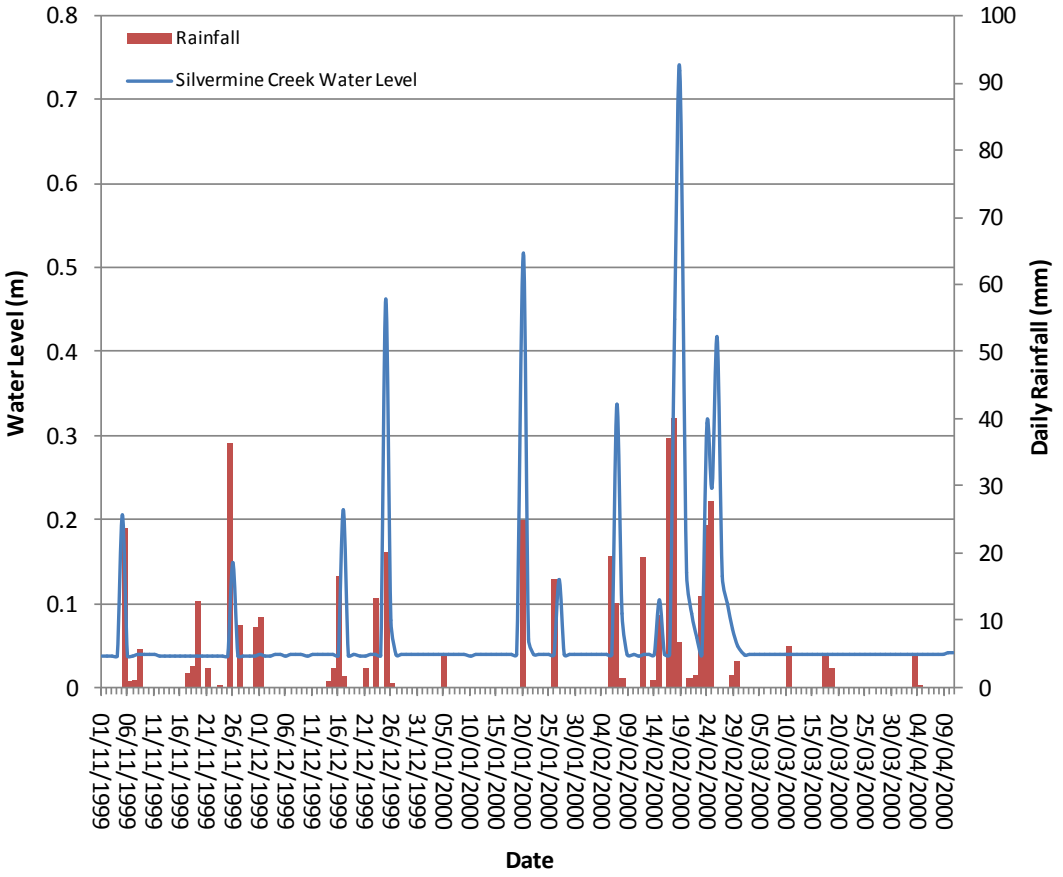


Figure 3.2 Silvermine Creek Recorded Rainfalls and Water Levels, Nov 1999 to Apr 2000

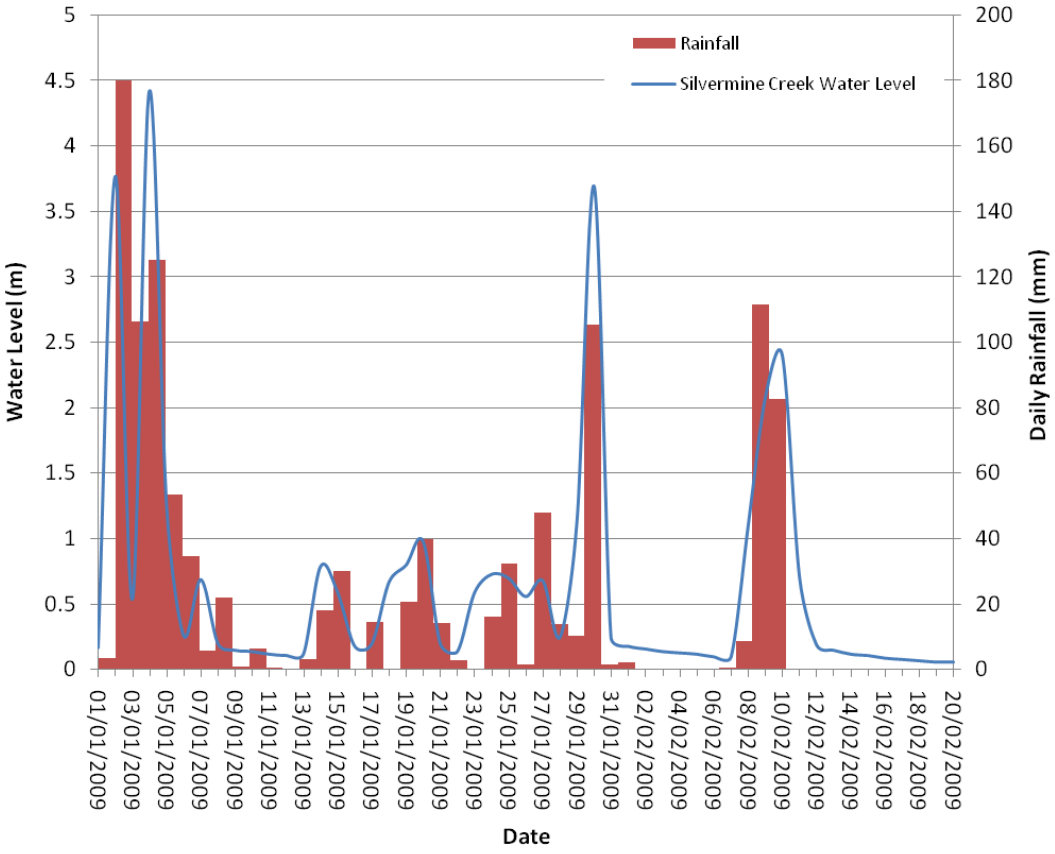


Figure 3.3 Silvermine Creek Recorded Rainfalls and Water Levels, Jan 2009 to Feb 2009

3.3.2 Dugald River

A stream gauging station has been operational in the Dugald River at the Railway Crossing (Station No. 915206A) since 1969. There is a complete record of data at this station from 1969 to date, except for the period between 1988 and 1991 as this station was decommissioned in 1988 and then re-activated again in 1991. Table 3.4 shows the average monthly and annual flows and runoff depths recorded at the Dugald River station during the period 1969 to 2006. Figure 3.4 shows annual flows at the Dugald River station between 1969 and 2006. Figure 3.5 and Figure 3.6 show daily flow duration curves for the Dugald River at the Railway Crossing for the full period of record and the wet seasons (November to April) during the period of record respectively.

Based on the available data, the following observations can be made regarding the flows/runoff near the Dugald River Project site.

- The average annual flow in the Dugald River is about 55,000 ML. The annual flow volumes vary considerably from year to year. During the 34 years of record, the minimum and maximum annual flows near the Project Site were about 1000 ML and 250,000 ML respectively;
- The average annual volumetric runoff coefficient for the Dugald Rive at the Railway Crossing is about 8.3%;
- The average monthly flows in the Dugald River exhibit distinct wet (November to April) and dry (May to October) seasons during the year, with dry season a low of 6 ML in August to a wet season high of 18,000 ML in January. The wet season average monthly

flows (1,200 ML to 18,000 ML) are significantly higher than the equivalent dry season monthly flows (6 ML to 440 ML); and

- The Dugald River flows only for 26% of the time (95 days per year on average). During the 34 year period of record, the daily flows have exceeded 10 m^3/s and 100 m^3/s only for 5.0% (18 days per year) and 1.5% (5 days per year) of the time respectively. During the wet season (Nov – April), the river flows for about 45% (81 days per wet season) of the time. The daily flows during the wet season have exceeded 10 m^3/s and 100 m^3/s only for 10% and 2.8% of the time respectively.

Table 3.4 Average Monthly and Annual Flows, Dugald River, 1969-2006

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Ave. Monthly Flow (ML)	18486	12291	15814	1290	64.4	52.3	42.8	6.0	41.8	440	1234	4754	54859
Ave. Monthly Runoff (mm)	28.0	18.6	24.0	1.95	0.097	0.079	0.065	0.009	0.063	0.667	1.87	7.20	83.1

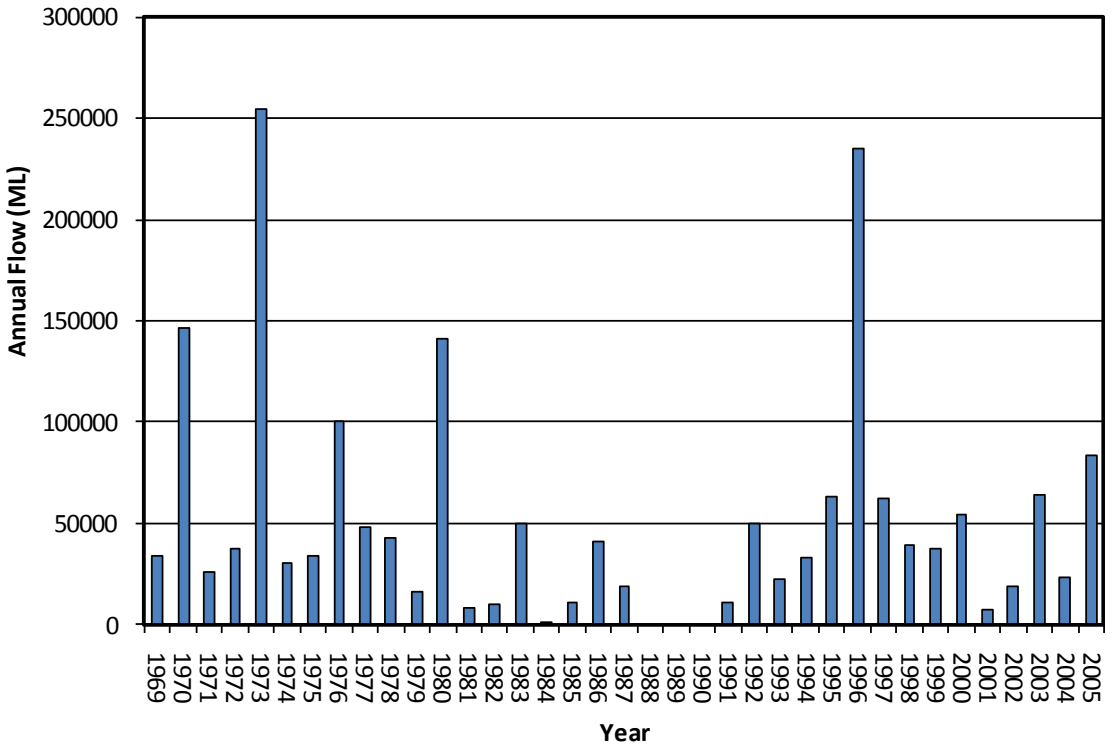


Figure 3.4 Average Annual Flows, Dugald River at the Railway Crossing (1969-2006)

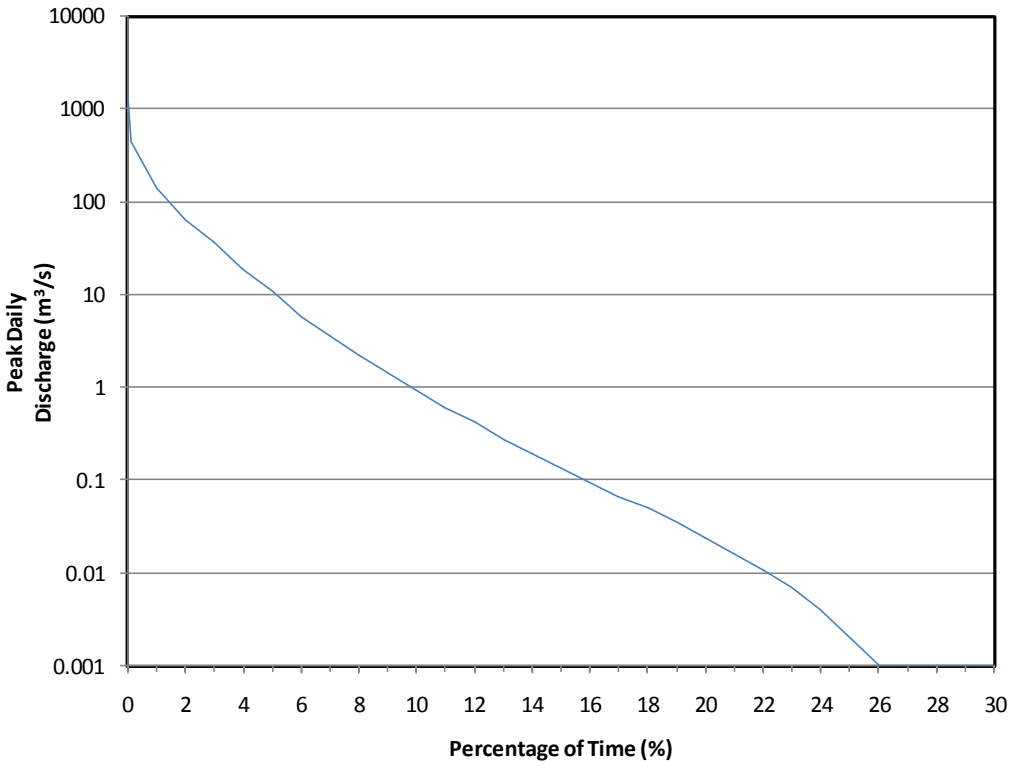


Figure 3.5 Daily Flow Duration Curve, Dugald River at the Railway Crossing, 1969-2006

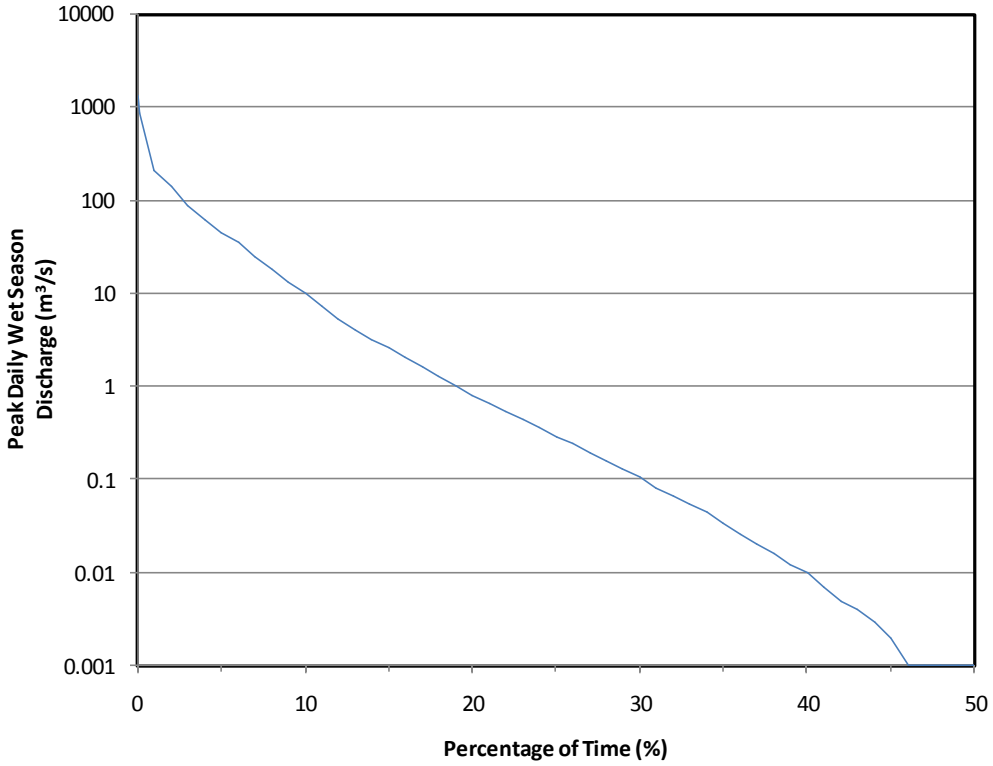


Figure 3.6 Daily Wet Season (November to April) Flow Duration Curve, Dugald River at the Railway Crossing, 1969-2006

3.4 FLOODING

3.4.1 Local Creeks

There is no flood data for the local creeks through the Project Site. Parts of the Project Site, access roads and the water pipeline route are susceptible to flooding from tributaries of the Dugald River, including Silvermine Creek. A flood study of Silvermine Creek and other key tributary creeks of interest through the Project Site is presented in Section 7.

3.4.2 Dugald River

The Project Site itself is not susceptible to flooding from the Dugald River. However, the main access road to the Project Site is susceptible to flooding from the Dugald River. During the period 1969-2010 several significant floods have been recorded in the Dugald River at the Railway Crossing, the most recent of which was the January 2009 flood event, which recorded a peak discharge of 1319m^3/s at the Railway Crossing gauge. Based on observations during the event and recorded water levels at the Silvermine Creek gauge site, no part of the Project Site was inundated during the January 2009 event; however access to the project site from the Burke Developmental Road was cut intermittently for about 2 months.

Other significant historical floods include the 1971 flood with a peak discharge of 1330 m^3/s and the 1974 and 1997 flood events with peak discharges of 1108 m^3/s and 1148 m^3/s respectively. The next most significant flood event was recorded in 1995 with a peak discharge of 507 m^3/s. Based on a flood frequency analysis (see Section 7), the Average Recurrence Intervals (ARI's) of the 2009 and 1971 events are between 50 and 100 years. The ARI of the 1974 and 1997 events is between 20 and 50 years. The ARI of the 1995 event is approximately 5 years.

Figures 3.7 to Figure 3.10 (overleaf) show some typical flood hydrographs recorded at the Dugald River gauging station for a range of flood events. The following is of note with respect to Dugald River flood events:

- The flood hydrographs have rapidly rising and falling limbs. This suggests that the catchment responds quickly to rainfall; and
- The total flood event may last from a few hours to several days depending on the rainfall pattern. If the rainfall lasts for an extended period the resultant flood hydrograph would be multi-peaked. However, the duration of each flood peak would be quite short. Most of the hydrographs would rise and fall within a period of about 12-18 hours.

A flood study of the Dugald River at the access road crossing is presented in Section 7.

3.5 WATER QUALITY

Water quality data are available for several sites within and in the vicinity of the Dugald River Project Site and the adjoining Roseby Copper Project Site. A review of the available water quality data is presented elsewhere (AARC, 2010b),

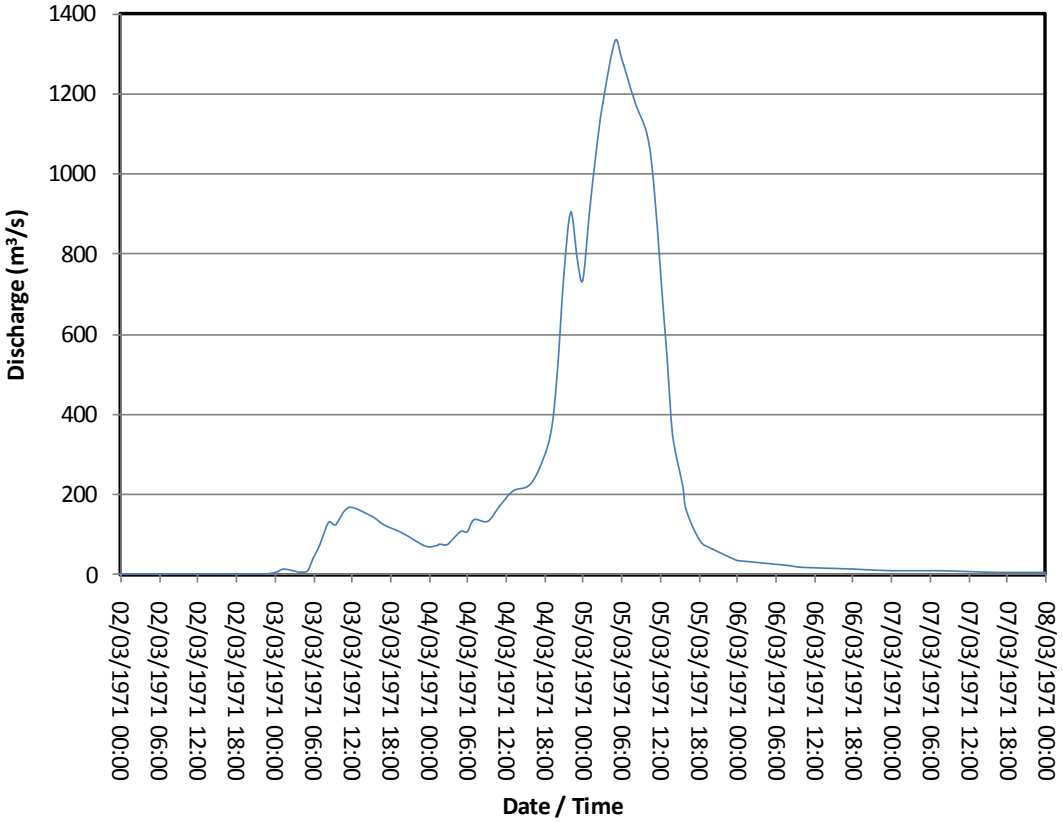


Figure 3.7 Dugald River Flood Hydrograph at the Railway Crossing, 1971 Flood Event

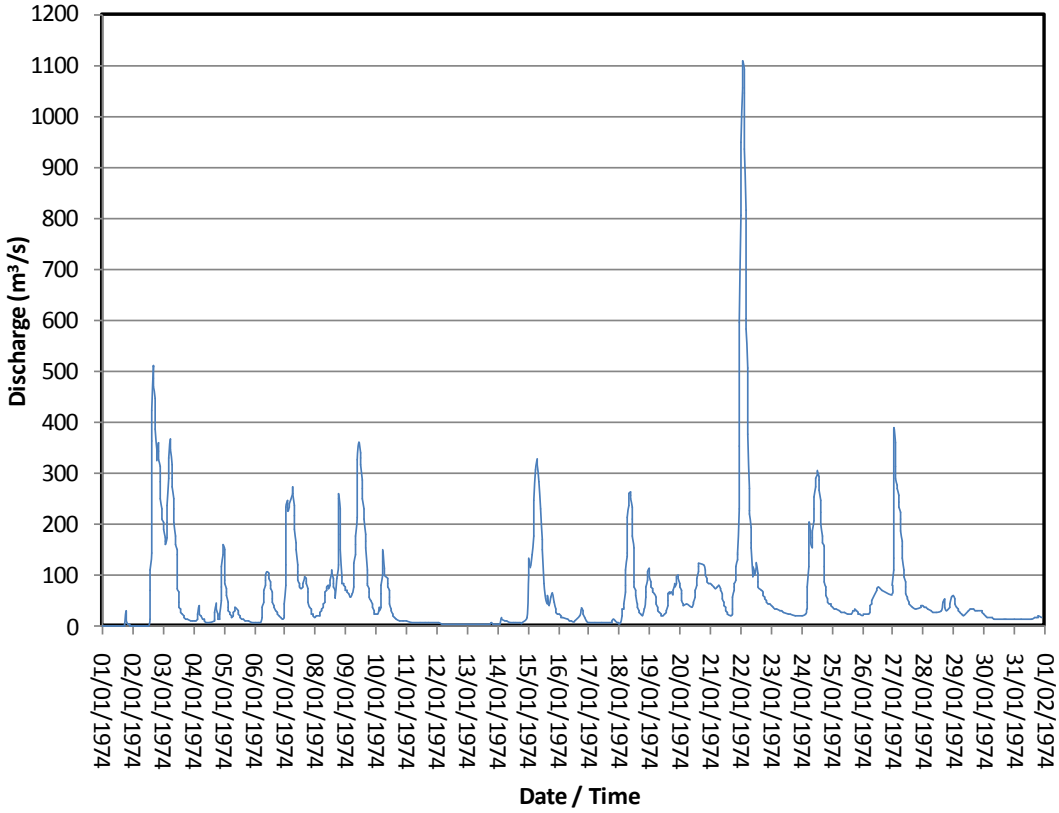


Figure 3.8 Dugald River Flood Hydrograph at the Railway Crossing, 1974 Flood Event

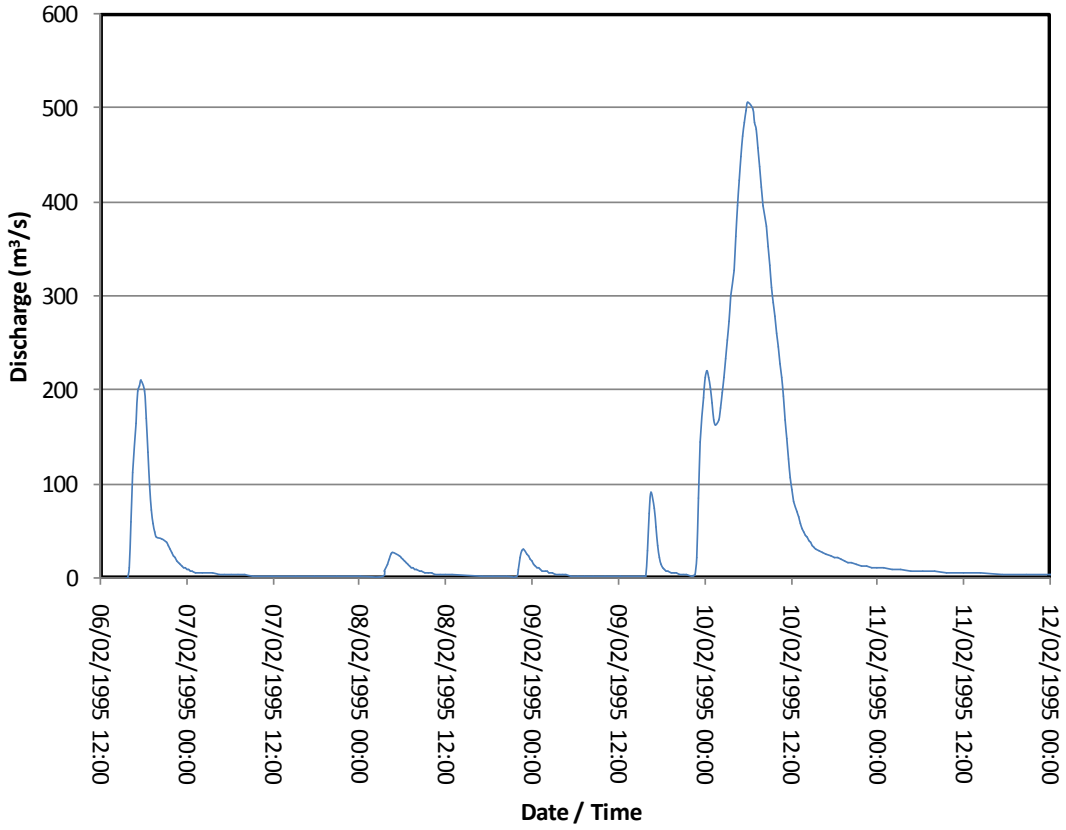


Figure 3.9 Dugald River Flood Hydrograph at the Railway Crossing, 1995 Flood Event

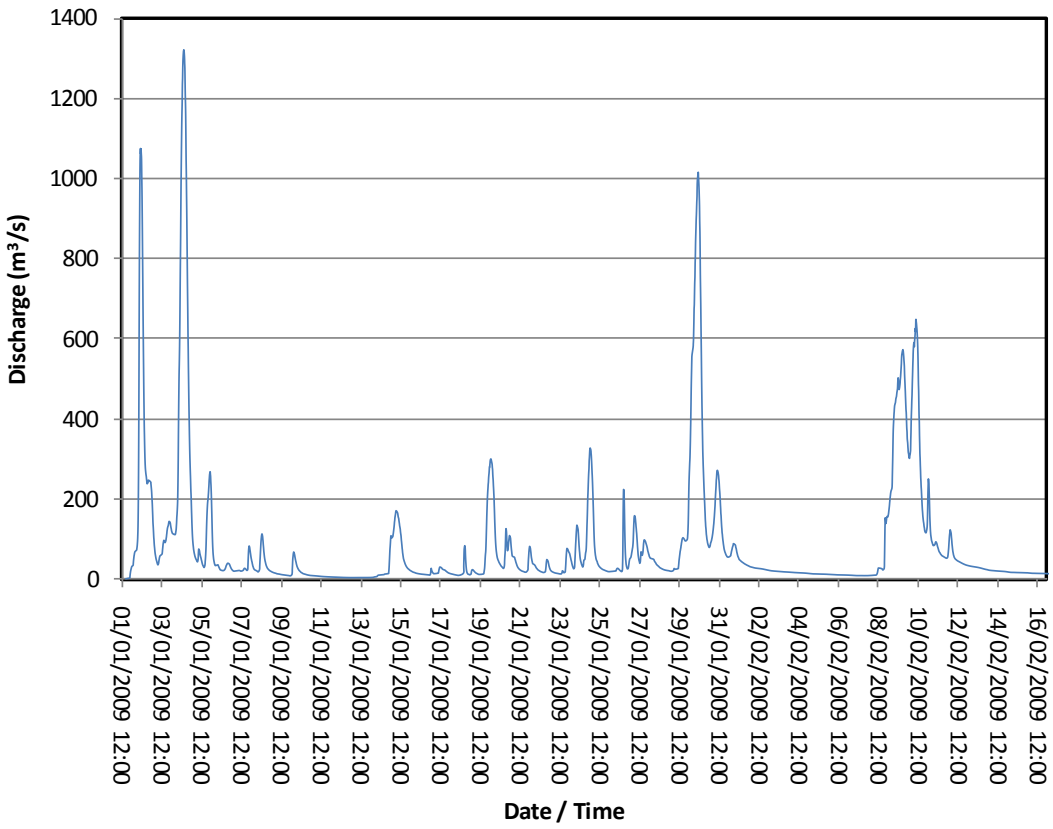


Figure 3.10 Dugald River Flood Hydrograph at the Railway Crossing, 2009 Flood Event

4 SURFACE WATER OBJECTIVES

4.1 SURFACE WATER TYPES

For surface water management purposes, the surface runoff generated in the Dugald River Project Site is divided into three types based on water quality:

- 'Clean' – surface runoff from areas of the Project Site where water quality is unaffected by mining operations. Clean water includes runoff from undisturbed areas.
- 'Dirty' ('non-toxic') – surface runoff water from the Project Site areas that are disturbed by mining operations such as office areas, road areas and stores. This runoff may contain silt and sediment, but does not contain contaminated material. However, this runoff must be of sufficient quality prior to discharge into natural watercourses, if required.
- 'Dirty' ('low-toxicity') – surface runoff water from the Project Site areas that are disturbed by mining operations such as workshops, paste plant and reagents stores areas. This runoff may contain silt and sediment, but unlikely to contain contaminated material. However, this runoff must be of sufficient quality prior to discharge into natural watercourses, if required.
- 'Contaminated' ('sub-lethal' and 'toxic') – surface water from areas affected by mining operations and normally containing chemicals of various types used in the mining operations. Contaminated water areas include areas where PAF waste rock is immediately encapsulated in NAF waste rock in a waste rock dump; NAF waste rock dumps; ore is stockpiled, crushed or transferred; areas where concentrates are processed, transferred or stored; areas where tailings are transferred for backfill underground; and areas where PAF waste rock will be stockpiled on the surface prior to disposal back underground. Runoff from these areas is potentially contaminated and therefore must be managed to avoid discharge of potentially contaminated water into the natural watercourses. There are restrictions on the use and release of this water.

4.2 MANAGEMENT MEASURES

The general principles for the construction and mining phases of the Dugald River Project to manage surface water are as follows.

- The fullest separation possible of 'clean', 'dirty' and 'contaminated' water runoff.
- Minimise the area of disturbance, thus minimising the volume of dirty or contaminated runoff.
- Contain all 'dirty' (non-toxic) water on site (via sediment ponds) whenever possible. If not, release it in a controlled manner in compliance with adopted water quality criteria.

- Contain all 'dirty' (low toxicity) water on site via low hazard dams. If necessary pump this water to the TSF via the process plant without releasing it to the natural watercourses. This water will only be released downstream during an extreme rainfall event and after notification to the Queensland Department of Environment and Resource Management.
- Segregate, collect and contain all potentially contaminated ('Toxic' and 'sub-lethal') water on site via significant and high hazard dams. If necessary pump this water to the TSF via the process plant without releasing it to the natural watercourses. This water will only be released downstream during an extreme rainfall event and after notification to the Queensland Department of Environment and Resource Management.

For management purposes, potentially contaminated catchments will be segregated into those that may produce 'Toxic', 'Sub-Lethal' and 'Low-Toxicity' stormwater runoff as per the following definitions based on guidelines provided in DME (1995):

- 'Toxic' – potentially greater than 100 times the drinking water standard;
- 'Sub-Lethal' – greater than 10 but less than 100 times the drinking water limit; and
- 'Low-Toxicity' – less than 10 time the drinking water standard.

Section 5 of this report details the proposed management measures to be used for the fullest separation of 'clean' runoff water away from the potentially 'dirty' and 'contaminated' runoff areas. The proposed measures to manage 'dirty' and 'contaminated' water from the Project Site, with the exclusion of the proposed Tailings Storage Facility area, are also described in detail in Section 5.

4.3 POTENTIAL CONSTRAINTS TO PROPOSED MINING ACTIVITIES

Based on available information, there are minimal constraints to the proposed Dugald River Project with respect to surface water management. The areas of disturbance caused by the Project are small and can be readily managed with minimal impact on the existing surface drainage systems.

5 PROPOSED SURFACE WATER MANAGEMENT CONTROLS

5.1 GENERAL

Surface water management controls would be implemented within the Project Site during both construction and operation phases in line with the surface water management objectives outlined in Section 4. This report details the management measures used for separation of 'clean' runoff water away from the 'dirty' and 'contaminated' runoff water areas and the management measures required to manage 'dirty' and 'contaminated' water from the Project Site.

The diversion of clean waters away from disturbed areas would reduce erosion and the potential for contamination of clean runoff. Diversion of 'clean' water will be achieved using a series of diversion banks.

The management of 'dirty' and 'contaminated' water from the Project Site will be achieved through the construction of 12 storages. The storages and catchments draining into these storages will be configured in a manner that will limit any mixing of 'dirty' and 'contaminated' water. Nine of the proposed storages are classified as low, significant or high hazard in accordance with DME (1995). The remaining three storages are classified as sediment ponds and will collect 'dirty' runoff that is not considered to pose a sufficient risk to require a hazard category classification. The behaviour of the proposed storages over the project life has been investigated using a long term water balance model, as described in Section 6 of this report.

The management measures related to the Tailings Storage Facility area are described elsewhere (AARC, 2010a).

5.2 PROPOSED CONTROLS

Figure 5.1 shows the locations of the proposed 'clean' surface water management system elements and controls on the Project Site. The 'clean' water management controls would be required for both construction and operational phases of the project.

The proposed clean water management controls include seven significant diversion drains (DB1 to DB7). These would be used to direct 'clean' water runoff from upstream catchments around the mine operations area and away from the back access road and other potentially disturbed and/or contaminated areas. A number of other minor diversion drains and bunds would be required to separate 'clean' surface water from areas around borrow pits, local roads and mine operations. These drainage works will be designed to suit local topographic conditions during the detail design phase of the project.

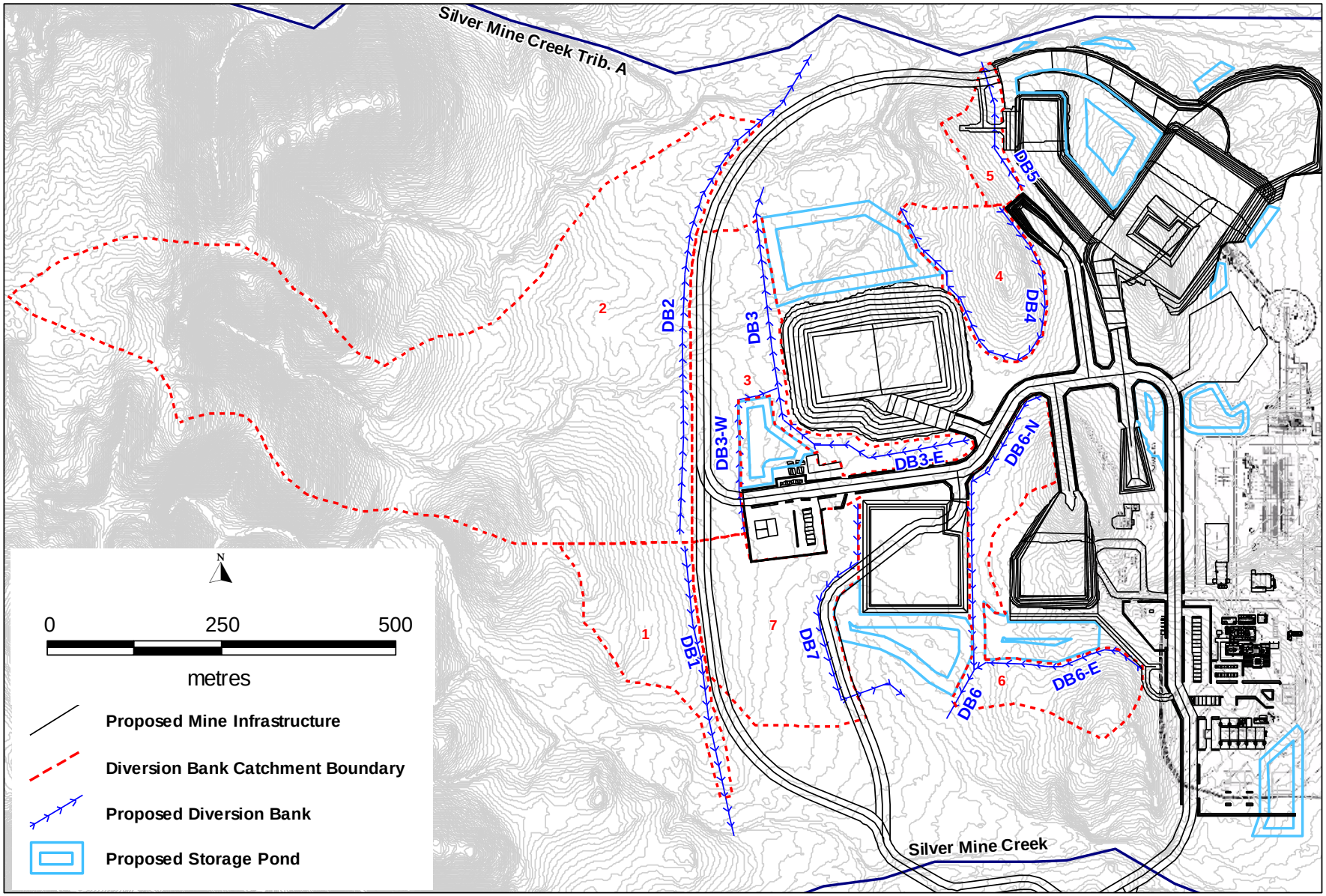


Figure 5.1 Proposed 'Clean' Surface Water Management Controls, Dugald River Project Site

5.2.1 Diversion Drain Configuration

Table 5.2 gives the proposed configuration of the diversion drains required to divert clean water runoff away from potentially disturbed and/or contaminated areas. Figure 5.1 shows the location and catchment areas of the proposed key diversion drains. Figure 5.2 shows the standard design dimensions for diversion banks and catch drains used within the site (Refer SD 5-6 in Landcom, 2004 for construction). The following is of note:

- All clean water diversion channels will be constructed to contain the 50 year ARI design discharge;
- Where possible, 'clean' water diversion drain structures have been designed to limit flow velocities to 1.8m/s or less for the 50 year ARI design event, however due to the steep topography and lack of groundcover vegetation around the mine operations area, rock check dams and other energy dissipation and sediment trapping structures will be required at regular intervals to limit erosion; and
- All structures should be inspected following significant storm events to ensure the structures have been able to sustain flow velocities without causing significant scour.
- The construction of DB3-E will depend on the extent of earthworks considered viable for construction of diversion banks. If extensive cut and fill is required to form this diversion bank then the catchment area of DB3-E will be added to Pond 9.

Table 5.1 Diversion Drain Specifications

Structure ID	Catchment Area (ha)	Channel Top Width (a) (m)	Channel Depth (b) (m)	Channel Bottom Width (c) (m)	Bank Height (d) (m)	Bank Top Width (e) (m)	Channel Grade (%)
DB1	3.33	4.1	0.33	1.5	0.63	1.5	1.1
DB2	26.84	9.8	0.47	6.0	0.77	1.5	1.4
DB3-W	1.62	3.2	0.34	0.5	0.64	1.5	1.0
DB3-E	1.05	2.7	0.30	0.25	0.60	1.5	1.0
DB3	5.89	5.1	0.51	1.0	0.81	1.5	1.0
DB4	2.90	4.6	0.46	1.0	0.76	1.5	0.5
DB5	1.12	3.2	0.34	0.5	0.64	1.5	0.5
DB6-N	2.01	4.1	0.39	1.0	0.69	1.5	0.5
DB6-E	1.82	4.0	0.37	1.0	0.67	1.5	0.5
DB6	4.15	5.3	0.29	3.0	0.59	1.5	1.5
DB7	5.43	6.5	0.44	3.0	0.74	1.5	0.5

* Rock check dams or cut and fill earthworks may be required to maintain channel grade.

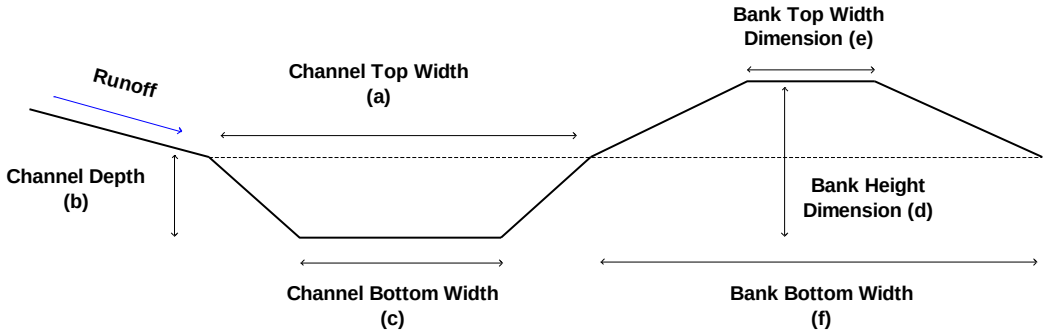


Figure 5.2 Diversion Bank Dimensions

Each diversion bank will exhibit the features identified below, with the dimensions for each diversion bank based on the upslope catchment area and slope.

- Trapezoidal channel;
- Bank batters between 1:3 to 1:6 (V:H);
- Channel batters 1:4 (V:H);
- Where necessary rock check dams (Refer SD 5-4 in Landcom, 2004) will be used to maintain specified channel grades;
- Bank bottom widths (f) will vary depending on the adopted bank batters;
- Level sill outlet to each channel;
- Stable grass cover to be maintained in the bed and banks of the channel and below sill outlets (as much as possible); and
- Sill width to be constructed with minimum 1.5 x channel base width. Ground slopes below the sill shall be less than or equal to the channel grade.

5.3 PROPOSED STORAGES

There are 12 storages proposed for the Project Site that will be used to manage 'dirty' and 'contaminated' runoff. The storages have been classified as sediment ponds or low, significant or high hazard storages in accordance with DME (1995) guidelines. Figure 5.3 shows the locations of the proposed storages, associated catchment areas, and the designated storage hazard category. The portal areas will be drained independently via sumps, with any water collected being reused in processing activities on site. It is of note that the numbering of the proposed storages in not consecutive, as it is based on a numbering system supplied by the client.

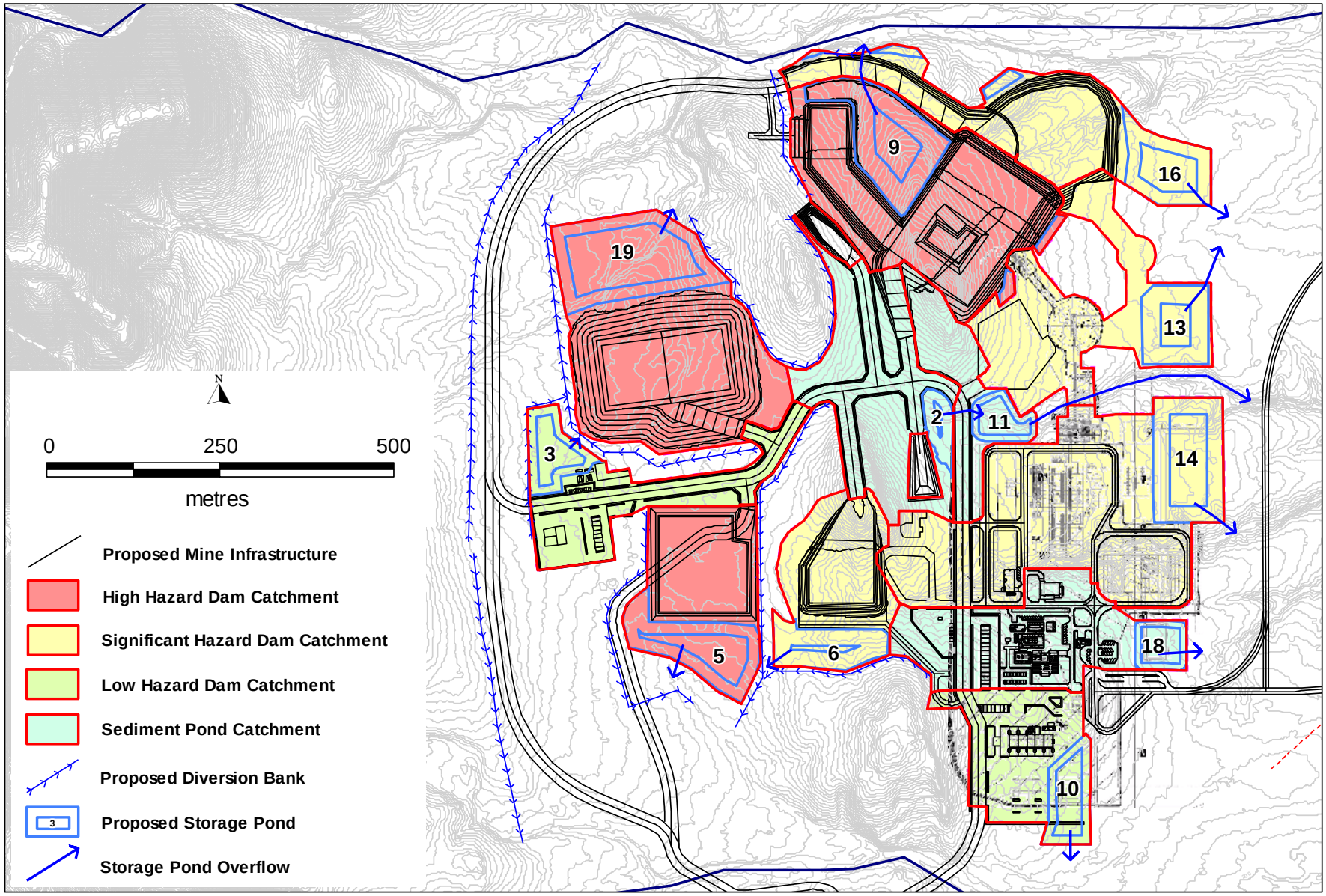


Figure 5.3 Proposed Dirty and Contaminated Runoff Storages, Dugald River Project Site

5.3.1 Sediment Ponds

Sediment ponds have catchments that will generate sediment laden runoff with little or no toxicity. On this basis, these dams have been sized to have a minimum sufficient storage capacity to capture runoff from a 10 year 24 hour duration storm event (160mm rainfall depth) using a runoff coefficient of 1.0. The proposed sediment ponds are described below:

- Pond 2: Collects runoff from road and natural catchment areas between the portals and processing plant. Overflows across road into Pond 11.
- Pond 11: Collects runoff from road and natural catchment area south of the Zinc ROM pad. Overflows to minor tributary of Silvermine Creek. Overflow channel passing beneath ore conveyors to be constructed to drain overflows to tributary.
- Pond 18: Collects runoff from go-line, offices, roads and natural catchment located between the south portal and south rockfill dump. Overflows to minor tributary of Silvermine Creek.

Table 5.3 gives the adopted catchment and storage parameters for the proposed low hazard dams.

Table 5.2 Sediment Pond Characteristics

Storage ID	Catchment Area (ha)	Storage Volume at FSL (ML)
Pond 2	4.99	7.98
Pond 11	2.42	3.87
Pond 18	4.77	7.64

FSL: Full Supply Level

5.3.2 Low Hazard Dams

The low hazard dam storages have catchment areas that are expected to generate 'dirty' (sediment laden) or 'low-toxicity' runoff only. Based on DERM's requirements, the Design Storage Allowance (DSA) for low hazard dams has been sized to provide storage capacity to capture runoff from an ARI 10 year (2 month) wet season (567mm rainfall depth) using a runoff coefficient of 1.0. The storages will be operated to ensure the DSA in each of the storages is available at November 1 every year. The MRL for each low hazard storage is calculated based on the storage volume required to capture runoff from a 10 year 72 hour design storm (210mm rainfall depth) using a runoff coefficient of 1.0.

- Pond 3: Collects runoff from contractor's workshop area and road between Off-ROM Ore stockpile and PAF dump. Overflows into DB3 (Silvermine Creek Trib.A).
- Pond 10: Collects runoff from mine workshop area. Overflows into Silvermine Creek.

Table 5.3 gives the adopted catchment and storage parameters for the proposed low hazard dams. It is of note that the Full Supply Level (FSL) of the low hazard dams is greater than the required DSA volume. This additional volume is required in order to ensure the DSA volume is available in each storage at November 1 each year, as no pumping or extraction has been modelled from any storages in the mine water management system. The DSA volume is contained within the FSL volume for each storage.

Table 5.3 Low Hazard Dam Characteristics

Storage ID	Catchment Area (ha)	Calculated DSA Volume (ML)	Adopted FSL Volume (ML)	MRL (ML)
Pond 3	3.63	20.55	22.84	15.23
Pond 10	3.55	20.12	24.80	17.35

FSL: Full Supply Level

5.3.3 Significant Hazard Dams

The significant hazard dam storages have catchment areas that may potentially generate 'sub-lethal' runoff. The Design Storage Allowance (DSA) for all significant hazard dams has been sized to provide storage capacity to capture runoff from an ARI 20 year (2 month) wet season (707mm rainfall depth) using a runoff coefficient of 1.0. Significant hazard dams will be operated to maintain water levels at or below the Mandatory Reporting Level (MRL), in accordance with DME (1995). Similarly, the storages will be operated to ensure the DSA in each of the storages is available at November 1 every year. The MRL for each storage is calculated based on the storage volume required to capture runoff from a 20 year 72 hour design storm (251mm rainfall depth) using a runoff coefficient of 1.0.

The proposed significant hazard dams are described below:

- Pond 6: Collects runoff from the south rockfill area. Overflows to Silvermine Creek via DB6.
- Pond 13: Collects runoff from Zinc and Copper stockpile areas and conveyors. Overflows to Silvermine Creek Tributary A.
- Pond 14: Collects runoff from Zinc and Copper process plant areas, reagent storage shed, paste plant and concentrate storage shed. Overflows to a minor tributary of Silvermine Creek.
- Pond 16: Collects runoff Copper ROM area and ramp. Overflows to Silvermine Creek Tributary A. Note that a number of smaller interceptions storages will be constructed along the northern edge of the Copper ROM and ramp areas to collect runoff from the embankments and seepage from the pad. Water collected in these small ponds will be pumped to Pond 16 as required. These storages will be sized as part of detail design and are not included in the water balance modelling.

Table 5.4 gives the adopted catchment and storage parameters for the proposed significant hazard dams. It is of note that a nominal Full Supply Level (FSL) volume has been adopted for each storage based on the available space for construction of the dam within the mine layout. The storage capacity of the adopted FSL exceeds the calculated DSA volume for each storage, and provides additional spill protection above the ARI 20 year (2 month) wet season design criteria. The adopted MRL and DSA volumes for significant hazard dams have been calculated in accordance with DME (1995). The DSA volume is contained within the FSL volume for each storage.

Table 5.4 Significant Hazard Dam Characteristics

Storage ID	Catchment Area (ha)	Calculated DSA Volume (ML)	Adopted FSL Volume (ML)	MRL (ML)
Pond 6	3.59	25.35	31.70	22.70
Pond 13	5.26	37.21	47.47	34.27
Pond 14	9.97	70.52	99.91	74.88
Pond 16	5.24	37.03	49.90	36.75

5.3.4 High Hazard Dams

The high hazard dam storages have catchment areas that may potentially generate 'toxic' runoff. The DSA's for all high hazard dams have been sized to provide storage capacity to capture runoff from an ARI 100 year (2 month) west season (1082mm rainfall depth) using a runoff coefficient of 1.0. High hazard dams will be operated to maintain water levels at or below the Mandatory Reporting Level (MRL), in accordance with DME (1995). Similarly, the storages will be operated to ensure the DSA in each of the storages is available at November 1 every year. The MRL for each storage is calculated based on the volume required to capture runoff from a 100 year 72 hour design storm (350mm rainfall depth) using a runoff coefficient of 1.0.

The proposed high hazard dams are described below:

- Pond 5: Collects runoff from the off-ROM stockpile area. Overflows to Silvermine Creek.
- Pond 9: Collects runoff from the Zinc ROM pad area. Overflows to Silvermine Creek Tributary A over the Copper ROM pad ramp. Note that a number of smaller interception storages will be constructed along the south-eastern edge of the Zinc ROM pad area to collect runoff from the embankments and seepage from the pad. Water collected in these small ponds will be pumped to Pond 9 as required. These storages will be sized as part of detail design and are not included in the water balance modelling.
- Pond 19: Collects runoff from the PAF dump area. Overflows to Silvermine Creek Tributary A.

Table 5.5 gives the adopted catchment and storage parameters for the proposed high hazard dams. It is of note that a nominal Full Supply Level (FSL) volume has been adopted for each storage based on the available space for construction of the dam within the mine layout. The storage capacity of the adopted FSL exceeds the calculated DSA volume, increasing the potential for each storage to have the DSA volume available at the 1st November each year. The adopted MRL and DSA volumes for high hazard dams have been calculated in accordance with DME (1995). The DSA volume is contained within the FSL volume for each storage.

Table 5.5 High Hazard Dam Characteristics

Storage ID	Catchment Area (ha)	Calculated DSA Volume (ML)	Adopted FSL Volume (ML)	MRL (ML)
Pond 5	4.14	44.82	48.50	34.01
Pond 9	7.97	86.18	101.50	73.63
Pond 19	8.47	91.62	93.50	63.97

6 WATER BALANCE MODELLING

6.1 GENERAL

An AWBM (Boughton, 2003) rainfall runoff model was developed to determine runoff volumes from hardstand, stockpile and natural catchment areas at the Project Site. The Goldsim (Goldsim Technology Group, 2010) model was then used to determine the behaviour of the proposed storages on the Project Site.

The models were run over the 121 year (from 1889 to 2010) period of daily rainfall data obtained from the Queensland DERM SILO Data Drill. The use of such a long period of continuous data provides a good indication of the behaviour of the various storages over extended dry and wet periods.

6.2 RAINFALL AND EVAPORATION

The rainfall and evaporation data obtained from the SILO Data Drill for the Project Site were used in the AWBM and Goldsim models. This data is discussed in greater detail in Section 3.2 of this report.

6.3 CATCHMENT RUNOFF

The catchment area draining to each storage was broken up into three types of runoff producing surfaces, natural, hardstand and stockpile. The AWBM model was used to represent the runoff characteristics of each of these surfaces. AWBM uses a group of connected conceptual storages (3 surface storages and 1 groundwater storage) to represent runoff from a catchment. Water in the conceptual storages is replenished by rainfall and reduced by evaporation on a daily basis. Simulated surface runoff occurs when these storages fill and overflow. The model parameters define the depth and relative area of each of the storages, as well as the rate of water flux between storages. These conceptual storages attempt to simulate the natural runoff processes where no runoff occurs on rain days when the conceptual stores are empty or partially empty and significant runoff occurs on days when the conceptual stores are full, i.e. when there are significant or consecutive wet days.

Table 6.1 shows the adopted AWBM parameters for each of the runoff surfaces. The following is of note:

- The soil moisture depths (conceptual storages) have been adjusted to achieve annual volumetric runoff coefficients of 0.08, 0.2 and 0.3 for natural, stockpile and hardstand surfaces.
- The adopted runoff coefficient for the natural catchment (0.08) was adopted based on the annual volumetric runoff coefficient calculated for the Dugald River in Section 3.3.2 of this report. The soil moisture store depths, baseflow index and surface flow recession

constants were adjusted so that the simulated runoff profile matched the timing and relative magnitude of the recorded hydrographs at the Silvermine Creek gauge for the available period of record. Note that the Silvermine Creek gauge site does not have a rating curve, and as such the magnitude of simulated and recorded runoff events cannot be directly compared.

- The adopted annual volumetric runoff coefficient for hardstand catchments is 275% greater than the adopted annual volumetric runoff coefficient for the natural catchment. The adopted stockpile annual volumetric runoff coefficient is 150% greater than that adopted for the natural catchment. No data is available to determine the reliability of these parameters, however based on experience the adopted rainfall runoff model is considered reasonable.

Table 6.1 Adopted AWBM Parameters - Natural, Hardstand and Stockpile Catchments

AWBM Model Parameter		Natural	Stockpile	Hardstand
Surface Stores (mm)	C1	10.4	7.0	3.4
	C2	106.7	70.0	35.1
	C3	213.4	150.0	70.1
Partial Areas	A1	0.134	0.134	0.134
	A2	0.433	0.433	0.433
	A3	0.433	0.433	0.433
Base flow index	BFI	0.5	0.0	0.0
Base flow recession constant	Kb	1.0	1.0	1.0
Surface flow recession constant	Ks	0.1	0.1	0.1
Runoff Coefficient	RC	0.08	0.20	0.30

6.4 PROCESS WATER DEMANDS

All process water demands will be met through a combination of water from Lake Julius and recycled water from the TSF. Full details of the mine site water demands and the process water circuit including recycling from the TSF are given in AARC (2010a).

6.5 OPERATION OF PROPOSED STORAGES

For water balance modelling purposes, it has been assumed that there would be no reuse of any water from the proposed storages for processing, or transfer of water between any of the storages (the exception being Pond 11, which receives spills from Pond 2). Each storage would essentially operate as an individual evaporation pond with the only inflows being catchment runoff and direct rainfall, and the only outflows being evaporation and spills. Seepage into and out of each storage has been assumed to be insignificant.

It is of note that there will be infrastructure in place to facilitate the pumping of water from significant and high hazard dams into the TSF via the process plant. This is considered to be an undesirable outcome as it will impact on the TSF water balance, and as such would only be relied on in order to manage water levels in the significant and high hazard dams to ensure the provision of DSA volumes on the 1st November each year, and to address water levels exceeding MRLs. The option of transferring water to the TSF has not been included in the water balance

model, and is viewed as an ***emergency only*** option for managing contaminated water on the Project Site.

6.6 WATER BALANCE MODEL CONFIGURATION

6.6.1 Inflows and Outflows

Inflows and outflows from each storage were modelled as described in Section 6.5.

6.6.2 Catchment Runoff Surfaces

The catchment area draining to each storage was broken up into natural, stockpile and hardstand runoff surfaces to facilitate more detailed modelling of the runoff volumes entering each storage. Table 6.2 gives the catchment runoff surface breakdown for each storage.

Table 6.2 Catchment Area Runoff Surfaces

Storage ID	Catchment Area (ha)			
	Natural	Stockpile	Hardstand	Total
Pond 2	2.54	0.70	1.75	4.99
Pond 3	0.23	0.86	2.54	3.63
Pond 5	0.00	4.14	0.00	4.14
Pond 6	0.79	2.56	0.24	3.59
Pond 9	0.30	7.58	0.10	7.97
Pond 10	0.00	0.84	2.71	3.55
Pond 11	1.26	0.59	0.57	2.42
Pond 13	0.81	3.19	1.26	5.26
Pond 14	0.90	2.61	6.46	9.97
Pond 16	0.00	5.24	0.00	5.24
Pond 18	0.68	1.10	2.99	4.77
Pond 19	0.98	7.49	0.00	8.47

6.6.3 Storage Characteristics

The adopted stage-storage relationships for the proposed storages are provided in Appendix A. Table 6.3 below summarises the adopted FSL volumes for each storage. The DSA volume for each storage is contained within the FSL volume. The Goldsim model was configured such that any excess volume above the FSL volume would spill from the storage instantaneously.

Table 6.3 Adopted FSL Volumes

Storage ID	FSL Volume (ML)
Pond 2	7.98
Pond 3	22.84
Pond 5	48.50
Pond 6	31.70
Pond 9	101.50
Pond 10	24.80
Pond 11	3.87
Pond 13	47.47
Pond 14	99.91
Pond 16	49.90
Pond 18	7.64
Pond 19	93.50

6.6.1 Sensitivity Analysis

A sensitivity analysis was carried out to investigate the effects of a 25% increase in predicted runoff volumes from all catchment surfaces.

6.7 WATER BALANCE MODEL RESULTS

This section discusses the results of the water balance modelling for low, significant and high hazard dams. Note that spill statistics are reported based on a water year commencing on the 1st July. As such the 121 year period of simulation encompasses 120 water years.

6.7.1 Sediment Pond Behaviour

Table 6.4**Error! Reference source not found.** shows details of the model results for the sediment ponds, including salient information on storage volumes and overflows.

Table 6.4 Water Balance Model Results, Sediment Ponds

Simulation Results	Storage ID		
	Pond 2*	Pond 11	Pond 18
Storage Volume			
FSL Volume (ML)	7.98	3.87	7.64
Max. Volume (ML)	7.98	3.87	7.64
Average Volume (ML)	3.23	0.53	2.37
80th %ile Volume (ML)	0.67	0.00	0.00
20th %ile Volume (ML)	5.59	0.99	4.79
Uncontrolled Spills			
No. Spill Years	28	25	33
Spill Frequency (1 in *X* Years)	4.3	4.8	3.6
Average No. Spills / Spill Year	2.4	2.3	2.5
Max. No. Spills / Spill Year	5.0	5.0	7.0
Average Annual Spill Volume / Spill Year (ML)	6.0	8.6	7.4
Max. Annual Spill Volume / Spill Year (ML)	26.8	39.5	34.5

*Note Pond 2 spills into Pond 11.

The following is of note with regards to Table 6.4**Error! Reference source not found.**:

- The sediment ponds are predicted to spill for 25 to 33 out of the 120 water years included in the simulation. This represents a probability of spills from the sediment ponds of 1 spill every 3 to 4 years.
- The sediment ponds would have an average of 2.3 to 2.5 spill events per spill year, and a maximum of 7 spill events per spill year.
- The average spill volume per spill year from the sediment ponds is between 6ML and 9ML. The maximum spill volume per spill year ranges from 26ML to 40ML.
- When compared to expected flow volumes in Silvermine Creek and Dugald River (downstream of the sediment ponds) during significant rainfall events, the predicted spill volumes are not significant.

6.7.2 Low Hazard Dam Behaviour

Table 6.5 shows details of the model results for the significant hazard storages, including salient information on storage volumes, overflows and DSA availability.

Table 6.5 Water Balance Model Results, Low Hazard Dams

Simulation Results	Storage ID	
	Pond 3	Pond 10
Storage Volume		
FSL Volume (ML)	22.84	24.80
Max. Volume (ML)	22.84	24.80
Average Volume (ML)	3.04	3.20
80th %ile Volume (ML)	0.00	0.00
20th %ile Volume (ML)	5.76	6.07
Uncontrolled Spills		
No. Spill Years	3	2
Spill Frequency (1 in *X* Years)	40	60
Average No. Spills / Spill Year	1.3	1.5
Max. No. Spills / Spill Year	2.0	2.0
Average Annual Spill Volume / Spill Year (ML)	4.9	5.3
Max. Annual Spill Volume / Spill Year (ML)	10.9	9.5
DSA and MRL		
DSA Volume (ML)	20.55	20.12
No. Years DSA Available at 1st November	89	98
MRL Volume (ML)	15.23	17.35
No. Years MRL Exceeded	5	5

The following is of note with regards to Table 6.5:

- The low hazard dams are predicted to spill for 2 to 3 out of the 120 water years included in the simulation. This represents a probability of spills from the low hazard dams of 1 spill every 40 to 60 years.
- The sediment ponds would have an average of 1.3 to 1.5 spill events per spill year, and a maximum of 2 spill events per spill year.
- The average spill volume per spill year from the sediment ponds is between 4ML and 6ML. The maximum spill volume per spill year ranges from 9ML to 10ML.
- When compared to expected flow volumes in Silvermine Creek and Dugald River (downstream of the low hazard dams) during significant rainfall events, the predicted spill volumes are not significant.

6.7.3 Significant Hazard Dam Behaviour

Table 6.6 shows details of the model results for the significant hazard storages, including salient information on storage volumes, overflows and DSA availability.

Table 6.6 Water Balance Model Results, Significant Hazard Dams

Simulation Results	Storage ID			
	Pond 6	Pond 13	Pond 14	Pond 16
Storage Volume				
FSL Volume (ML)	31.70	47.47	99.91	49.90
Max. Volume (ML)	29.02	44.93	91.30	47.99
Average Volume (ML)	2.82	5.45	15.21	4.01
80th %ile Volume (ML)	0.03	0.00	0.06	0.00
20th %ile Volume (ML)	4.99	10.32	28.49	7.39
Uncontrolled Spills				
No. Spill Years	0	0	0	0
Spill Frequency (1 in *X* Years)	NA	NA	NA	NA
Average No. Spills / Spill Year	NA	NA	NA	NA
Max. No. Spills / Spill Year	NA	NA	NA	NA
Average Annual Spill Volume / Spill Year (ML)	NA	NA	NA	NA
Max. Annual Spill Volume / Spill Year (ML)	NA	NA	NA	NA
DSA and MRL				
DSA Volume (ML)	25.35	37.21	70.52	37.03
No. Years DSA Available at 1st November	112	104	105	114
MRL Volume (ML)	22.70	34.27	74.88	36.75
No. Years MRL Exceeded	1	1	1	1

The following is of note with regards to Table 6.6:

- None of the significant hazard storages are predicted to spill over the 120 year period of simulation.
- The water balance model predicts the DSA volume will be available in all significant hazard storages on the 1st November for at least 104 years out of the 120 year period of simulation.
- The significant hazard storages are predicted to exceed the MRL in only 1 year out of the 120 year period of simulation.

6.7.4 High Hazard Dam Behaviour

Table 6.7 shows details of the model results for the high hazard storages, including salient information on storage volumes, overflows and DSA availability.

Table 6.7 Water Balance Model Results, High Hazard Dams

Simulation Results	Storage ID		
	Pond 5	Pond 9	Pond 19
Storage Volume			
FSL Volume (ML)	48.50	101.50	93.50
Max. Volume (ML)	38.12	71.38	73.77
Average Volume (ML)	2.20	8.12	3.80
80th %ile Volume (ML)	0.00	0.00	0.00
20th %ile Volume (ML)	3.50	15.18	5.35
Uncontrolled Spills			
No. Spill Years	0	0	0
Spill Year Frequency (1 in *X* Years)	NA	NA	NA
Average No. Spills / Spill Year	NA	NA	NA
Max. No. Spills / Spill Year	NA	NA	NA
Average Annual Spill Volume / Spill Year (ML)	NA	NA	NA
Max. Annual Spill Volume / Spill Year (ML)	NA	NA	NA
DSA and MRL			
DSA Volume (ML)	44.82	86.18	91.62
No. Years DSA Available at 1st November	106	103	101
MRL Volume (ML)	34.01	73.63	63.97
No. Years MRL Exceeded	1	0	1

The following is of note with regards to Table 6.7:

- None of the high hazard storages are predicted to spill for the 120 year period of simulation.
- The water balance model predicts the DSA volume will be available in all high hazard storages on the 1st November for at least 101 years out of the 120 year period of simulation.
- The high hazard storages are predicted to exceed the MRL in only 1 year out of the 120 year period of simulation.

6.7.5 Sensitivity Analysis Results

A sensitivity analysis to investigate the behaviour of the proposed storages under higher runoff conditions was carried using the water balance model. Runoff from each surface area (natural, stockpile and hardstand) was increased by 25% for the analysis. The results of the sensitivity analysis are discussed below.

Sediment Ponds

Table 6.8**Error! Reference source not found.** shows details of the model results for the low hazard storages, including salient information on storage volumes and overflows.

Table 6.8 Sensitivity Analysis Results, Sediment Ponds

Simulation Results	Storage ID		
	Pond 2*	Pond 11	Pond 18
Storage Volume			
FSL Volume (ML)	7.98	3.87	7.64
Max. Volume (ML)	7.98	3.87	7.64
Average Volume (ML)	3.64	0.62	2.69
80th %ile Volume (ML)	1.05	0.00	0.00
20th %ile Volume (ML)	5.97	1.29	5.22
Uncontrolled Spills			
No. Spill Years	35	32	40
Spill Frequency (1 in *X* Years)	3.4	3.8	3.0
Average No. Spills / Spill Year	2.5	2.3	2.5
Max. No. Spills / Spill Year	5.0	6.0	5.0
Average Annual Spill Volume / Spill Year (ML)	7.4	10.4	9.2
Max. Annual Spill Volume / Spill Year (ML)	34.8	50.9	44.0

*Note Pond 2 spills into Pond 11.

The following is of note with regards to Table 6.8**Error! Reference source not found.**:

- The additional runoff results in an increase in spills from the sediment ponds, with the predicted spill frequency increasing to 1 spill in every 3 to 4 years.
- The predicted average and maximum number of spills per spill year is generally unchanged.
- The average spill volume per spill year from the low hazard storages is predicted to increase to between 7ML and 11ML. The maximum spill volume per spill year increases significantly to between 34ML to 51ML.

Low Hazard Dams

Table 6.9 shows water balance model results for the low hazard dams under the sensitivity analysis conditions.

Table 6.9 Sensitivity Analysis Results, Low Hazard Dams

Simulation Results	Storage ID	
	Pond 3	Pond 10
Storage Volume		
FSL Volume (ML)	22.84	24.80
Max. Volume (ML)	22.84	24.80
Average Volume (ML)	4.48	4.50
80th %ile Volume (ML)	0.00	0.00
20th %ile Volume (ML)	8.84	8.86
Uncontrolled Spills		
No. Spill Years	5	5
Spill Frequency (1 in *X* Years)	24	24
Average No. Spills / Spill Year	1.6	1.6
Max. No. Spills / Spill Year	2.0	2.0
Average Annual Spill Volume / Spill Year (ML)	7.4	5.8
Max. Annual Spill Volume / Spill Year (ML)	17.7	16.3
DSA and MRL		
DSA Volume (ML)	20.55	20.12
No. Years DSA Available at 1st November	71	89
MRL Volume (ML)	15.23	17.35
No. Years MRL Exceeded	15	10

The following is of note with regards to Table 6.9:

- The additional runoff results in an increase in spills from the low hazard storages, with the predicted spill frequency increasing to 1 spill in every 24 years.
- The predicted average and maximum number of spills per spill year is generally unchanged.
- The average spill volume per spill year from the low hazard storages is predicted to increase to 6ML. The maximum spill volume per spill year increases significantly to between 15ML and 17ML.
- The availability of the DSA volume in each significant hazard storage on 1st November each year is reduced to 75 years out of the 120 year simulation period.

- The number of years when the MRL is exceeded also increases to 15 years out of the 120 year simulation period.

Significant Hazard Dams

Table 6.10 shows details of the sensitivity analysis model results for the significant hazard storages.

Table 6.10 Sensitivity Analysis Results, Significant Hazard Dams

Simulation Results	Storage ID			
	Pond 6	Pond 13	Pond 14	Pond 16
Storage Volume				
FSL Volume (ML)	31.70	47.47	99.91	49.90
Max. Volume (ML)	31.70	47.47	99.91	49.90
Average Volume (ML)	3.97	8.43	24.39	5.87
80th %ile Volume (ML)	0.14	0.06	1.70	0.00
20th %ile Volume (ML)	7.09	15.65	44.25	11.10
Uncontrolled Spills				
No. Spill Years	1	1	1	1
Spill Frequency (1 in *X* Years)	120	120	120	120
Average No. Spills / Spill Year	1	2	2	1
Max. No. Spills / Spill Year	1	2	2	1
Average Annual Spill Volume / Spill Year (ML)	3.3	8.2	23.7	8.0
Max. Annual Spill Volume / Spill Year (ML)	3.3	8.2	23.7	8.0
DSA and MRL				
DSA Volume (ML)	25.35	37.21	70.52	37.03
No. Years DSA Available at 1st November	99	83	79	110
MRL Volume (ML)	22.70	34.27	74.88	36.75
No. Years MRL Exceeded	4	6	6	4

The following is of note with regards to Table 6.10:

- The increased runoff is predicted to cause the significant hazard dams to spill in one year out of the 120 year period of simulation.
- For the sole spill year, the model predicts spill volumes of between 3ML and 24ML from each storage.

- The availability of the DSA volume in each significant hazard storage on 1st November each year is reduced to 79 years out of the 120 year simulation period.
- The number of years when the MRL is exceeded also increases to 6 years out of the 120 year simulation period.

High Hazard Dams

Table 6.11 shows details of the sensitivity analysis model results for the high hazard storages.

Table 6.11 Sensitivity Analysis Results, High Hazard Dams

Simulation Results	Storage ID		
	Pond 5	Pond 9	Pond 19
Storage Volume			
FSL Volume (ML)	48.50	101.50	93.50
Max. Volume (ML)	45.38	88.31	87.64
Average Volume (ML)	3.04	12.34	5.17
80th %ile Volume (ML)	0.00	0.06	0.00
20th %ile Volume (ML)	5.29	22.66	8.04
Uncontrolled Spills			
No. Spill Years	0	0	0
Spill Year Frequency (1 in *X* Years)	NA	NA	NA
Average No. Spills / Spill Year	NA	NA	NA
Max. No. Spills / Spill Year	NA	NA	NA
Average Annual Spill Volume / Spill Year (ML)	NA	NA	NA
Max. Annual Spill Volume / Spill Year (ML)	NA	NA	NA
DSA and MRL			
DSA Volume (ML)	44.82	86.18	91.62
No. Years DSA Available at 1st November	100	85	98
MRL Volume (ML)	34.01	73.63	63.97
No. Years MRL Exceeded	2	1	2

The following is of note with regards to Table 6.11:

- The increased runoff is not predicted to cause the high hazard dams to spill.
- The availability of the DSA volume in each significant hazard storage on 1st November each year is reduced to 85 years out of the 120 year simulation period.

- The additional runoff will cause the MRL to be exceeded in the high hazard dams for 2 years out of the 120 year period of simulation.

6.7.6 Summary of Results

The water balance model does not predict any spills from significant or high hazard dams during the 120 year period of simulation. The low hazard dams are predicted to spill for 3 years out of the 120 year simulation period. The model also predicts that DSA volumes will be available in significant and high hazard storages for over 100 years out of the 120 year simulation period. Model results indicate that DSA volumes will be available in low hazard storages for over 80 years out of the 120 year simulation period.

Sensitivity analysis modelling indicates that a 25% increase in predicted runoff volumes would only result in several minor spills from the significant hazard dams, and a minor increase in spills from low hazard dams (5 spill years for the 120 year simulation period).

The high hazard dams are still not predicted to spill during the high runoff scenario. It is of note that the water balance modelling has not included any pumping (transfer) of water from significant and high hazard dams to the TSF and/or reuse of captured stormwater in processing. If captured stormwater is pumped (transferred) to the TSF and/or reused on-site this would potentially reduce the predicted average storage volumes and predicted spills.

The water balance modelling results indicate that the proposed water management system is robust and has more than adequate storage capacity for managing surface water runoff within the Project Site. As such there may be a case for potentially reducing the size of high hazard dams, for which the adopted FSL volume currently exceeds both the calculated DSA and the maximum storage volume predicted by the water balance model for each dam.

7 FLOOD STUDIES

7.1 OVERVIEW

The HEC-RAS hydraulic model (USACE, 2003) was used to investigate design 10 and 100 Year ARI flood levels in Silvermine Creek and Silvermine Creek Tributary A, and also in Dugald River and Dugald River Tributary A. The HEC-RAS model was also used to design the proposed access road crossings shown in Figure 2.3 (Locations B, C, D, E, F and H). The crossings are described as follows:

- Location B – Mine Access Road at Silvermine Creek;
- Location C – Mine Access Road at Dugald River;
- Location D – Mine Access Road at Dugald River Overflow 1;
- Location E – Mine Access Road at Dugald River Overflow 2;
- Location F – Mine Access Road at Dugald River Tributary ; and
- Location H – Mine Access Road at Silvermine Creek Tributary A.

The design flood level for the water supply pipeline crossing at Location N was estimated using the Manning's Equation and is described in Section 7.6. The flood level at pipeline crossing Locations A and O were estimated using the HEC-RAS model. The proposed access road crossing at Locations G, I, J, K, L and M were designed using pipe nomographs. The proposed configuration of all access road crossings is given in Table 7.7.

7.2 DISCHARGE ESTIMATION

Design discharges for the 10 and 100 Year ARI flood events in Silvermine Creek, Silvermine Creek Tributaries A, B and other minor tributaries and Dugald River Tributaries A and B were estimated using the Rational Method as described in Australian Rainfall and Runoff (IEAust, 1998).

A flood frequency analysis (FFA) was undertaken at the Dugald River Railway Crossing (DERM Gauge. No. 915206a) to estimate design discharges in the Dugald River in the vicinity of the project site.

7.2.1 Rational Method Discharge Estimates

Figure 7.1 shows the Rational Method discharge estimation points. Table 7.1 shows the Rational Method 10 and 100 Year ARI discharge estimates for each location. Design rainfall intensities for the area for different storm durations were determined using standard procedures in IEAust (1998). The Rational Method discharge estimates have been adopted for this study.

Table 7.1 Rational Method Discharge Estimates

Rational Method Parameters	Discharge Location																
	SMC1	SMC2	SMC3	SMC5	SMC_TribA1	SMC_TribA2	SMC_TribA3	SMC_TribA5	SMC_TribB1	SMC_Out	DR_TribA1	DR_TribB1	X-ing I	X-ing J	X-ing K	X-ing L	X-ing M
Catchment Area (ha)	187.8	250.6	299.4	520.3	119.7	243.9	350.6	683.5	69	1314.6	350.5	219.5	41.0	4.9	20.0	23.0	11.2
Stream Length (km)	2.82	2.82	3.42	5.86	2.18	2.65	3.46	4.76	1.56	6.91	3.11	2.57	0.62	0.30	0.58	0.60	0.20
Equal Area Slope (%)	2.1	2.1	1.8	1.1	3.5	2.8	2	1.4	5.6	1.1	0.5	1.0	0.5	0.7	0.9	0.8	1.0
Time of Concentration (min)	28.2	27.4	34.7	68.4	18.5	23	33.1	49.2	11.6	73.6	51.7	34.0	13.0	6.9	10.3	10.8	5.0
10 Year ARI Rainfall Intensity (mm/hr)	80	81	73	52	97	87	74	61	118	49	60	73	111	139	121	119	154
100 Year ARI Rainfall Intensity (mm/hr)	122	124	112	79	148	133	114	93	180	75	92	112	169	212	184	181	234
C_{10}	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
C_{100}	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
10 Year ARI Discharge (m^3/s)	32.7	44.2	47.6	58.5	25.3	46.2	56.5	90.8	17.7	140.3	45.8	34.5	9.9	1.5	5.3	6.0	3.7
100 Year ARI Discharge (m^3/s)	59.6	80.9	87.3	106.7	46.1	84.4	103.5	165.4	32.3	256.6	83.6	64.0	18.0	2.7	9.6	10.8	6.8

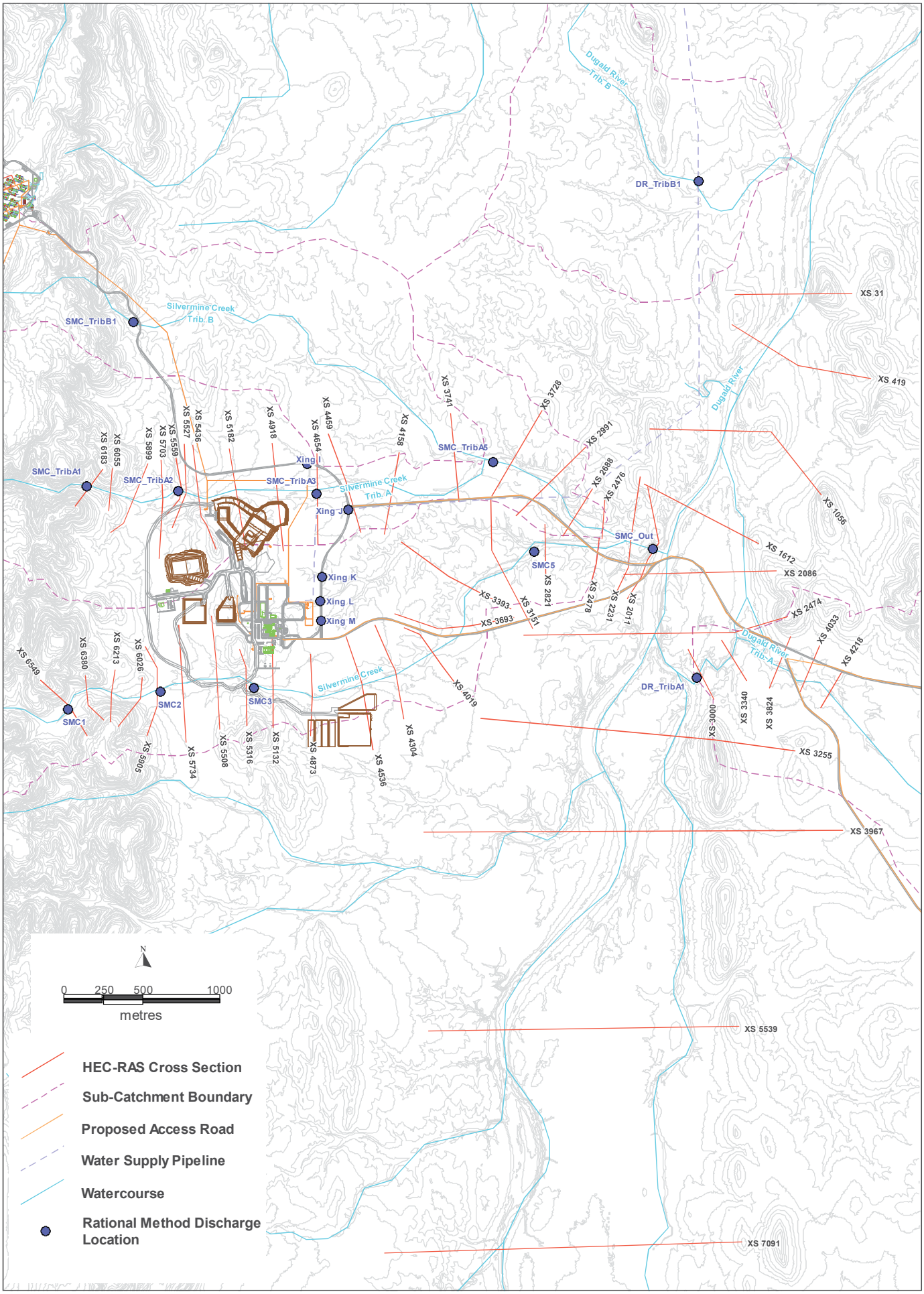


Figure 7.1 Rational Method Discharge Locations and HEC-RAS Model Configuration

7.2.2 Dugald River Flood Frequency Analysis

The methodology recommended in IEAust (1998) was used to fit a Log-Pearson Type III distribution to an annual series of recorded peak flood discharges at the Dugald River Railway Crossing gauge. The location of the Dugald River Railway Crossing gauge site is shown in Figure 2.1.

The peak annual discharge recorded at the gauge site was obtained from the DERM website. The annual peak series record at the gauge extends from 1969 to 2006; however data appears to be missing for 1976, 1988, 1989, 1990, 1991 and 2002. This leaves an available annual peak series of 31 years for use in the FFA. Figure 7.2 shows the flood frequency distribution plot for the Railway Crossing gauge, and Table 7.2 gives the flood frequency analysis discharge estimates for the gauge. The FFA design discharge estimates have been adopted for Dugald River in the vicinity of the project site.

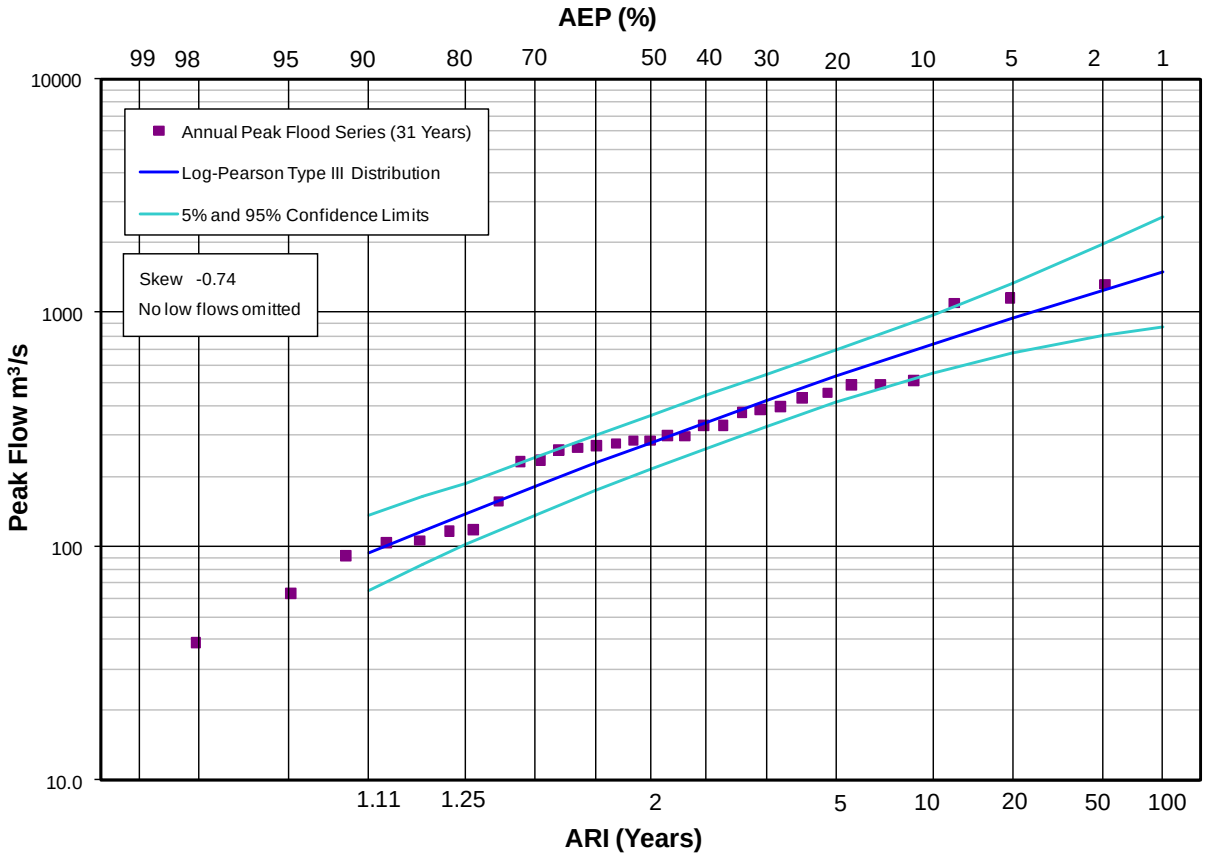


Figure 7.2 Flood Frequency Distribution Plot, Dugald River at Railway Crossing (DERM GS915206a)

Table 7.2 Flood Frequency Analysis Results, Dugald River at Railway Crossing (DERM GS 915206a)

ARI (Years)	Estimated Peak Discharge (m^3/s)		
	95% Confidence Limit	Adopted Value	5% Confidence Limit
2	80	128	206
5	414	536	693
10	553	737	983
20	673	950	1342
50	798	1250	1959
100	870	1492	2560

7.2.3 Concurrent Event Analysis

Due to the difference in catchment size, it is inappropriate to assume that a 100 Year ARI flood event occurring in the Dugald River would coincide with a 100 Year ARI flood event occurring in the tributaries draining the project site (NRW, 2008). As such it was necessary to undertake a concurrent event analysis to determine the appropriate critical combination of events in the Dugald River and the tributaries draining the subject site. The Quick IFD method, as described in the Queensland Urban Drainage Manual (NRW, 2008) was selected to determine the critical combination of events.

Based on the Quick IFD Method it was determined that a 100 Year ARI event in the Dugald River would correspond with a 10 Year ARI event in the project site tributaries, and vice-versa.

7.3 MODEL CONFIGURATION

7.3.1 Adopted Discharges

The discharges given in Section 7.2 have been adopted for use in the HEC-RAS model. Two discharge scenarios were adopted for investigation using the HEC-RAS model, and can be described as follows:

- Scenario 1: 100 Year ARI Discharge in Dugald River and 10 Year ARI discharges in Silvermine Creek, Silvermine Creek Trib. A and Dugald River Trib. A.
- Scenario 2: 10 Year ARI Discharge in Dugald River and 100 Year ARI discharges in Silvermine Creek, Silvermine Creek Trib. A and Dugald River Trib. A.

Table 7.3 gives the cross sections ID's at which the discharges described in Section 7.2 are applied in the HEC-RAS model.

Table 7.3 HEC-RAS Model Discharge Locations

Discharge Location	HEC-RAS Cross Section ID
Dugald River at Railway Crossing (FFA Estimates)	All Dugald River Cross Sections (XS 31, XS 419, XS 1056, XS 1612, XS 2086, XS 2474, XS 3255, XS 3967, XS 5539, XS 7091)
SMC1	Silvermine Creek XS 6549
SMC2	Silvermine Creek XS 5905
SMC3	Silvermine Creek XS 5316
SMC5	Silvermine Creek XS 3151
SMC_TribA1	Silvermine Creek Trib. A. XS 6183
SMC_TribA2	Silvermine Creek Trib. A. XS 5559
SMC_TribA3	Silvermine Creek Trib. A. XS 4654
SMC_TribA5	Silvermine Creek Trib. A. XS 3278
SMC_Out	Silvermine Creek XS 2231
DR_TribA1	Dugald River Trib. A. XS 4218

7.3.2 Model Cross Sections

Model cross sections were developed from project site survey data provided by Oz Minerals Pty Ltd, the previous owners of the Project Site.

7.3.3 Adopted Manning's 'n'

Site visit notes and aerial photography were used to determine appropriate channel and overbank Manning's 'n' values for the Dugald River and the tributaries draining the subject site. Table 7.4 gives the Manning's 'n' values were adopted for the study.

Table 7.4 Adopted Manning's 'n' Values

Location	Manning's 'n'
Dugald River Main Channel	0.04
Dugald River Overbank Areas	0.07
Tributary Main Channels	0.07
Tributary Overbank Areas	0.08

7.3.4 Boundary Conditions

Normal depth slopes were adopted as the upstream and downstream boundary conditions for the Dugald River, and also as the upstream boundary conditions for the tributaries draining the project site. Table 7.5 gives the adopted upstream and downstream normal depth slopes for Dugald River and the upstream normal depth slopes for the tributaries. The adopted values are based on channel slopes at the upstream and downstream ends of each branch.

Table 7.5 Adopted Normal Depth Slope Boundary Conditions

Branch	Normal Depth Slope (%)	
	Upstream	Downstream
Dugald River	0.3	0.08
Silvermine Creek	1.6	NA
Silvermine Creek Trib. A.	1.3	NA
Dugald River Trib. A.	0.5	NA

7.3.5 Waterway Crossing Configurations

The crossings proposed for Locations A, B, C, D, E, F, H and O were included in the HEC-RAS model at the following cross sections:

- Location A: Between XS 2991 and XS 2688
- Location B: Between XS 4019 and XS 3693;
- Location C: Between XS 2086 and XS 1612;
- Location D: Between XS 2474 and XS 2086;
- Location E: Between XS 2474 and XS 2086;
- Location F: Between XS 4033 and XS 3824;
- Location H: Between XS 4654 and XS 4459; and
- Location O: Between XS 1056 and XS 419

The crossing configurations are described in detail in Section 7.5 (Table 7.8).

7.4 DESIGN FLOOD LEVELS

Table 7.6 gives the worst case design flood levels in Dugald River, Silvermine Creek, Silvermine Creek Tributary A and Dugald River Tributary A. The worst case extent of flooding is shown in Figure 7.3. The following is of note:

- Scenario 1 produces the worst case flood levels in Dugald River;
- Scenario 2 produces the worst case flood levels in the upper reaches of Silvermine Creek, Silvermine Creek Tributary A and Dugald River Tributary A. In the lower reaches of the tributaries Scenario 1 produces the worst case flood levels;
- Worst case flood levels in Dugald River range from 190.76m at XS 7091 to 181.55m at XS 31;
- Worst case flood levels in Silvermine Creek range from 218.12m at XS 6549 to 184.60m at XS 2011;
- Worst case flood levels in Silvermine Creek Tributary A range from 213.06m at XS 6183 to 184.68m at XS 2476; and
- Worst case flood levels in Dugald River Tributary A range from 186.51m at XS 4218 to 185.39m at XS 3000.

Table 7.6 Design Flood Levels, Worst Case Scenario

Cross Section ID	Worst Case Flood Level (m)
Dugald River	
XS 31	181.55
XS 419	181.93
XS 1056	183.17
XS 1612	183.91
XS 2086	184.41
XS 2474	184.56
XS 3255	185.64
XS 3967	186.48
XS 5539	188.55
XS 7091	190.76
Silvermine Creek	
XS 2011	184.60
XS 2231	184.67
XS 2478	184.68
XS 2821	184.71
XS 3151	186.44
XS 3393	188.29
XS 3693	190.19
XS 4019	193.15
XS 4304	195.01
XS 4536	197.02
XS 4873	199.33
XS 5132	201.68
XS 5316	203.96
XS 5508	206.00
XS 5734	207.81
XS 5905	209.67
XS 6026	211.35
XS 6213	213.63
XS 6380	215.82
XS 6549	218.12

Table 7.6 (cont) Design Flood Levels, Worst Case Scenario

Cross Section ID	Worst Case Flood Level (m)
Silvermine Creek Trib. A	
XS 2479	184.68
XS 2688	184.72
XS 2991	185.16
XS 3728	186.78
XS 3741	189.06
XS 4158	192.15
XS 4459	194.01
XS 4654	195.76
XS 4918	197.92
XS 5182	200.45
XS 5436	202.74
XS 5527	203.89
XS 5559	204.26
XS 5073	205.91
XS 5899	208.25
XS 6055	211.05
XS 6183	213.06
Dugald River Trib. A	
XS 3000	185.39
XS 3340	185.41
XS 3824	185.46
XS 4033	185.45
XS 4218	186.51

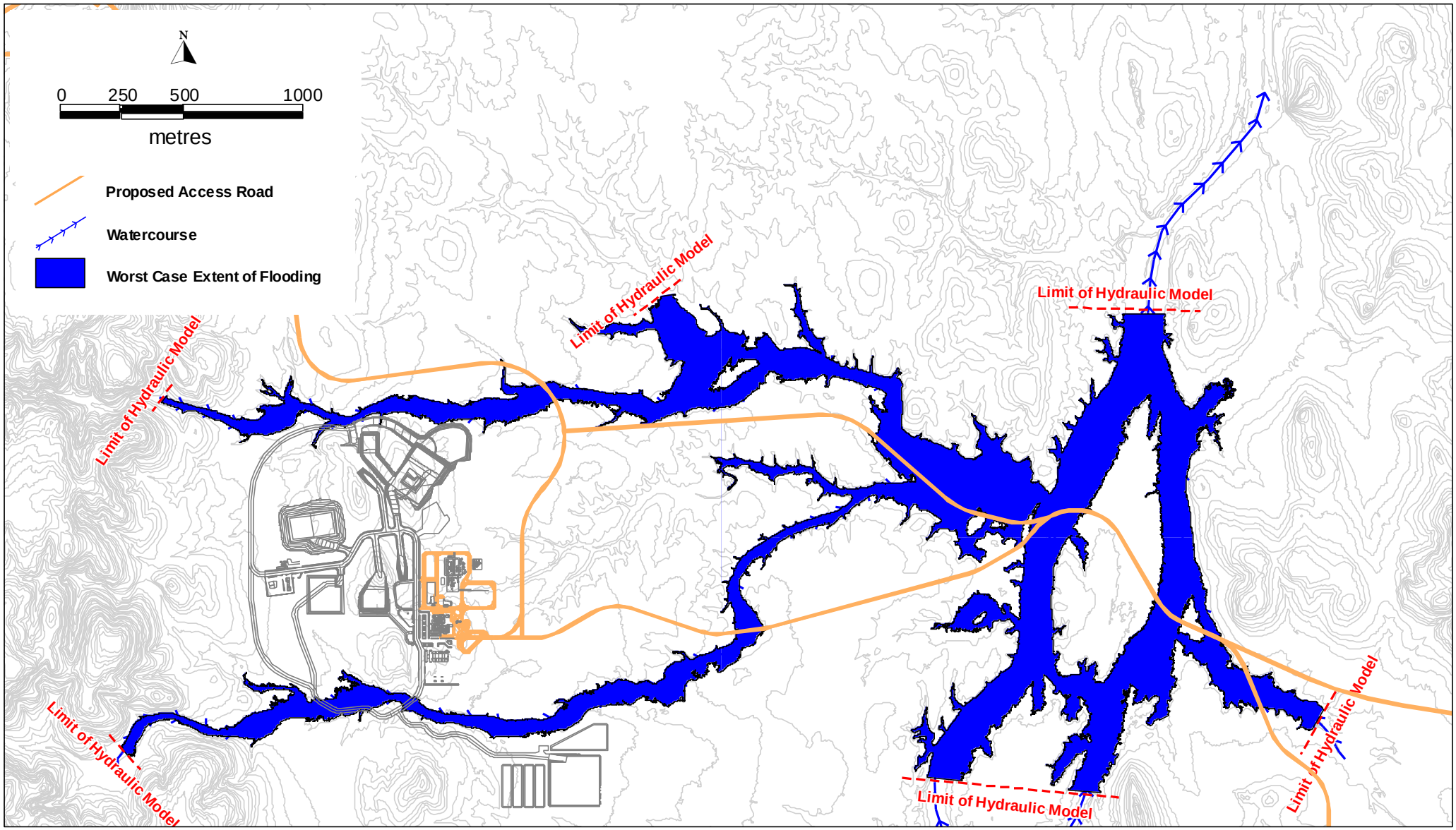


Figure 7.3 Worst Case Scenario Extent of Flooding

7.5 MINE ACCESS AND HAUL ROADS AND CROSSINGS

7.5.1 Proposed Crossing Configuration

Table 7.7 gives the proposed configuration of each waterway crossing. Crossings proposed for Locations B, C, D, E, F, and H were designed using the HEC-RAS Model, and the crossings proposed for Locations G, I, J, K, L and M were designed using the Manning's Equation and pipe nomographs. Figures B1 to B6, Appendix B, show the proposed crossings and waterway sections at Locations B to F and H. The following is of note:

- The proposed crossings at Locations B, C and F are configured as low level causeways, and are designed to be overtopped during relatively minor flood events;
- The Silvermine Creek crossing at Location B is designed to be overtopped for discharges greater than 13m^3/s;
- The Dugald River crossing at Location C is designed to be overtopped for discharges greater than 32m^3/s;
- The Dugald River Overflow crossings at Locations D and E would only be overtopped for discharges in excess of the 50 Year ARI flood in Dugald River (1250m^3/s);
- The Dugald River Tributary A crossing at location F is designed to be overtopped for discharges greater than 4m^3/s;
- The proposed crossings at Locations G and H have been configured to provide the Accommodation Camp Road with immunity from the 100 Year ARI flood events in Silvermine Creek Tributaries A and B (84.4m^3/s and 32.3m^3/s respectively);
- The proposed crossings at Locations I, J, K, L and M also have been configured to provide 100 year ARI flood immunity from local creek flooding. The proposed crossing at Location O has been configured to provide 100 year flood immunity from Dugald River backwater flooding; and
- In order to maximise available flow area the crossings proposed for Locations B and D include high and low level culverts with different invert levels.
- All proposed waterway crossings will require erosion and scour protection on the upstream and downstream road embankments. Particular attention should be paid to erosion and scour protection for the low level crossings proposed at locations B, C and F.

Table 7.7 Proposed Access Road Waterway Crossing Configurations

Crossing Parameter	Crossing Location													
	B		C	D		E	F	G	H	I	J	K	L	M
Culvert Size	4.2m W x 1.2m H	1.8m W x 0.3m H	4.2m W x 1.5m H	0.3m Dia.	0.45m Dia.	1.8m W x 0.6m H	1.8m W x 0.3m H	4.2m W x 1.2m H	4.2m W x 1.5m H	4.2m W x 1.2m H	1.8m W x 0.6m H	4.2m W x 1.2m H	4.2m W x 1.5m H	4.2m W x 1.2m H
Number Culvert Barrels	1	2	7	1	2	2	2	5	5	4	8	2	2	2
Upstream Culvert Invert Level (m AHD)	188.6	189.5	176.5	183.93	183.7	183.34	183.9	211.03	192.65	195.93	195.50	194.86	195.04	196.88
Downstream Culvert Invert Level (m AHD)	188.35	189.25	176.3	183.73	183.5	183.14	183.5	210.84	192.07	195.62	195.33	194.68	194.90	196.59
Deck Elevation (m AHD)	190.1		178.5	184.25		184.25	184.5	212.7	194.65	197.53	196.30	196.70	197.00	198.80
Height of Deck Above Channel Invert (m)	1.5		2	0.55		0.91	1	1.67	2.0	1.6	0.8	1.84	1.96	1.92
Length of Causeway Deck (m)	25		40	99		42	27	55	25	20	100	15	25	40

7.5.2 Duration of Crossing Overtopping

The HEC-RAS model was used to investigate the duration of overtopping of the Dugald River Crossing at Location C for the March 1971 and January 1974 floods. Figure 7.4 and Figure 7.5 show the stage hydrographs at the Location C crossing for the March 1971 flood and January 1974 floods respectively. The following is of note:

- The 1971 flood had a peak discharge of 1331m³/s, and occurred between 2nd and 7th March 1971. The flood included an initial peak of some 650m³/s on the 3rd March followed by the major flood peak on the 5th March;
- Based on the crossing configuration given in Table 7.7, during the March 1971 flood the Dugald River crossing at Location C would have been inundated for just over 3 days;
- The 1974 flood had a peak discharge of 1104m3/s and occurred over the period 1st to 31st January 1974. The flood was multi-peaked, with a number of flood peaks with discharges greater than 500m³/s occurring prior to the main peak on the 22nd January; and
- Based on the crossing configuration given in Table 7.7, during the January 1974 flood the Dugald River crossing at Location C would have been inundated intermittently for up to 10 days.

Based on available flow recordings, the Silvermine Creek crossing at Location B and Dugald River Tributary Crossing at Location F are unlikely to be inundated for longer than 2 days at a time, as flood events in these watercourses generally occur over a far shorter duration than those in the Dugald River.

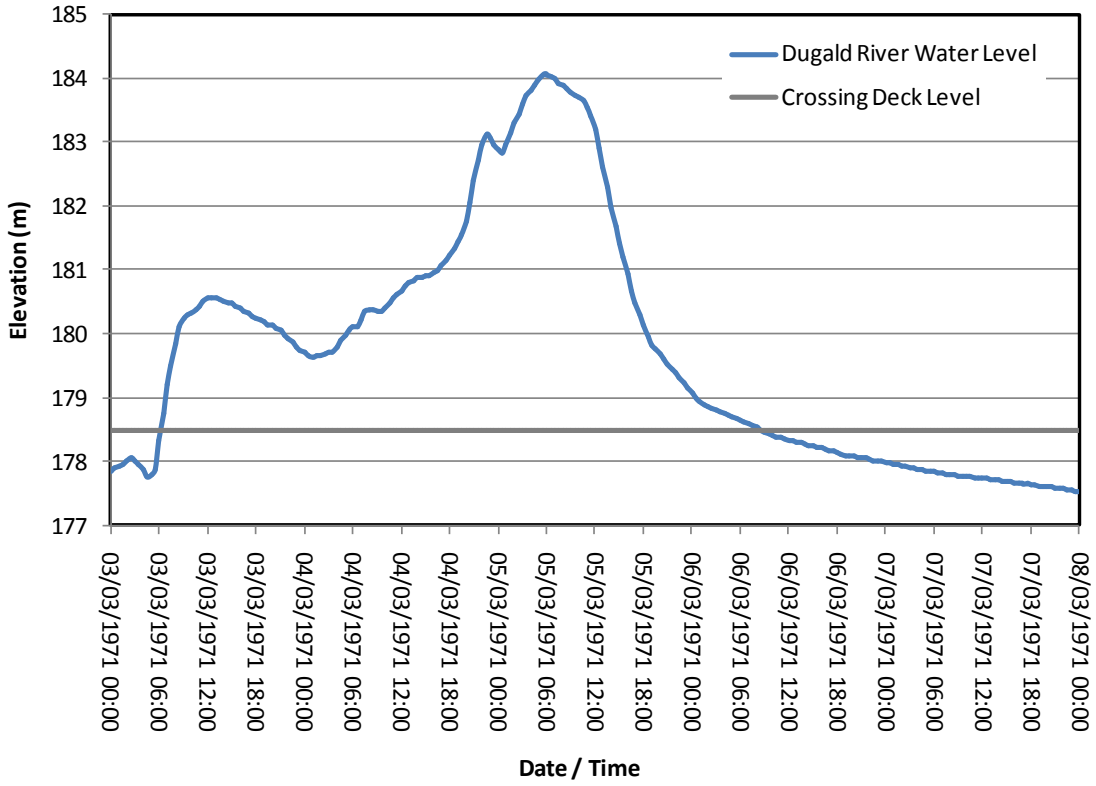


Figure 7.4 March 1971 Flood, Stage Hydrograph, Dugald River Crossing at Location C

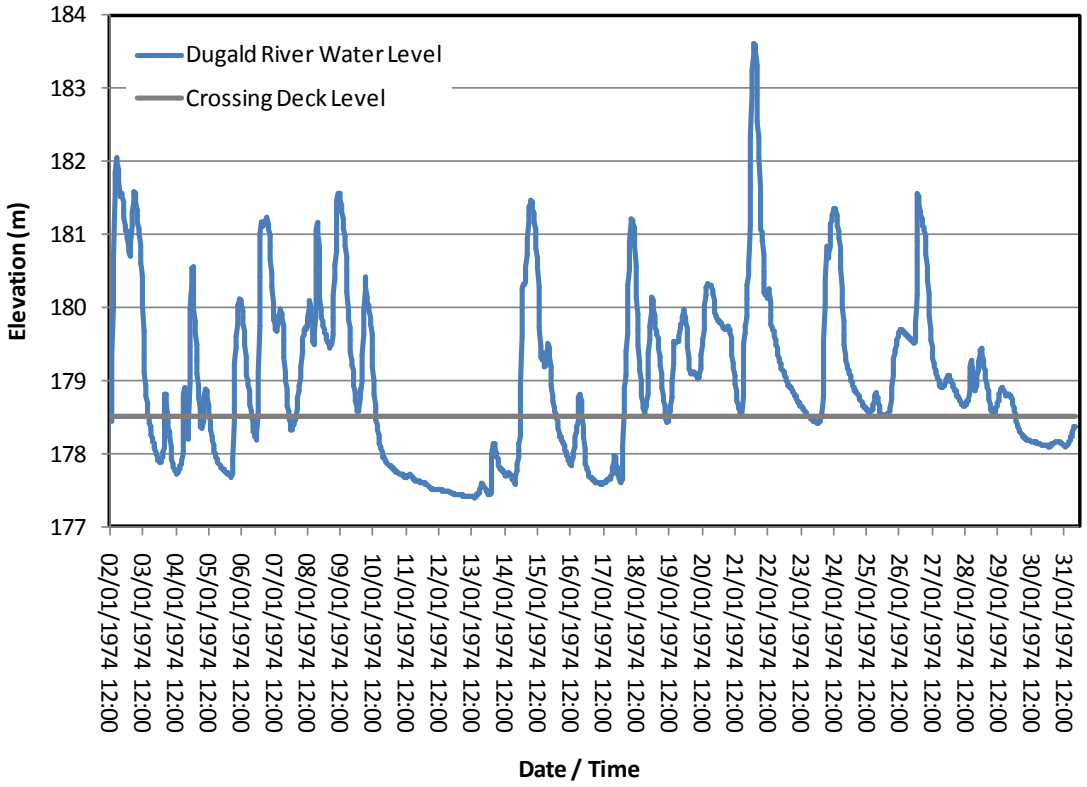


Figure 7.5 January 1974 Flood, Stage Hydrograph, Dugald River Crossing at Location C

7.6 PIPELINE ROUTE

The Manning's Equation was used to estimate the 100 Year ARI flood level at the pipeline crossings at Location N. The 100 Year ARI flood level at Locations A and O were obtained from the HECRAS model. Table 7.8 gives the estimated flood levels and cross section details at Locations A, N and O. It is understood that the pipeline will be located above the 100 Year ARI flood level.

Table 7.8 Estimated 100 Year ARI Flood Levels, Pipeline Crossing Locations A, N and O

	Location A	Location N	Location O*
Channel Bed Level (m)	181.36	179.72	178.00
Channel Slope (%)	0.3	0.5	0.6
100 Year ARI Discharge (m^3/s)	165.4	64.0	NA
100 Year ARI Flood Level (m)	184.94	182.06	182.76
100 Year ARI Flood Depth (m)	3.6	2.3	4.8

*Peak Flood Level at Location O is from Dugald River backwater flooding

8 ASSESSMENT OF POTENTIAL IMPACTS

8.1 SURFACE WATER IMPACTS

With appropriate control measures in place, the impact of the Project on flows and water quality in downstream waterways will be insignificant. Only about 230ha out of the 3370 ha Project Site will be disturbed by the Project. Further, the areas of disturbance within the local and regional catchments caused by the Dugald River Project are minimal. The biggest impact will be on Silvermine Creek flows. Mining operations and infrastructure would disturb about 9.5% of the Silvermine Creek catchment area (13.2 km^2). This area is only about 0.2% of the Dugald River catchment area (620 km^2) at the confluence with Silvermine Creek. The TSF occupies an area of about 0.9km^2, which is only about 0.3% of the Cabbage Tree Creek catchment area to the confluence with Vieuex Rose Creek (250km^2). The areas disturbed by the accommodation camp, the water pipeline and the access roads are not significant.

The proposed surface water management system includes a number of diversion drains to divert clean runoff away from disturbed areas and containment storages to capture dirty and contaminated runoff on-site. The proposed surface water management system in will ensure that:

- The area of surface disturbance within the Project Site is minimised;
- The clean water within the Project Site are separated to the fullest extent and diverted away from disturbed areas; and
- The dirty and contaminated surface water are collected and contained within the disturbed area of the Project Site via sediment and containment ponds or pumped to the TSF (under emergency conditions). Contaminated water will not be released out of the Project Site, except during an extreme rainfall event and after notification to the Queensland Environmental Protection Agency.

It is understood that the Tailing Storage Facility would be designed not to overflow for extreme rainfall events up to ARI 100 Year (2 month) wet season. Therefore the likelihood of contaminated water overflowing into Cabbage Tree Creek is extremely low.

Long term water balance modelling, described in Section 6 of this report has been used to investigate the behaviour of the storages proposed as part of the water management system (with the exception of the TSF). Based on a 120 year period of simulation, the water balance modelling indicates the following:

- No contaminated water is predicted to be released from high and significant hazard dams at the project site, although periodic releases of dirty water from sediment ponds and low hazard dams would occur. Any release of dirty water from the sediment ponds and low hazard dams is likely to only occur during significant flow events in Silvermine

Creek and its tributaries. Further these release volumes would be insignificant when compared to expected flow volumes in Silvermine Creek during such flow events.

- The appropriate DSA is predicted to be available on 1st November in all high and significant hazard storages for at least 101 years out of the 120 year simulation period. DSA volumes in the low hazard storages are predicted to be available for at least 89 years out of the 120 year simulation. It should be noted that there will be infrastructure in place to transfer water from high and significant hazard storages to the TSF via the process plant in order to ensure the DSA is available on the 1st November, however this would only be utilised as an *emergency management option*.

Based on the results of the water balance modelling it is considered that the potential for contaminated water overflowing into Silvermine Creek or its tributaries is very low. Due to the low-toxic nature of the sediment pond and low hazard dam catchments and the potential for significant dilution of any overflows from these storages, the periodic release of dirty water is not considered likely to have any significant impact on Silvermine Creek and its tributaries.

It is of note that the water balance modelling has not included any pumping (transfer) of water to the TSF and/or reuse of captured stormwater in processing. If captured stormwater is pumped to the TSF and/or reused on-site this would potentially reduce the predicted average storage volumes and predicted spills.

The water balance modelling results indicate that the proposed water management system is robust and has more than adequate storage capacity for managing surface water runoff within the Project Site. As such there may be a case for potentially reducing the size of high hazard dams, for which the adopted FSL volume currently exceeds both the calculated DSA and the maximum storage volume predicted by the water balance model for each dam.

8.2 FLOOD IMPACTS

A flood study of the Dugald River and Silvermine Creek indicates that the mining operations and infrastructure are located above the 100 year ARI flood levels along these waterways. Therefore, mining operations and infrastructure would not be impacted by flooding at least up to the 100 year ARI flood event.

The main access road to the Project Site from the Burke Developmental Road is susceptible to flooding at 4 locations from the Dugald River and its tributaries, including Silvermine Creek. Therefore, the main access road will be impacted at the above locations by flooding in the respective waterways. In addition, the road crossings would have some local impact of flows in these waterways, especially during flood events. It is noted that the main access road crossings have been designed as low level (causeway) crossings with minimum loss of waterway area and floodplain storage to minimise any potential impacts on the waterways. This means that these crossings would be overtopped whenever a significant runoff event occurs in these catchments. During major flood events, the Dugald River crossing would be overtopped intermittently for periods varying from a few hours up to about 2 weeks. The Silvermine Creek and other minor tributary floods would overtop the respective road crossings for periods varying from a few hours up to 1 or 2 days depending on the magnitude of the flood event.

The road connecting the mine operations area to the accommodation camp is susceptible to flooding at 7 locations from Silvermine Creek Tributary A, Silvermine Creek Tributary B and several minor unnamed tributaries of Silvermine Creek. The crossings at these locations have been designed to provide 100 year ARI flood immunity. The impact of these crossings on the respective waterways would be minimal.

The water pipeline route (off the Ernest Henry/Lake Julius Pipeline) crosses Silvermine Creek Tributary A and two minor unnamed tributaries of Dugald River. The pipeline crossings are expected to have minimal impact on flood behaviour in the affected waterways. It is understood that the pipelines would cross these creeks at levels above the 100 year ARI flood levels. The supports holding the pipeline across the waterways would slightly reduce the waterway areas at these locations but would have minimal impact on the flooding behaviour of these waterways.

It is understood that surface subsidence caused by underground mining activities is not significant. Therefore, any subsidence impacts on flooding behaviour and erosion along local waterways would be insignificant.

9 CONCLUSIONS

The results of the investigations presented in this report indicate that there are minimal constraints to the proposed Dugald River Project with respect to surface water management. The areas of disturbance caused by the Project are small and can be readily managed with minimal impact on the existing surface drainage systems.

The impact of the Project on flows and water quality in downstream waterways would be insignificant. Only about 230ha out of the 3370ha Project Site would be disturbed by the Project. Further, the areas of disturbance within the local and regional catchments caused by the Dugald River Project are minimal. Mining operations and infrastructure would disturb about 9.5% of the Silvermine Creek catchment area (13.2 km^2), and about 0.2% of the Dugald River catchment area (620 km^2) at the confluence with Silvermine Creek. The TSF occupies an area of about 0.9 km^2, which is only about 0.3% of the Cabbage Tree Creek catchment area to the confluence with Vieuex Rose Creek (250 km^2). The areas disturbed by the accommodation camp, the water pipeline and the access roads are not significant.

It is understood that the Tailing Storage Facility would be designed not to overflow for extreme rainfall events up to ARI 100 year (2 month) wet season. Therefore the likelihood of contaminated water overflowing into Cabbage Tree Creek is extremely low.

The proposed surface water management system will ensure that the disturbed area runoff within the Project Site is minimised, the clean runoff within the Project Site is separated to the fullest extent and diverted away from disturbed areas, and that the dirty and contaminated surface water are segregated, collected and contained within the disturbed area of the Project Site via sediment and containment ponds or pumped to the TSF.

The proposed water management system can be described as follows:

- Clean runoff is diverted away from disturbed catchment areas by diversion banks and drains.
- Sediment laden runoff that will contain no potential contaminants will be captured by sediment ponds. Proposed sediment ponds have sufficient capacity to capture runoff from a 10 year 24 hour duration storm event.
- Dirty (low-toxicity) runoff will be captured by containment ponds, classified as low hazard storages by DME (1995).
- Sub-lethal contaminated runoff will be captured by containment ponds, classified as significant hazard storages by DME (1995).
- Toxic contaminated runoff will be captured by containment ponds, classified as high hazard storages by DME (1995).
- No significant reuse of captured runoff in on-site processing is proposed, and no water will be transferred between storages. In effect, each storage will operate as an individual evaporation basin.
- There is potential to transfer water from high and significant hazard dams to the TSF via the process plant, however this would only occur as an emergency measure to ensure DSA volumes are available, or prevent an MRL exceedance.

- Both high and significant hazard storages have been sized as 'no-spill' storages, and will be operated such that the appropriate DSA volume is available in each storage on 1st November each year.

Based on a 120 year period of simulation, the water balance modelling undertaken to investigate the long-term behaviour of the minesite storages indicates the following:

- No contaminated water is predicted to be released from high and significant hazard dams at the project site, although periodic releases of dirty water from sediment ponds and low hazard dams would occur. Any release of dirty water from the sediment ponds and low hazard dams is likely to only occur during significant flow events in Silvermine Creek and its tributaries. Further these release volumes would be insignificant when compared to expected flow volumes in Silvermine Creek during such flow events.
- The appropriate DSA is predicted to be available on 1st November in all high and significant hazard storages for at least 101 years out of the 120 year simulation period. DSA volumes in the low hazard storages are predicted to be available for at least 89 years out of the 120 year simulation. It should be noted that there will be infrastructure in place to transfer water from high and significant hazard storages to the TSF via the process plant in order to ensure the DSA is available on the 1st November, however this would only be utilised as an ***emergency management option***.

Based on the results of the water balance modelling it is considered that the potential for contaminated water overflowing into Silvermine Creek or its tributaries is very low. Due to the low-toxic nature of the sediment pond and low hazard catchments and the potential for significant dilution of any overflows from these storages, the periodic release of dirty water is not considered likely to have any significant impact on Silvermine Creek and its tributaries.

All process water demands will be met through a combination of water from Lake Julius and recycled water from the TSF.

The water balance modelling results indicate that the proposed water management system is robust and has more than adequate storage capacity for managing surface water runoff within the Project Site. As such there may be a case for potentially reducing the size of high hazard dams, for which the adopted FSL volume currently exceeds both the calculated DSA and the maximum storage volume predicted by the water balance model for each dam.

Based on the results of the water balance model the high hazard dams could potentially be reduced in size to reflect the predicted maximum storage volume predicted by the water balance model (with an appropriate freeboard allowance).

A flood study of the Dugald River and Silvermine Creek indicate that the mining operations and infrastructure are above the 100 year ARI flood levels along these waterways. Therefore, mining operations and infrastructure would not be impacted by flooding at least up to the 100 year ARI flood event.

It is of note that the existing Silvermine Creek gauging station is currently backwater affected by the Dugald River during major flow events in the River. As such it is recommended that the gauging station is relocated to an appropriate site, at least 300m upstream of its current position.

The main access road to the Project Site from the Burke Developmental Road is susceptible to flooding at 4 locations from the Dugald River and its tributaries, including Silvermine Creek. The access road crossings have been designed as low level (causeway) crossings with minimum loss of waterway area and floodplain storage to minimise any potential impacts on the waterways. These crossings would be overtopped whenever a significant runoff event occurs in these

catchments. During major flood events, the Dugald River crossing would be overtopped intermittently for periods varying from a few hours up to about 2 weeks. The Silvermine Creek and other minor tributary flood would overtop the respective road crossings for periods varying from a few hours up to 1 or 2 days depending on the magnitude of the flood event.

The road connecting the mine operations area to the accommodation camp is susceptible to flooding at 7 locations from Silvermine Creek Tributary A, Silvermine Creek Tributary B and several minor unnamed tributaries of Silvermine Creek. The crossings at these 2 locations have been designed to provide 100 year ARI flood immunity. The impact of these crossings on the respective waterways would be minimal.

The water pipeline route (off the Ernest Henry/Lake Julius Pipeline) crosses Silvermine Creek Tributary A and two minor unnamed tributaries of Dugald River. The pipeline crossings will be designed to have minimal impact on flood behaviour in the affected waterways.

10 REFERENCES

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APPENDIX A

ADOPTED STAGE STORAGE RELATIONSHIPS FOR PROPOSED MINE STORAGES

Table A1 Adopted Stage Storage Relationship, Pond 2

Stage (m)	Surface Area (m²)	Volume (ML)
0.0	353	0.00
0.5	664	0.27
1.0	975	0.66
1.5	1286	1.24
2.0	1597	1.95
2.5	1908	2.84
3.0	2219	3.86
3.5	2530	5.06
4.0	2841	6.39
4.5	3152	7.90
5.0	3463	9.54

Table A2 Adopted Stage Storage Relationship, Pond 3

Stage (m)	Surface Area (m²)	Volume (ML)
0.0	3563	0.00
0.5	4100	1.94
1.0	4637	4.10
1.5	5173	6.58
2.0	5710	9.27
2.5	6247	12.29
3.0	6784	15.52
3.5	7320	19.07
4.0	7857	22.84

Table A3 Adopted Stage Storage Relationship, Pond 5

Stage (m)	Surface Area (m²)	Volume (ML)
0.0	4989	0.00
0.5	5775	2.90
1.0	6561	6.22
1.5	7348	9.54
2.0	8134	13.17
2.5	8920	17.43
3.0	9706	22.09
3.5	10492	27.14
4.0	11278	32.58
4.5	12065	38.42
5.0	12851	44.65
5.5	13637	51.27
6.0	14423	58.24

Table A4 Adopted Stage Storage Relationship, Pond 6

Stage (m)	Surface Area (m²)	Volume (ML)
0.0	648	0.00
0.5	1170	0.48
1.0	1691	1.17
1.5	2213	2.17
2.0	2734	3.38
2.5	3256	4.91
3.0	3777	6.64
3.5	4299	8.68
4.0	4820	10.94
4.5	5342	13.50
5.0	5863	16.28
5.5	6385	19.37
6.0	6906	22.66
6.5	7428	26.27
7.0	7949	30.09
7.5	8471	34.22
8.0	8992	38.56

Table A5 Adopted Stage Storage Relationship, Pond 9

Stage (m)	Surface Area (m²)	Volume (ML)
0.0	3876	0.00
0.5	4574	2.15
1.0	5272	4.57
1.5	5971	7.42
2.0	6669	10.54
2.5	7367	14.09
3.0	8065	17.91
3.5	8763	22.15
4.0	9462	26.68
4.5	10160	31.62
5.0	10858	36.84
5.5	11556	42.47
6.0	12254	48.39
6.5	12953	54.73
7.0	13651	61.34
7.5	14349	68.38
8.0	15047	75.69
8.5	15745	83.43
9.0	16444	91.44
9.5	17142	99.87
10.0	17840	108.58

Table A6 Adopted Stage Storage Relationship, Pond 10

Stage (m)	Surface Area (m^2)	Volume (ML)
0.0	4000	0.00
0.5	4550	2.17
1.0	5100	4.55
1.5	5650	7.27
2.0	6200	10.20
2.5	6750	13.47
3.0	7300	16.95
3.5	7850	20.77
4.0	8400	24.80

Table A7 Adopted Stage Storage Relationship, Pond 11

Stage (m)	Surface Area (m^2)	Volume (ML)
0.0	2714	0.00
0.5	3111	1.48
1.0	3509	3.11
1.5	3906	4.98

Table A8 Adopted Stage Storage Relationship, Pond 13

Stage (m)	Surface Area (m^2)	Volume (ML)
0.0	3076	0.00
0.5	3495	1.66
1.0	3914	3.51
1.5	4333	5.57
2.0	4752	7.84
2.5	5170	10.32
3.0	5589	13.01
3.5	6008	15.91
4.0	6427	19.02
4.5	6846	22.34
5.0	7265	25.87
5.5	7684	29.61
6.0	8103	33.55
6.5	8522	37.71
7.0	8940	42.07
7.5	9359	46.65
8.0	9778	51.43
8.5	10197	56.43
9.0	10616	61.61

Table A9 Adopted Stage Storage Relationship, Pond 14

Stage (m)	Surface Area (m^2)	Volume (ML)
0.0	6918	0.00
0.5	7614	3.66
1.0	8311	7.64
1.5	9007	11.97
2.0	9704	16.65
2.5	10400	21.68
3.0	11096	27.05
3.5	11793	32.77
4.0	12489	38.84
4.5	13185	45.26
5.0	13882	52.03
5.5	14578	59.14
6.0	15275	66.61
6.5	15971	74.42
7.0	16667	82.58
7.5	17364	91.08
8.0	18060	99.91

Table A10 Adopted Stage Storage Relationship, Pond 16

Stage (m)	Surface Area (m^2)	Volume (ML)
0.0	4214	0.00
0.5	4760	2.27
1.0	5306	4.79
1.5	5852	7.58
2.0	6399	10.61
2.5	6945	13.97
3.0	7491	17.58
3.5	8037	21.46
4.0	8583	25.62
4.5	9129	30.04
5.0	9676	34.75
5.5	10222	39.72
6.0	10768	44.97
6.5	11314	50.47

Table A11 Adopted Stage Storage Relationship, Pond 18

Stage (m)	Surface Area (m^2)	Volume (ML)
0.0	2838	0.00
0.5	3200	1.51
1.0	3562	3.20
1.5	3924	5.07
2.0	4286	7.12
2.5	4649	9.36

Table A12 Adopted Stage Storage Relationship, Pond 19

Stage (m)	Surface Area (m^2)	Volume (ML)
0.0	13907	0.00
0.5	14803	7.22
1.0	15698	14.80
1.5	16594	22.92
2.0	17489	31.40
2.5	18385	40.41
3.0	19280	49.78
3.5	20176	59.69
4.0	21071	69.96
4.5	21967	80.76
5.0	22862	91.92
5.5	23758	103.62
6.0	24653	115.68

APPENDIX B

PROPOSED ACCESS ROAD CROSSINGS AND WATERWAY SECTIONS

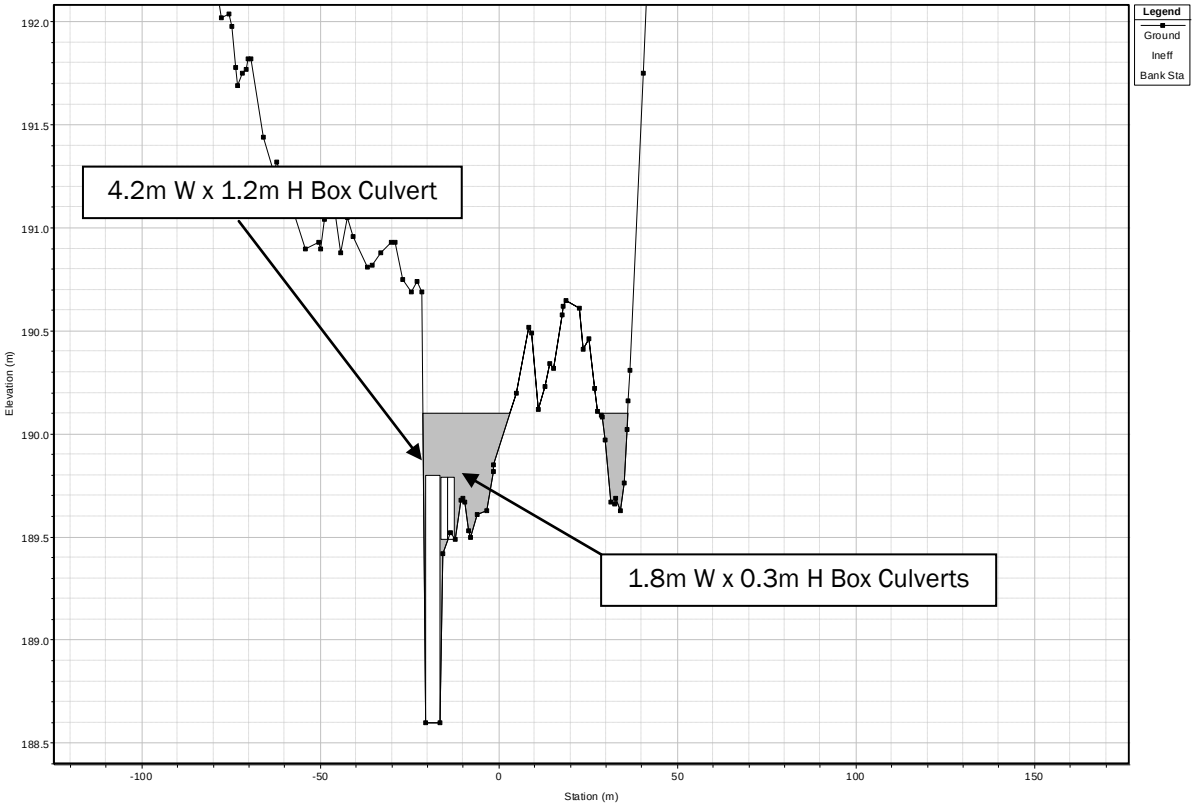


Figure B1 Proposed Cross Section, Silvermine Creek, Location B

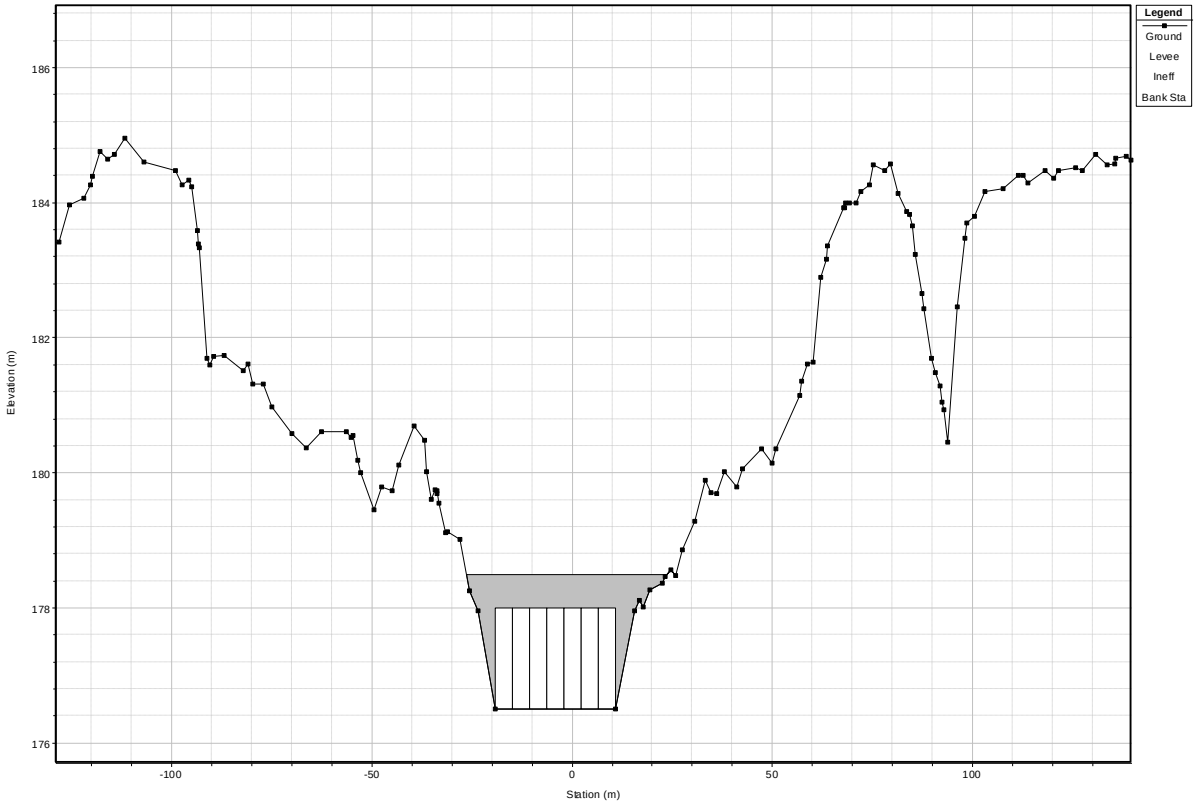


Figure B2 Proposed Cross Section, Dugald River, Location C



Figure B3 Proposed Cross Section, Dugald River Overflow, Location D

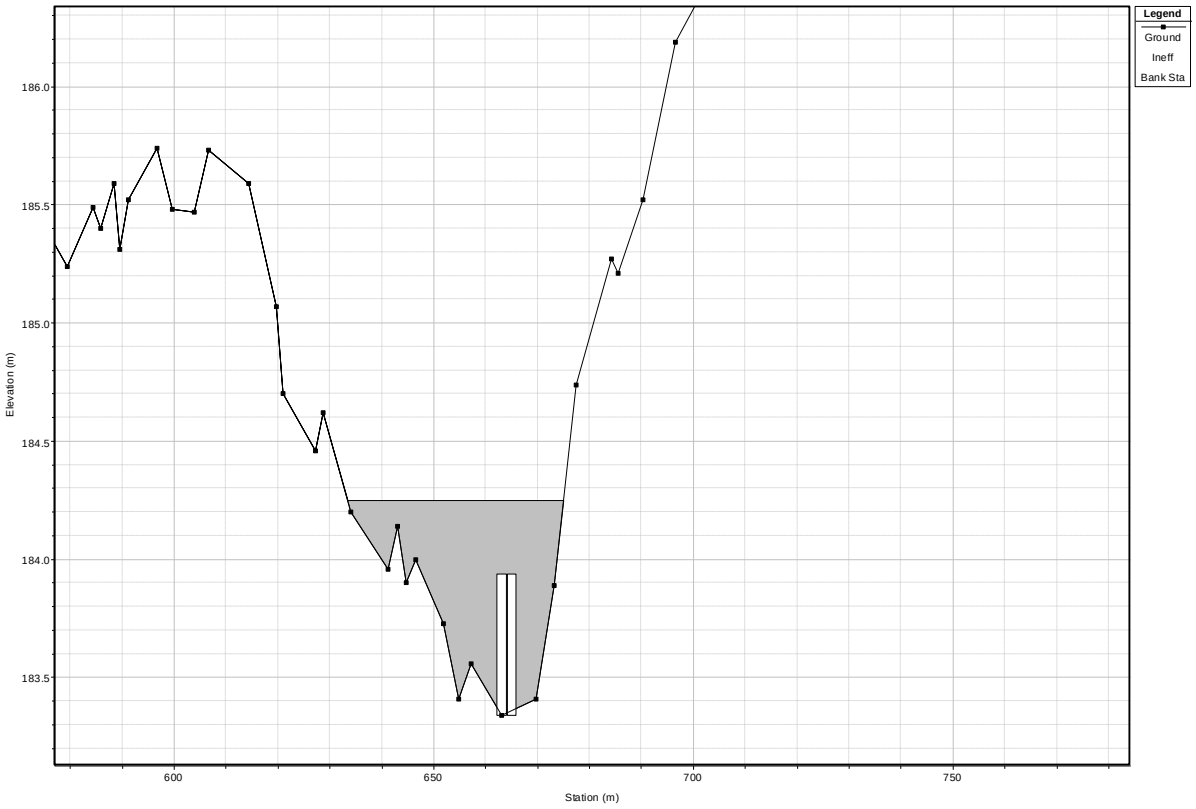


Figure B4 Proposed Cross Section, Dugald River Overflow, Location E

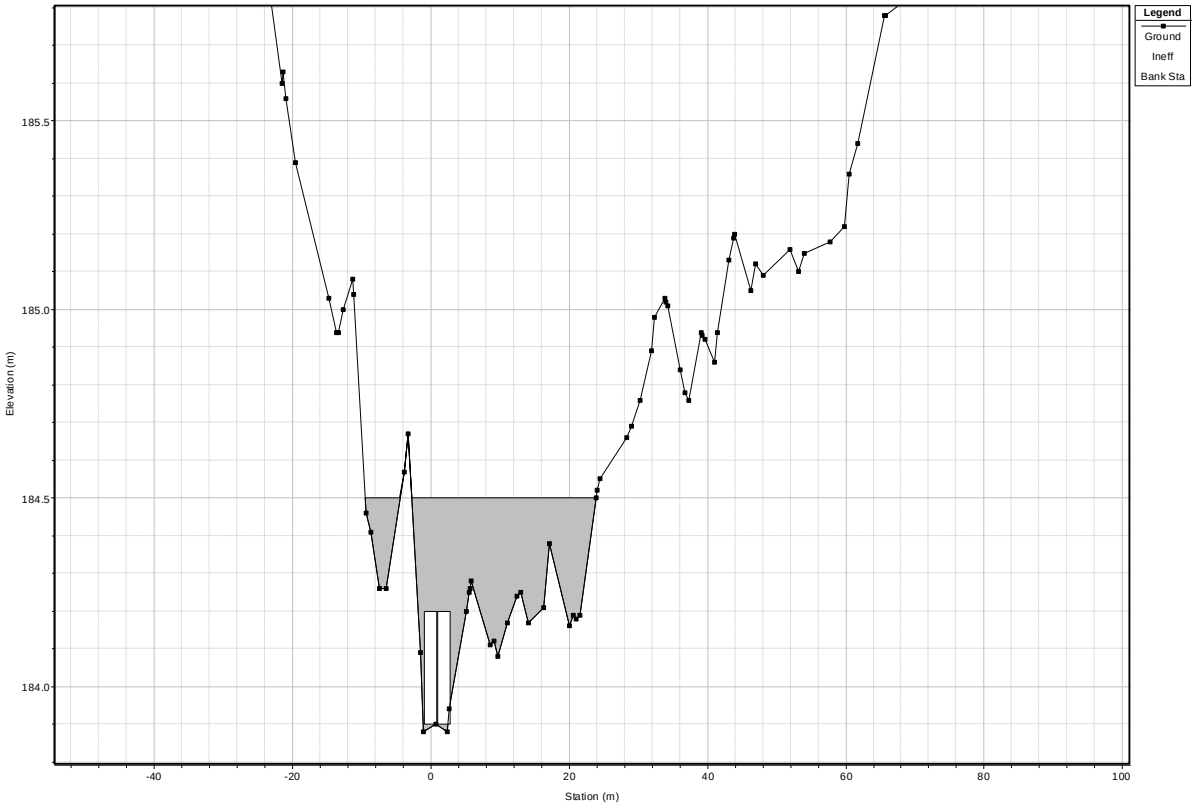


Figure B5 Proposed Cross Section, Dugald River Tributary A, Location F

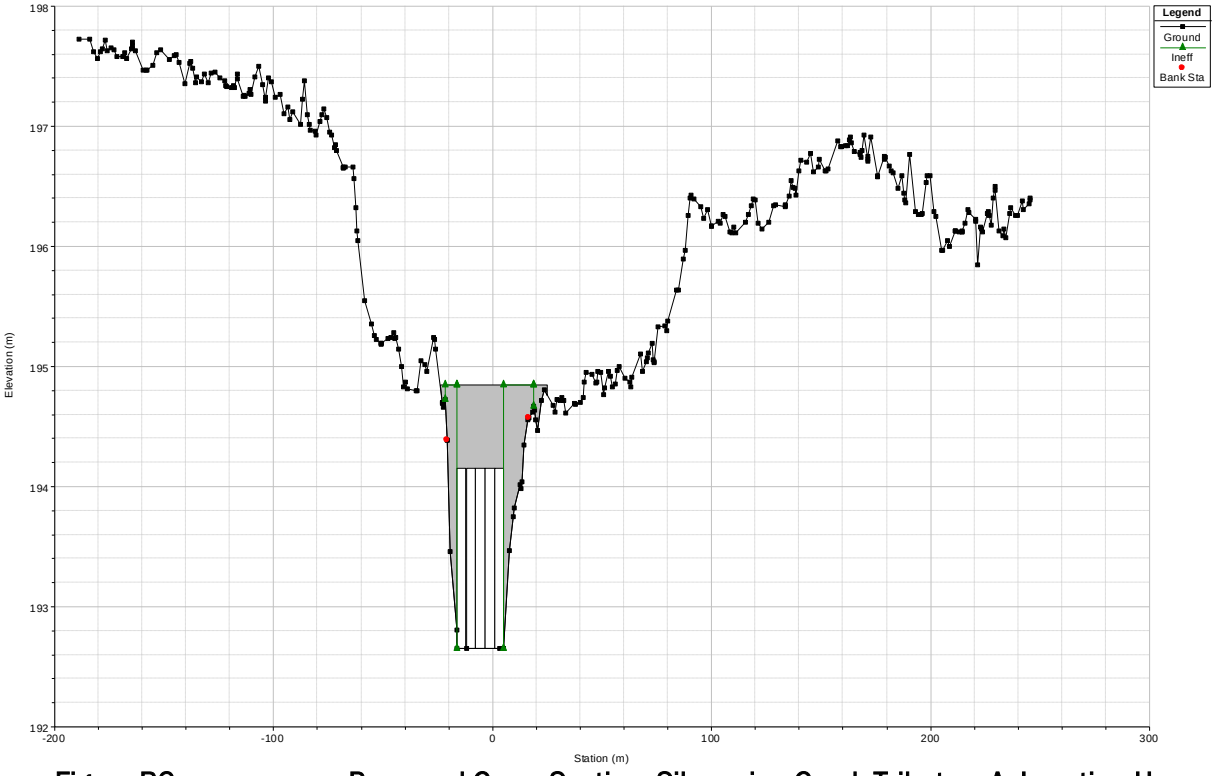


Figure B6 Proposed Cross Section, Silvermine Creek Tributary A, Location H

Appendix F

TSF and Process Area Hydraulic Impact Assessment



REPORT

MMG AUSTRALIA PTY LTD
ABN: 14 069 603 587

Dugald River Mine – Progressive Closure and Closure Planning – TSF and Process Area Hydraulic Impact Assessment

108003-49
MAY 2021

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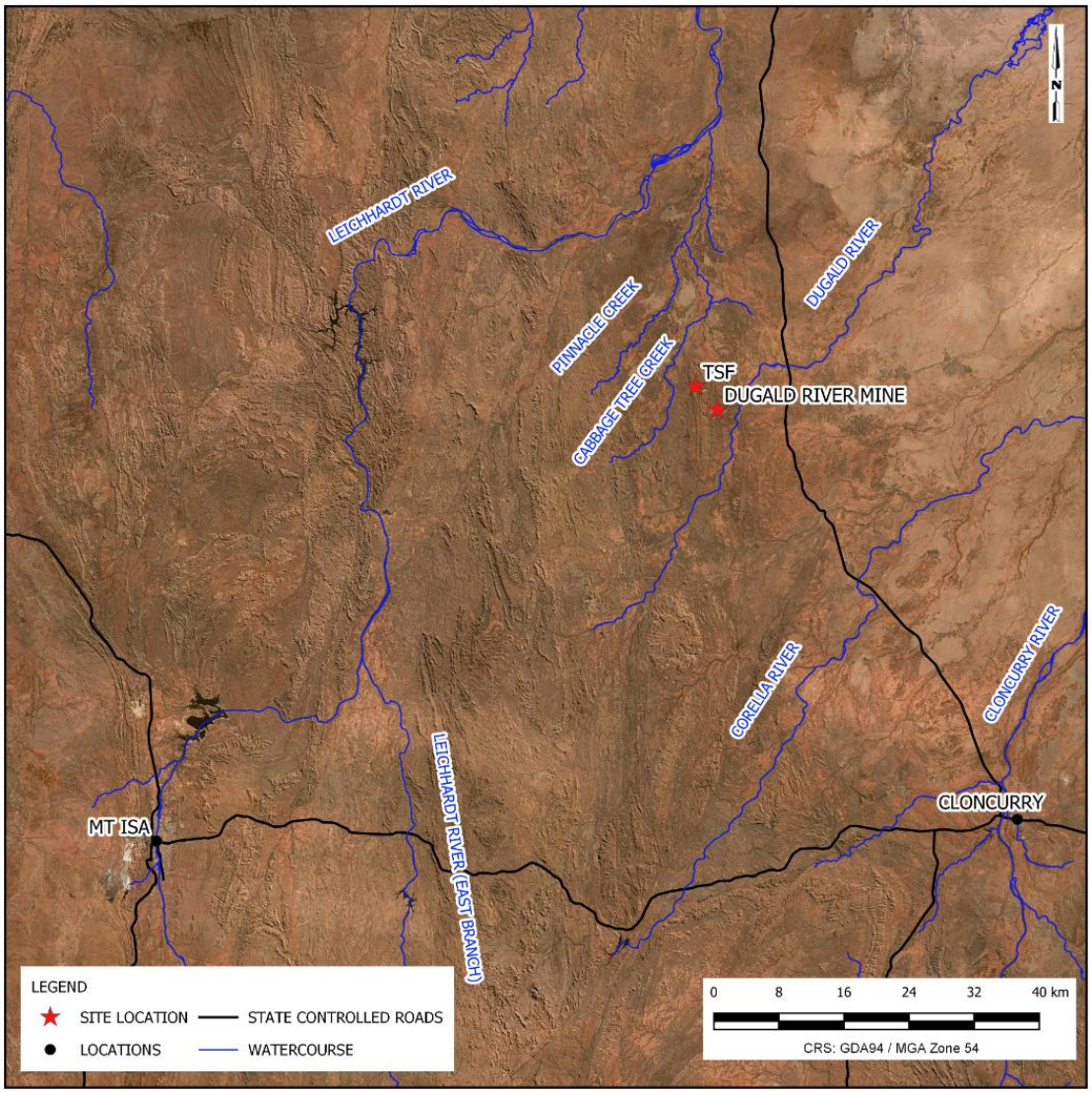
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1 INTRODUCTION

1.1 Background and Purpose

MMG Australia Pty Ltd (MMG) owns and operates the Dugald River Mine (DRM) in northwest Queensland. The DRM is located approximately 60 km northwest of Cloncurry and is accessed from the Burke Development Road. DRM and its TSF locations are shown on **DIAGRAM 1**.

DIAGRAM 1: SITE LOCATION



The purpose of this study is to provide flood modelling in support of the DRM Progressive Closure and Rehabilitation Plan (PCRP). The PRCP requires flood risk assessments for two aspects of closure: to identify whether any mine voids will be in a floodplain post-closure; and to assess the flood risk to remaining infrastructure (in this case the closed and capped TSF). The floodplain is defined under the PRCP as being areas within the 0.1% AEP flood level.

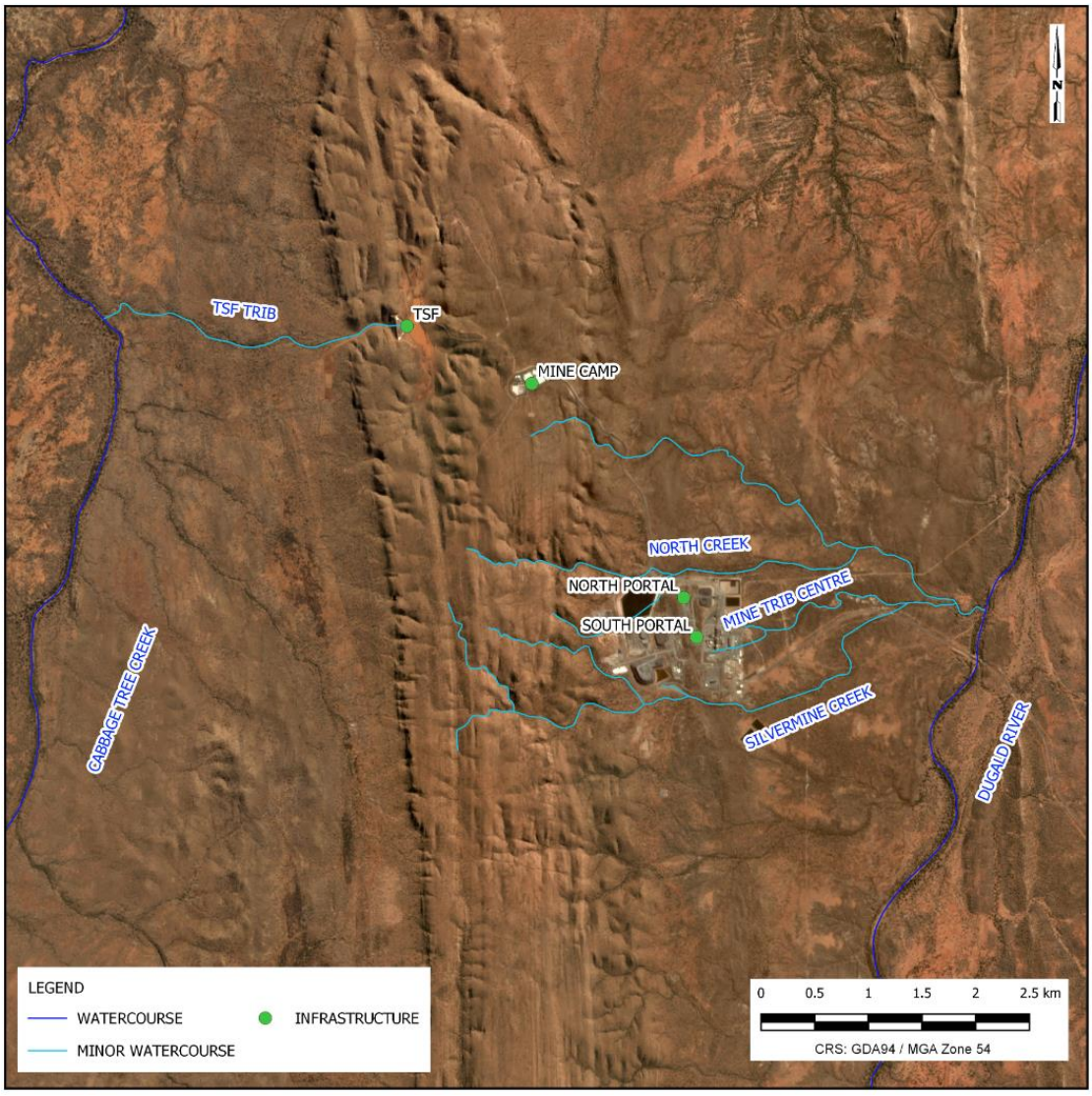
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1.2 Site Watercourses/Drainage Setting

The DRM is located approximately 3 km west of the Dugald River. The TSF is located in the adjacent catchment, approximately 3 km east of Cabbage Tree Creek, as shown on **DIAGRAM 2**. The Dugald River is located within the Flinders River Basin, whereas Cabbage Tree Creek is located in the Leichardt River Basin. Both the Flinders River and Leichardt River discharge into the Gulf of Carpentaria.

Within the DRM area there are several small tributaries of the Dugald River, namely North Creek and Silvermine Creek. For the purpose of this study, the unnamed tributary to the centre of the DRM area has been named 'Mine Trib Centre'. The single tributary to Cabbage Tree Creek has been named 'TSF Trib'. The locations of these tributaries are depicted on **DIAGRAM 2**, along with key existing mine infrastructure.

DIAGRAM 2: SITE TRIBUTARIES AND INFRASTRUCTURE



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1.3 Project Scope and Methodology

The scope of works for the PRCP and updated flood study consist of:

- Hydrologic assessment of the site and upstream catchments.
- Hydraulic modelling of the site and upstream catchments.

As part of the PCRP, a flood profile for the TSF and DRM was required to be developed. In consultation with MMG, it was agreed to model the following events:

- Probable Maximum Flood (PMF) resulting from the Probable Maximum Precipitation (PMP);
- 1:1,000 AEP (0.1% AEP); and,
- 1:100 AEP (1% AEP) storm events.

Australian Rainfall and Runoff (ARR) (2019) **[1]** has been utilised to develop the rainfall estimates for input into a TUFLOW hydraulic model. Due to the size of the upstream catchments, the Regional Flood Frequency Estimation (RFFE) tool **[2]** was proposed to be used to estimate the peak discharges in the Dugald River and Cabbage Tree Creek that would be applied in the hydraulic model. Further details regarding the methodology and application of the RFFE is provided in **Section 3.0**.

1.4 Structure of Report

The structure of the report, to address the above scope of works, is as follows.

Section 2.0 Details the inputs and outcomes of the rainfall estimation process for the 1% AEP and PMP design events. The inputs from the Regional Flood Frequency Estimate (RFFE) for the Dugald River and Cabbage Tree Creek upstream catchment are presented.

Section 3.0 Details the development and outcomes of the TUFLOW hydraulic model utilised for determining the response of site areas to the hydrographs determined in **Section 2.0.**

Section 4.0 This section discusses the results of the base case and the design case scenarios, plus the sensitivity analyses outcomes.

Section 5.0 Discusses the hydraulic assessment with respect to the PRCP.

Section 6.0 Outlines the conclusions and recommendations from the hydraulic assessment.

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2 HYDROLOGY ASSESSMENTS

2.1 Overview

Upstream of the TSF and DRM areas the catchments are relatively small at 335 ha and 750 ha, respectively. The catchments have short times of concentration when compared the full regional catchments within which they are located. As such, the regional and local extreme storm events have very different characteristics and the impact of regional flooding from Cabbage Tree Creek and the Dugald River will be experienced hours after any rainfall at the TSF and DRM sites has passed. As a result of this, coincident flood event scenarios for the local mine site and TSF and the regional catchments have been applied, as detailed in **TABLE 1**.

TABLE 1: COINCIDENT FLOODING SCENARIOS

Site Rainfall Event	Dugald River/Cabbage Tree Creek Rainfall Event
PMP	1.0 % AEP
0.1 % AEP	1.0 % AEP
1 % AEP	5% AEP

The input hydrology for the PMP, 1:1,000, 1:100 and 1:20 AEP events was developed in accordance with ARR (2019) **[1]**, in line with the PRCP Guideline requirements**.** Development of the hydrology estimates for the TSF and DRM sites is detailed in **Sections 2.2** and **2.3,** below. The hydrology estimation methodology for the Dugald River and Cabbage Tree Creek is detailed in **Section 2.4**.

2.2 Probable Maximum Precipitation

The DRM site is located in the Generalised Tropical Storm coastal zone and therefore the Generalised Short Duration Method (GSDM) **[3]** was adopted for event durations between 0.25 hours and 6 hours.

The GSDM method requires catchment factors to be applied to the initial rainfall depth to estimate the PMP for the site. The GSDM factors are summarised in **TABLE 2**. A summary of the PMP calculations have been in included in **Appendix A**.

TABLE 2: GSDM FACTORS FOR PMP ESTIMATE

Parameter	Value
Duration Limit	0.25 - 6 hours
Proportion Smooth	0.0
Proportion Rough*	1.0
Mean elevation at site (m AHD)	210
Moisture Adjustment Factor (MAF)	0.9606

*Rough terrain is classified as that in which elevation changes of 50 m or more within horizontal distances of 400 m are common **[3]**.

These values were applied to generate the PMP envelope for 0.25 hours to 6 hours durations shown on **DIAGRAM 3** and summarised in **TABLE 3**.

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DIAGRAM 3: PMP RAINFALL DEPTH ESTIMATE

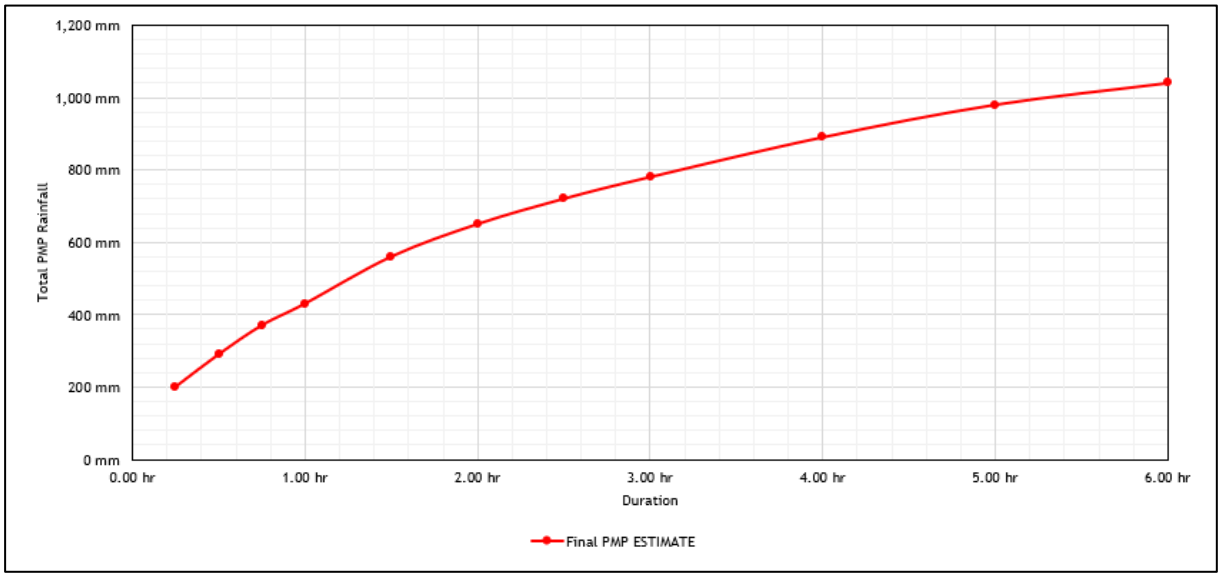


TABLE 3: PMP RAINFALL DEPTH ESTIMATE

Duration (hr)	Rainfall Depth (mm)
0.25	200
0.5	290
0.75	370
1.0	430
1.5	560
2.0	650
2.5	720
3.0	780
4.0	890
5.0	980
6.0	1,040

The GSDM temporal pattern was applied to the rainfall depths in PMP rainfall estimates from **TABLE 3** to obtain a rainfall hyetograph. The hyetographs were applied as direct rainfall to the hydraulic model.

2.3 Rare Precipitation Estimation

Rainfall estimates for the centroids of the Dugald River and Cabbage Tree Creek upstream catchments were obtained from the Bureau of Meteorology's 'Design Rainfall Data System' **[4]**. Rainfall depths for the 1% and 0.1% AEP events are summarised in **TABLE 4**.

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TABLE 4: RARE RAINFALL DEPTH ESTIMATES

Duration	Rainfall Depth (mm)	
	1% AEP	0.1% AEP
1 min	6.41	9.55
2 min	10.7	15.7
3 min	15.2	22.4
4 min	19.5	28.9
5 min	23.5	34.9
10 min	39.8	59.4
15 min	51.5	76.9
20 min	60.5	90.2
25 min	67.7	101
30 min	73.7	110
45 min	87.2	129
1 hour	96.9	144
1.5 hour	111	165
2 hour	122	181
3 hour	138	206
4.5 hour	157	236
6 hour	173	260
9 hour	200	301
12 hour	222	334
18 hour	260	390
24 hour	291	434
30 hour	318	464
36 hour	340	492
48 hour	378	542
72 hour	430	616
96 hour	463	664
120 hour	483	695
144 hour	494	713
168 hour	499	722

Rare events are defined as having an AEP equal to or greater than the 5% AEP event. Each event duration has an ensemble of ten different design temporal patterns (TP), as detailed in the Australian Rainfall and Runoff (ARR) Datahub **[1]**. The variations in the temporal patterns account for rainfall patterns not being uniform or the same for their duration, with periods of more intense and less intense rainfall occurring within a rainfall event. The ensemble temporal patterns have been designed to permit assessment of different rainfall patterns within a catchment. Rainfall estimates from **TABLE 4** were applied directly to the hydraulic model as rain on grid. This is discussed further in **Section 3.2**.

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2.4 Regional Flood Frequency Estimate

To represent the risk of co-incident flooding from Cabbage Tree Creek and the Dugald River, flood discharge estimates were included in the model as upstream inflow boundary conditions in the TUFLOW hydraulic model. It was decided to adopt the flood discharge estimates of these catchments generated by the Regional Flood Frequency Estimator (RFFE) **[2]**. The RFFE utilises the data from 853 gauged catchments across Australia and utilises Log Pearson Type 3 distributions to estimate flows based on records in similar catchments.

The decision to use the RFFE data was made because first, it was considered that there would be very little impact from the rivers on the TSF or the DRM sites. This was tested by undertaking sensitivity tests on the discharge in the rivers. Secondly, the duration of the regional flood events in the Dugald River and Cabbage Tree Creek would be much longer than that in the tributaries from the TSF and the DRM so a steady state condition could be applied to the major creeks under the coincident flood event conditions as a conservative, but reasonable approach.

The resultant flow estimates for the Dugald River and Cabbage Tree Creek are summarised in **TABLE 5**.

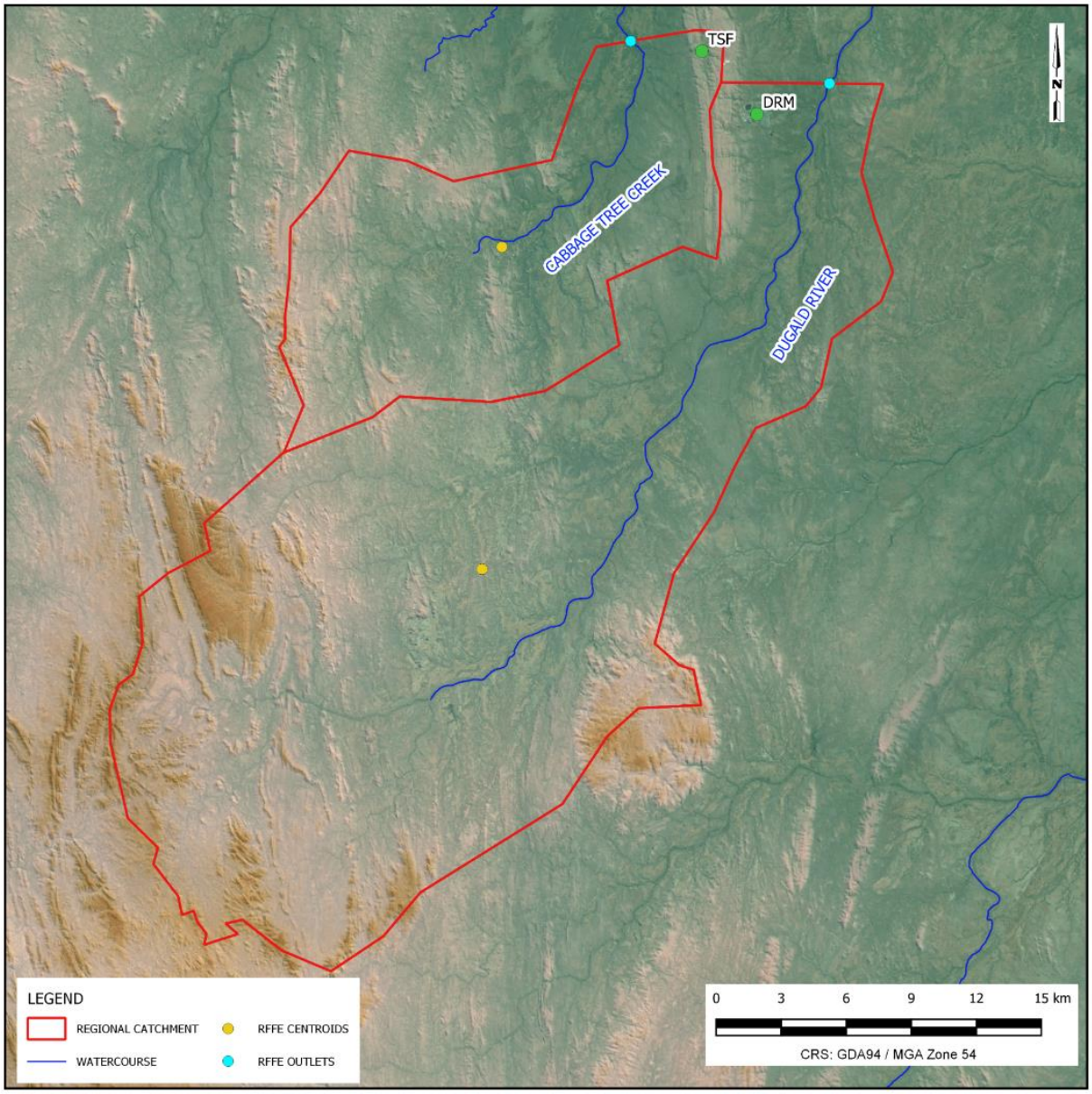
TABLE 5: RFFE MEAN DISCHARGE SUMMARY

AEP (%)	Dugald River (m^3/s)	Cabbage Tree Creek (m^3/s)
50	394	203
20	809	410
10	1,150	583
5	1,570	790
2	2,130	1,070
1	2,680	1,340

The catchment areas, outlet locations and centroid locations for the Dugald River and Cabbage Tree Creek were derived from Shuttle Radar Topographic Mission (SRTM) data **[5]**. This information is shown on **DIAGRAM 4**.

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DIAGRAM 4: RFFE CATCHMENTS



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3 HYDRAULIC ASSESSMENT

3.1 Model Overview

Hydraulic analysis of the study area has been undertaken using the two dimensional (2D) finite difference program TUFLOW, which is an industry accepted software package highly suited to the investigation of flood behaviour in complex flow scenarios. The model can simulate unsteady hydrodynamic flow in two dimensions on a rectilinear grid, as well as a one-dimensional unsteady hydrodynamic flow through waterway structures such as culverts. The model is based on a robust finite difference solution scheme that is able to compute both sub-critical and supercritical flow regimes. The selected hydraulic solver for the 2D model was the HPC scheme.

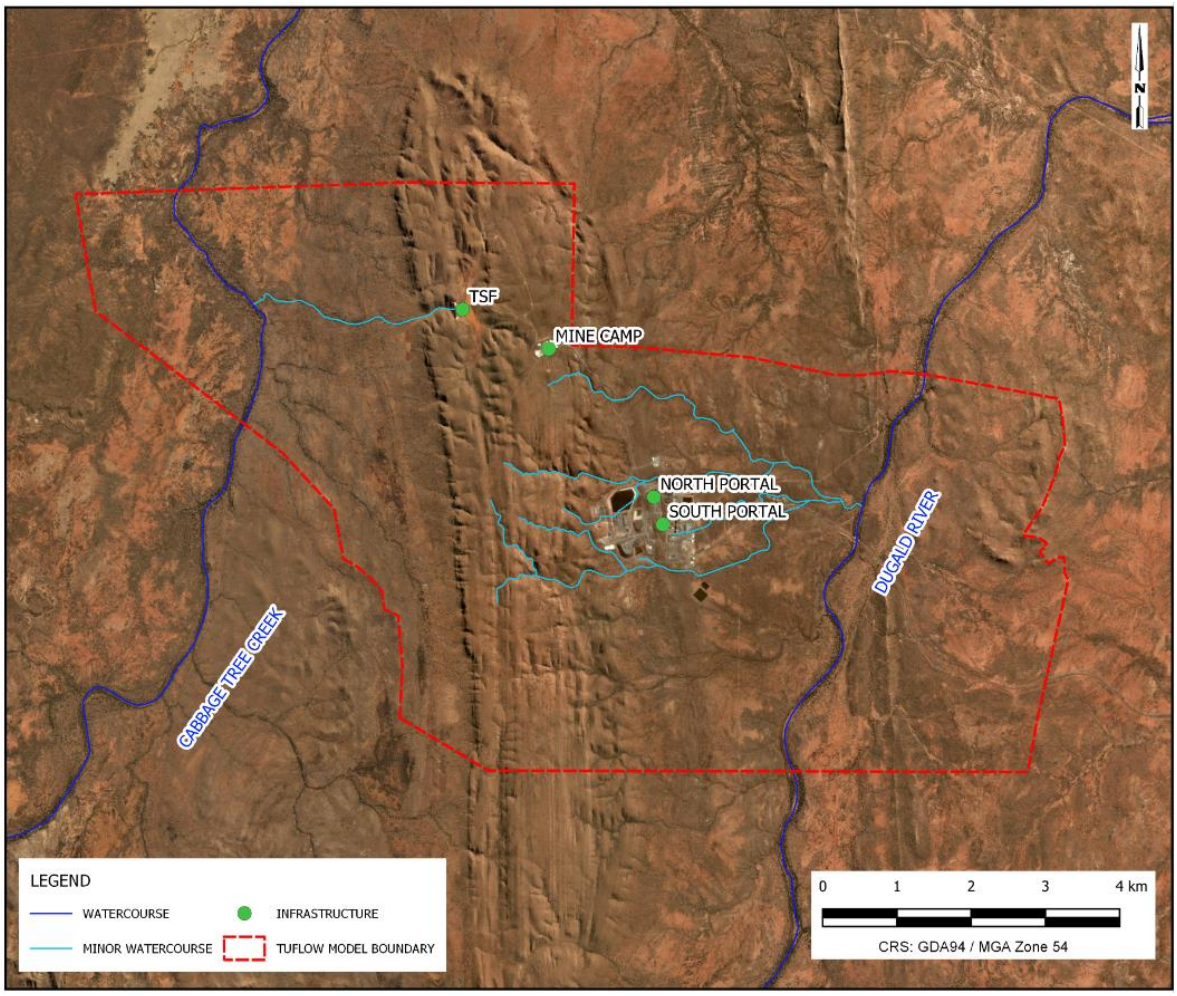
3.2 Model Domain, Grid Size and Time Step

3.2.1 Domain

The 2D TUFLOW model was set up to quantify the impacts of the PMP, 0.1% AEP and 1% AEP design storm events. The model domain is depicted on **DIAGRAM 5** and includes the following structures and areas:

- TSF (Post closure surface and spillway)
- North Portal
- South Portal

DIAGRAM 5: TUFLOW MODEL DOMAIN



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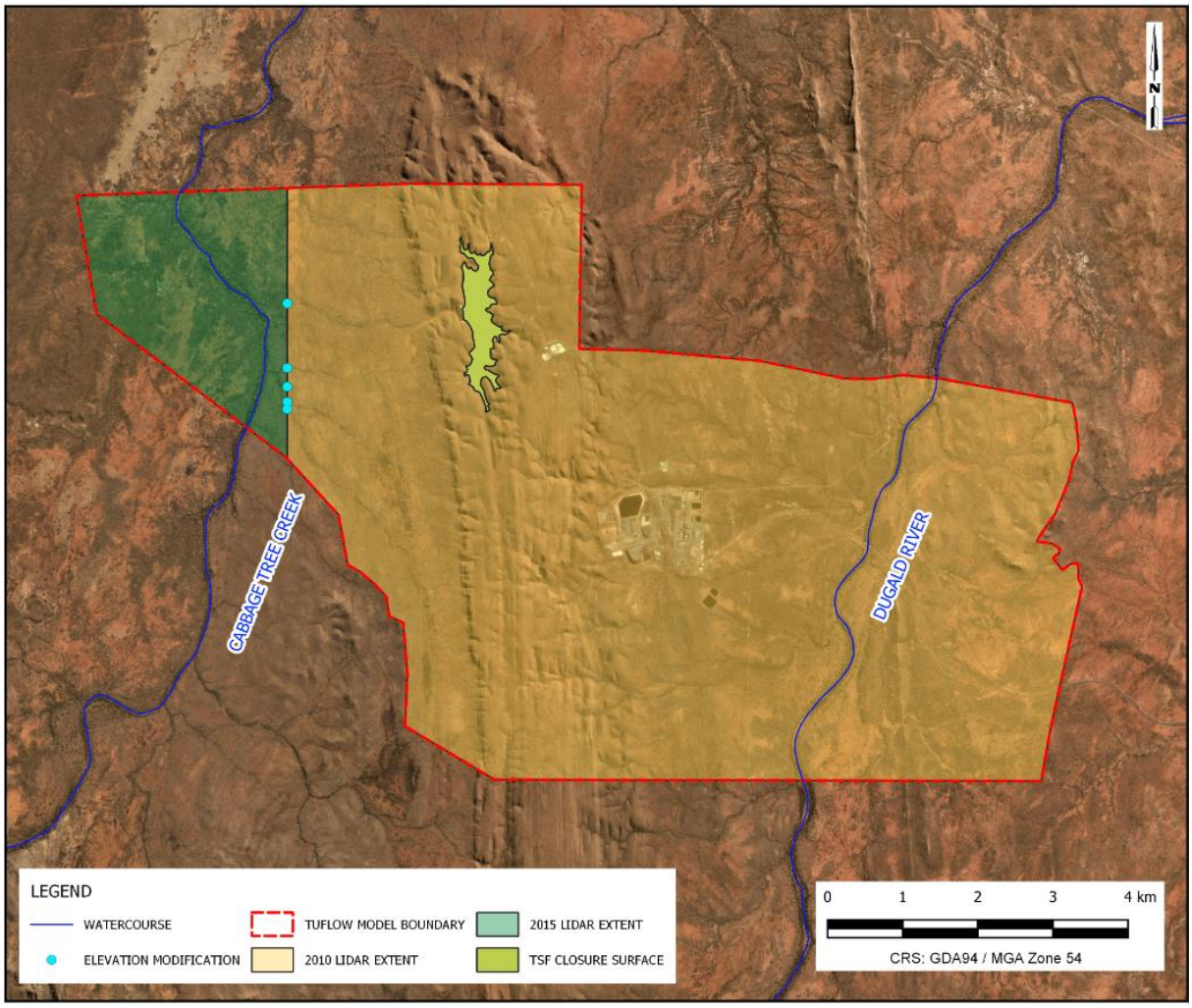
3.2.2 Topography

The TUFLOW model development was based on a 5m x 5m gridded elevation raster model, resampled from site LIDAR survey provided by MMG, to form a base topography. The LIDAR survey files provided by MMG including the following:

- Site Lidar – 2010 **[6]**
- Site Lidar – 2015 **[7]**

It is understood that MMG intend to rehabilitate the main mine site and camp to the pre-mining topography as much as is practically possible. As such, the MMG provided 2010 Site LIDAR was used as the base topographic input, supplemented on the western extent by the 2015 Site LIDAR (refer **DIAGRAM 6**). The TSF is to remain, with a capping layer added, so a TSF closure surface and spillway were incorporated within the topography, with details provided in **Sections 3.2.3** and **3.2.4**, respectively. The survey elevations were modified by smoothing in the TUFLOW model at the intersection of the surveys to ensure free flowing drainage through the drainage features where there were differences in level between the two data sets. These points are shown by the blue dots on **DIAGRAM 6**.

DIAGRAM 6: TOPOGRAPHICAL INPUTS



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3.2.3 TSF Closure Surface

In 2016, ATC Williams undertook the design of the TSF **[8]**. This design included a concept closure plan and surface of the TSF **[9]**. The cover system is proposed to be self-shedding, with a nominal gradient of 1.5%. The embankment will be modified with a 1:5 (V:H) grade at the crest of the embankment, transiting to 1:8 (V:H) at the base, where it then joins natural surface. The closure plan is included in **Appendix B**. This proposed closure surface has been incorporated within the hydraulic model.

Further work on the design of the closure cover system was undertaken by SGM Environmental in 2019, consisting of column trials and a semi-calibrated model, which indicated that the TSF cover will likely require a 1.0 m thick infiltration storage layer (ISL) to reduce the potential for seepage into the tailings **[10].** Run-of-mine NAF waste rock blends will be used in the TSF final cover to protect against surface erosion of the ISL. The final cover will be reshaped for effective drainage to the nominal 1.5% gradient. Although the cover system will store some rainfall runoff, the hydraulic assessment has assumed a self-shedding cover (refer **Section 3.4**).

3.2.4 TSF Closure Spillway

During the design of the TSF, it was envisaged that two (2) closure spillways would be constructed to convey flows up to and including the Probable Maximum Flood. Based on preliminary modelling results, it is proposed to construct a single spillway with the details provided in **TABLE 6**.

TABLE 6: TSF CLOSURE SPILLWAY DETAILS

Parameter	Value
Upstream Invert Level	235.0 m AHD
Downstream Invert Level	228.3 m AHD
Base Width	30.0 m
Side Slopes	1: 2 (V:H)
Length	330 m
Longitudinal Grade	2.0 %

3.2.5 Grid Size and Time Step

A 5 m x 5 m grid was applied to the digital terrain model. Direct rainfall was applied to the grid with an initial timestep of 2.5 seconds. To ensure the maximum impacts of the proposed development were captured in the model, a lag time of approximately 3 hours was applied to the direct rainfall to allow for the RFFE flows in the Dugald River and Cabbage Tree Creek to reach the TSF and DRM areas before rainfall was applied to the study areas. The adopted simulation times are summarised in

TABLE 7.

TABLE 7: HYDRAULIC MODEL SIMULATION TIME

Event Duration	Simulation Time (hr)
20 min	4.0
25 min	4.0
45 min	4.0
1 hour	4.5
1.5 hour	5.0
2 hour	5.5
3 hour	6.5

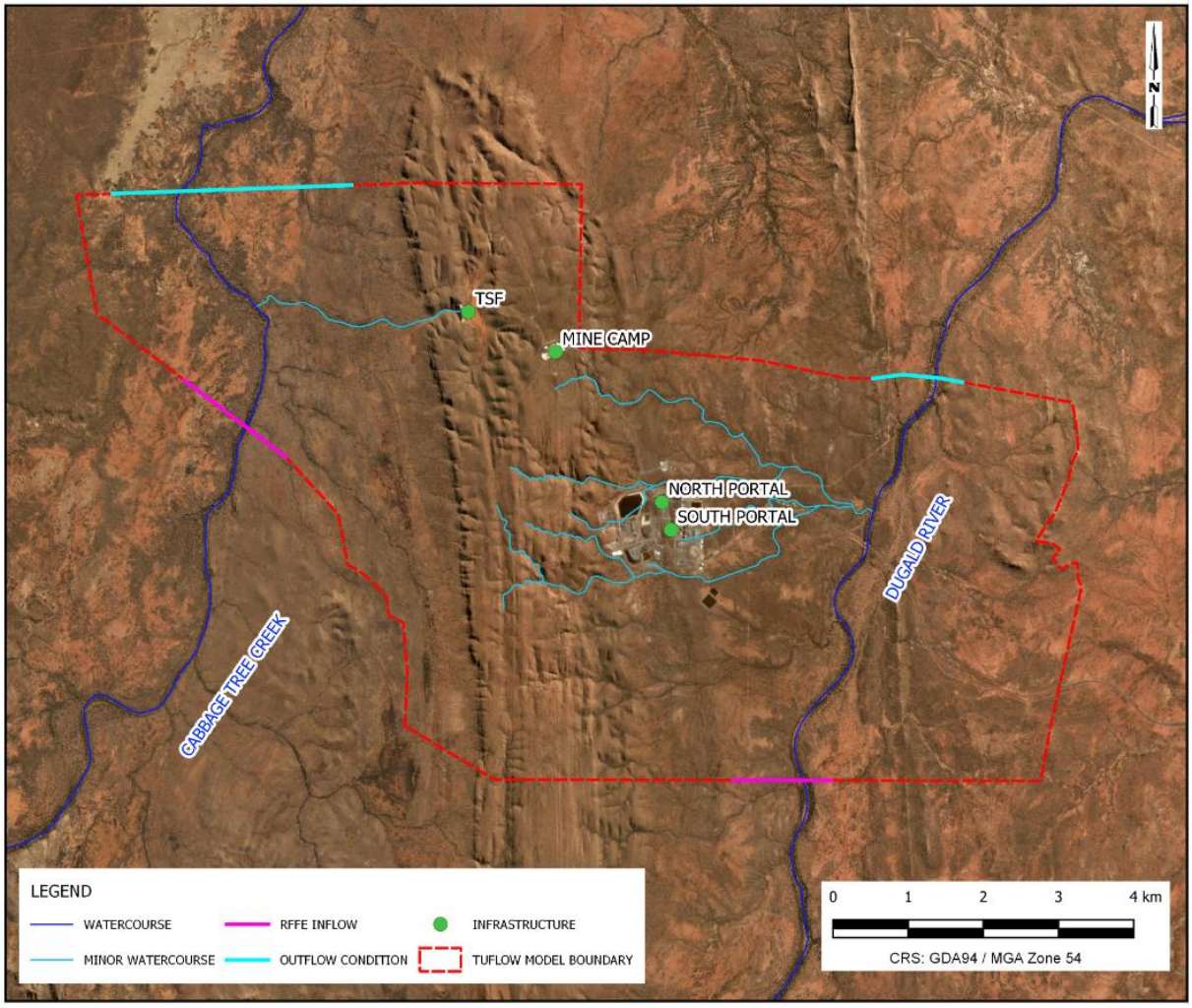
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Event Duration	Simulation Time (hr)
4.5 hour	8.0
6 hour	8.5
9 hour	13.0
12 hour	16.0

3.3 Boundary Conditions

As detailed in **Section 2.4**, RFFE flows for the Dugald River and Cabbage Tree Creek were applied to the upstream inflow boundaries in the model domain. The location of upstream inflows are depicted by pink lines on **DIAGRAM 7** and are detailed in **TABLE 8**.

DIAGRAM 7: BOUNDARY LOCATIONS



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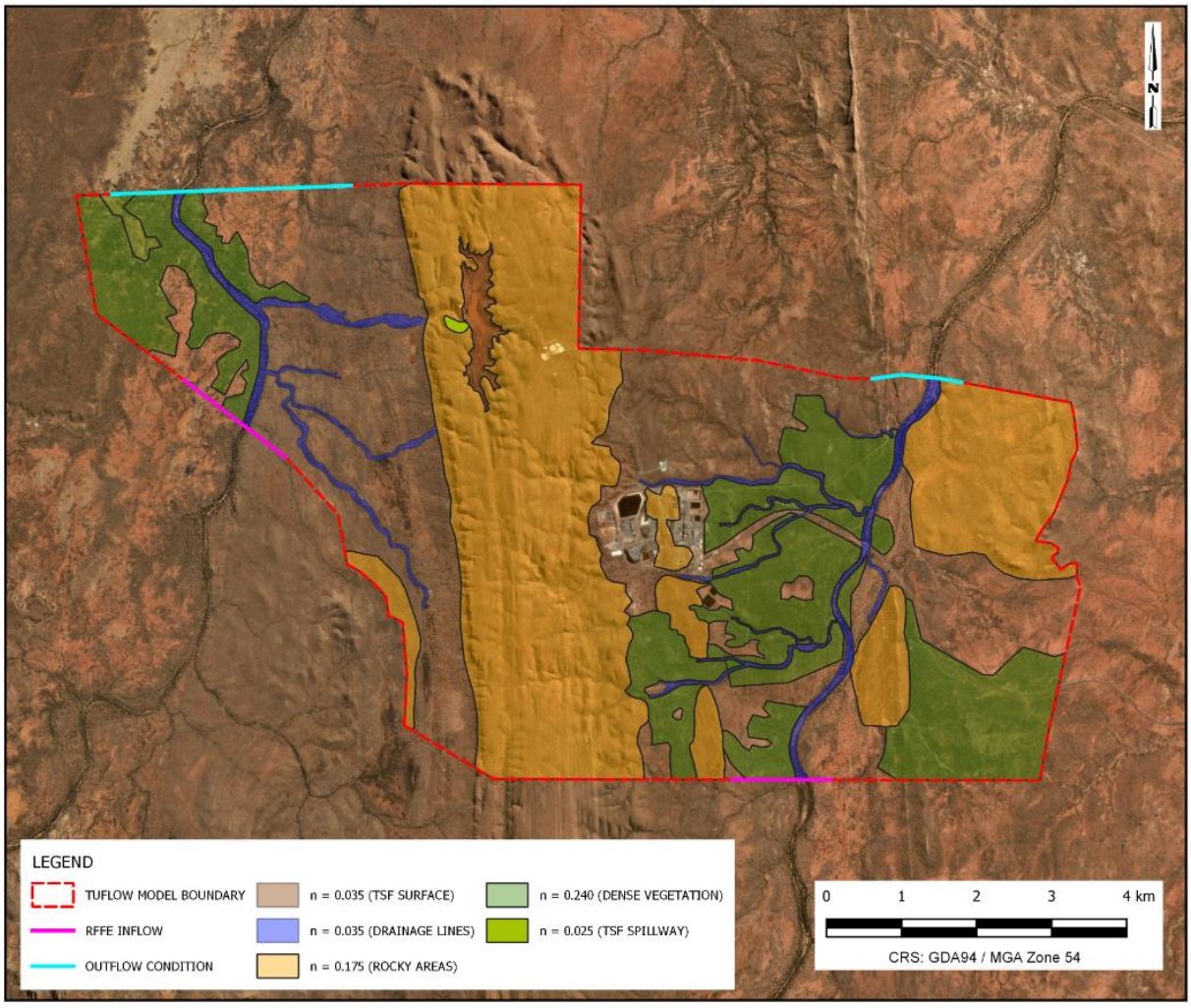
TABLE 8: BOUNDARY CONDITIONS

Site Rainfall Event	RFFE Event	Dugald River (m^3/s)	Cabbage Tree Creek (m^3/s)
PMP	1 % AEP Mean Flow	2,680	1,340
0.1 % AEP	1 % AEP Mean Flow	2,680	1,340
0.1 % AEP Sensitivity	1% AEP 95th Percentile Flow	11,500	5,540
1 % AEP	5% AEP Mean Flow	1,570	790

3.4 Surface Roughness

The Manning's 'n' surface roughness coefficient is used to describe the surface conditions within the model domain. Manning's roughness coefficients were assigned to the model domain, as depicted on **DIAGRAM 8**. Selection of the coefficient was made considering the apparent roughness of surfaces based upon inspection of available aerial imagery. The default surface roughness of 0.13 was adopted to represent the areas of bare earth and sparse vegetation.

DIAGRAM 8: MANNINGS ROUGHNESS



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Reference values from Innovyze (2019) **[11]** were adopted for the following surfaces. Innovyze are the developers of a range of hydraulic and hydrology software with a comprehensive online resource library.

- Natural flow and deep flow within the drainage features – adopted a roughness of 0.035 representing steams on a plain; clean, winding, some pools and shoals, and major streams; tranquil flow with dunes.
- TSF surface – adopted a roughness of 0.035 representing a finished surface that sheds water,
- TSF spillway channel – adopted a roughness of 0.025 representing a straight unlined channel,
- Dense vegetation – adopted a roughness of 0.240 representing dense vegetation,
- Rocky elevated surfaces – adopted a roughness of 0.175.

3.5 Sensitivity Analysis

As discussed in previous sections of the report, there are aspects of the hydraulic modelling that have been assumed or estimated. Sensitivity analyses were undertaken to accommodate for uncertainties adopted in the approach. The following considerations were adopted as part of the sensitivity analyses:

- 1.0% AEP 95th percentile RFFE inflows – takes into account the uncertainty in the hydrological inputs from the RFFE (refer **TABLE 8**).
- A 20% increase in rainfall depths – takes into account the uncertainty with more extreme rainfall events due to climate change.
- Assigning a 20% increase in Manning's roughness coefficients. Higher roughness coefficients reduce the flow velocity and consequently increase the modelled flow depths.

Initially, a 10 m x 10 m grid size was selected, but it did not provide sufficient model refinement in the TSF spillway. A 5 m x 5 m grid size gave better model resolution and so was adopted for all scenarios. The 2015 site LIDAR topography **[6]**, used on the western extent of the model, was provided with a cell size of 5 m, so the accuracy of the modelled surface matched that of the data provided.

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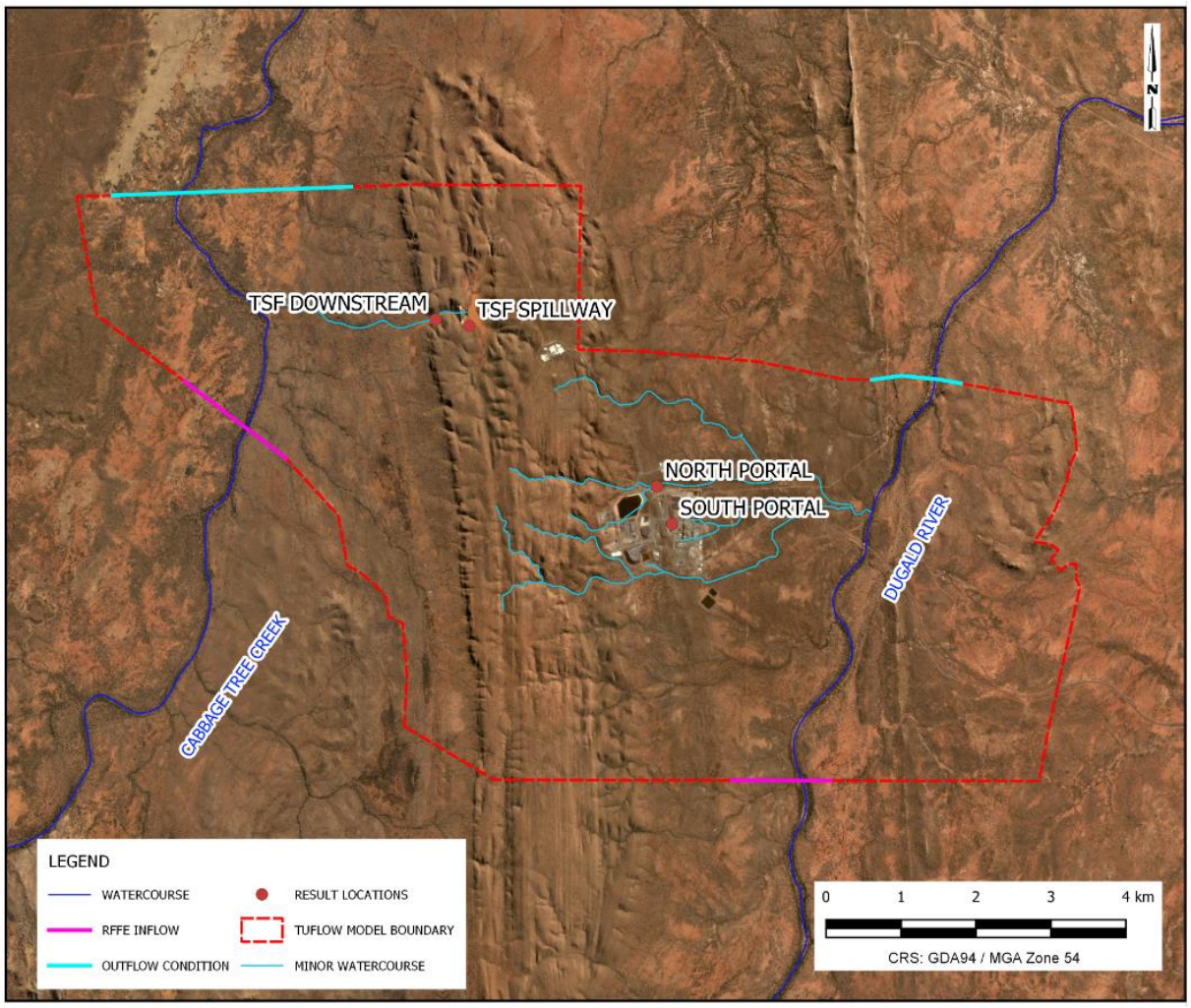
4 RESULTS AND IMPACTS

4.1 General

The results of the TUFLOW model showing maximum water depths and velocities are presented in **Figure 001** to **Figure 012**.

A summary of impacts on the TSF, North Portal, South Portal, and the tributaries downstream of the sites are summarised below. The key locations at which results are derived are outlined on **DIAGRAM 9**.

DIAGRAM 9: PEAK FLOOD LEVEL LOCATIONS



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4.2 TSF

The maximum recorded flow immediately downstream of the TSF, as well as the storm duration and temporal pattern producing the peak flow are summarised in **TABLE 9**. The impacts on the TSF Spillway are summarised in **TABLE 10**. It is noted that upon closure, with only a single spillway, the embankment crest should be raised to a level of 238.5 m AHD.

TABLE 9: TSF PEAK FLOWS

	PMP	0.1% AEP	1% AEP
Peak Flow m³/s	282.9	74.6	44.6
Critical Storm Duration and Temporal Pattern	90 min	540 min TP10	540 min TP10

TABLE 10: TSF SPILLWAY IMPACTS

	PMP	0.1% AEP	1% AEP
TSF Embankment Levels (m AHD)	238.0	238.0	238.0
Upstream Spillway Elevation (m AHD)	235.0	235.0	235.0
Upstream Maximum Surface Elevation (m AHD)	237.59	236.00	235.67
Upstream Maximum Flow Depth (m)	2.59	1.0	0.67
Upstream Spillway Flow Velocity (m/s)	4.2	2.9	2.5
Downstream Spillway Elevation (m AHD)	228.3	228.3	228.3
Downstream Maximum Surface Elevation (m AHD)	230.0	229.12	228.92
Downstream Maximum Flow Depth (m)	1.70	0.82	0.62
Downstream Spillway Flow Velocity (m/s)	6.2	4.1	3.5
Peak Spillway Flow (m³/s)	274.1	72.4	43.7

Modelled results for the TSF indicate that for the PMP event a backwater effect was present at the downstream toe of the TSF closure embankment. The flow down the spillway is confined by the downstream channel and some of the spillway discharge is forced upstream to the TSF closure embankment. The modelled maximum depth at the toe of the TSF closure embankment was some 3.7 m. This backwater effect could be limited by re-alignment of the spillway channel during the detailed design process, to allow for greater alignment with the downstream flow path. Furthermore, maximum velocities recorded for the PMP event were some 6.2 m/s within the spillway channel. These modelled velocities have a high potential for erosion, and as such erosional velocity dampeners or a similar method of limiting velocity through the spillway channel would potentially need to be implemented. These issues will require further examination during detailed design of the closure spillway.

4.3 Portals and Tributaries

The maximum recorded water surface elevations immediately adjacent to the North Portal (recorded in North Creek) are summarised in **TABLE 11**. Maximum recorded water surface elevations immediately adjacent to the South Portal (recorded in Mine Trib Centre) are summarised in **TABLE 12**. The locations where water surface elevations are recorded are depicted on **DIAGRAM 9.**

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TABLE 11: NORTH PORTAL IMPACTS

	PMP	0.1% AEP	1% AEP
Portal Crest Level at top of ramp (m AHD)	207.5	207.5	207.5
Maximum Water Surface Elevation (m AHD)	204.00	201.77	201.45
Depth of water impacting portal (m)	-	-	-
Freeboard to portal crest level (m)	3.50	5.73	6.05

As can be seen in **TABLE 11**, the North Portal is not subject to inundation in any events up to and including the PMF, and as such is not considered to be in the floodplain.

TABLE 12: SOUTH PORTAL IMPACTS

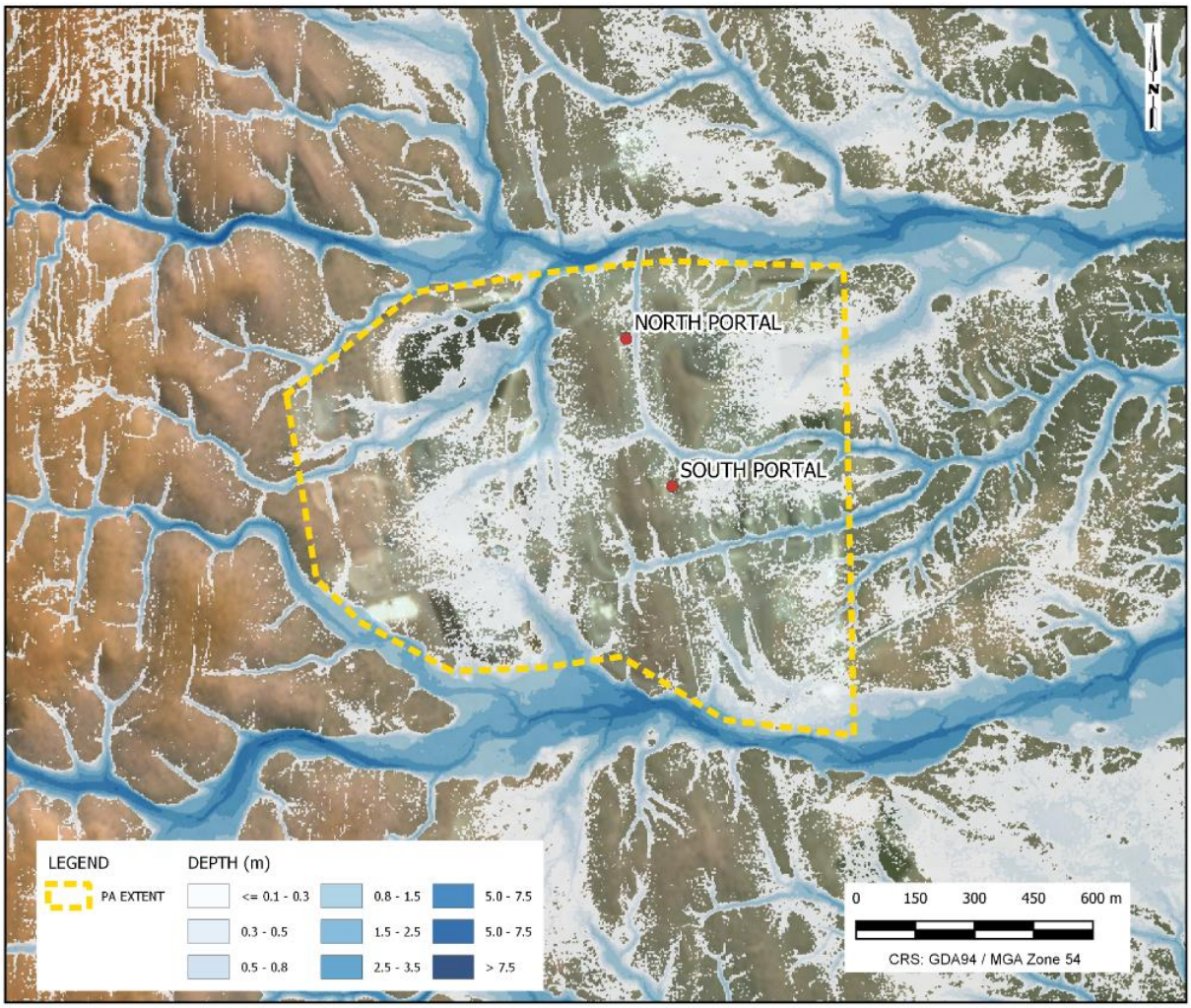
	PMP	0.1% AEP	1% AEP
Portal Crest Level at top of ramp (m AHD)	206.0	206.0	206.0
Maximum Water Surface Elevation (m AHD)	205.50	204.84	204.74
Depth of water impacting portal (m)	-	-	-
Freeboard to portal crest level (m)	0.50	1.16	1.26

TABLE 12 shows the South Portal is not subject to inundation in any events up to and including the PMF, and as such is not considered to be in the floodplain.

The modelled results indicate that the mine portals are clear of local flooding and are outside the floodplain. Notwithstanding, there are small drainage lines in the area which are depicted on **DIAGRAM 10**. These drainage lines are artefacts of the original topography prior to any mine disturbance and not a definitive representation of the final landform. Local topography and drainage will be modified during closure, to ensure that local runoff is directed away from the portals and will aim to reconnect drainage lines with downstream watercourses.

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DIAGRAM 10: PROCESS AREA - PMP FLOOD DEPTH



The maximum recorded water surface elevation and maximum velocities in North Creek, Mine Trib Centre and Silvermine Creek downstream of the Process Area are summarised in **TABLE 13** and **TABLE 14**. The locations where results are recorded in **TABLE 13** and **TABLE 14** are depicted on **DIAGRAM 11**.

TABLE 13: PROCESS AREA TRIBUTARY PEAK WATER SURFACE ELEVATIONS

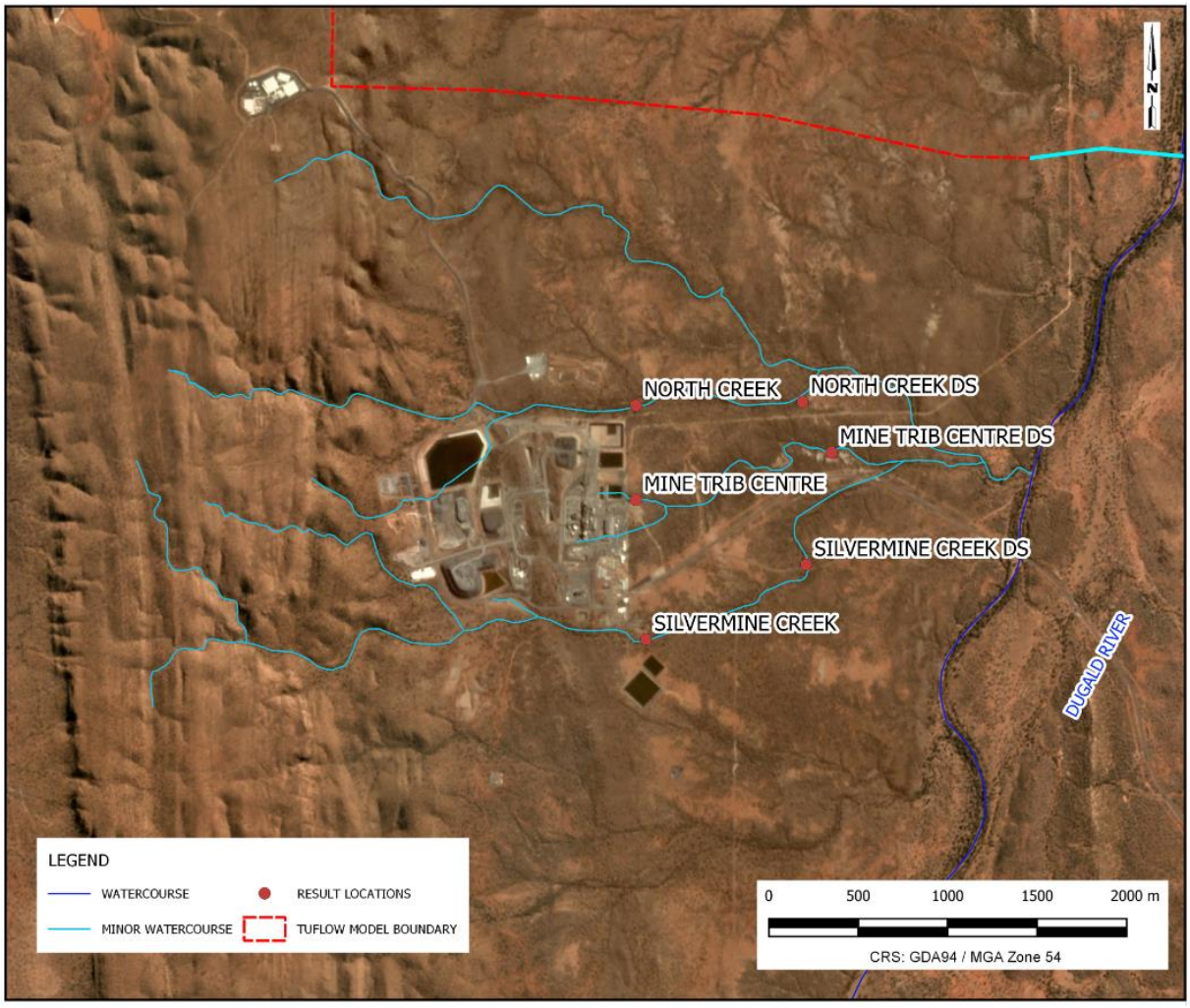
Location	Peak Water Surface Elevation (m AHD)		
	PMP	0.1% AEP	1% AEP
North Creek	197.48	195.43	195.19
North Creek DS	191.65	191.63	191.62
Mine Trib Centre	198.33	197.14	196.86
Mine Trib Centre DS	189.95	188.28	188.00
Silvermine Creek	200.97	198.91	198.57
Silvermine Creek DS	193.29	191.05	190.74

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TABLE 14: PROCESS AREA TRIBUTARY MAXIMUM VELOCITIES

Location	Maximum Velocity (m/sec)		
	PMP	0.1% AEP	1% AEP
North Creek	3.15	2.74	2.46
North Creek DS	3.14	2.46	2.27
Mine Trib Centre	0.79	0.50	0.43
Mine Trib Centre DS	0.41	0.37	0.31
Silvermine Creek	2.51	1.90	1.83
Silvermine Creek DS	2.07	1.97	1.95

DIAGRAM 11: PROCESS AREA FLOOD LEVEL LOCATIONS



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4.4 Sensitivity Outcomes

The sensitivity analysis was conducted for the conditions listed in **Section 3.5**. The results for the 1.0% AEP 95th percentiles RFFE inflows indicated no impacts on the TSF closure embankment and spillway from flows in Cabbage Tree Creek, and no impacts on the plant process area from flows in the Dugald River. Under the modelled scenario a backwater effect from the increased sensitivity inflow does not impact the model.

Relative to the base model, a 20% increase in Manning's roughness coefficient does not have a significant impact on the maximum water surface elevations at the North Portal and has a slight negative impact at the South Portal. A 20% increase in the applied rainfall depth results in an increase in flows depths up to 0.36 m adjacent to the North Portal and 0.15 m at the South Portal. A comparison of base model and sensitivity test results is shown in **TABLE 15**.

TABLE 15: PORTAL SENSITIVTY IMPACTS

Location	Model Type	Maximum Water Surface Elevation (m AHD)		
		PMP	0.1% AEP	1% AEP
North Portal	Base Model	204.00	201.77	201.45
	+ 20% Manning's Sensitivity	204.04	201.79	201.46
	+ 20% Rainfall Depth	204.36	201.98	201.60
	Maximum Modelled Difference	+ 0.36 m	+ 0.21 m	+ 0.15 m
South Portal	Base Model	205.50	204.84	204.74
	+ 20% Manning's Sensitivity	205.35	204.77	204.75
	+ 20% Rainfall Depth	205.65	204.90	204.79
	Maximum Modelled Difference	+ 0.15 m	+ 0.06 m	+ 0.05 m

Relative to the base model, an increase of 20% in Manning's roughness coefficient has no significant impact on the water surface elevation of the model in all events up to the PMF. An increase of 20% rainfall depth results in an increase in water surface elevation of up to 0.27 m in the TSF spillway. Increasing the surface roughness decreases the peak flow rate because surface flows are retarded upstream of the spillway, as reflected in **TABLE 17**. Conversely, increasing rainfall depths by 20% had the result of increasing peak flow rate by between 18% and 27% for the PMP and 1% AEP events, respectively. Comparisons of base model results and sensitivity test results are shown in **TABLE 16** and **TABLE 17**.

TABLE 16: TSF SPILLWAY IMPACTS – MAXIMUM DEPTH

Location	Model Type	Maximum Water Surface Elevation (m AHD)		
		PMP	0.1% AEP	1% AEP
TSF Spillway - Upstream	Base Model	237.59	236.00	235.67
	+ 20% Manning's Sensitivity	237.51	235.94	235.68
	+ 20% Rainfall Depth	237.85	236.14	235.78
	Maximum Modelled Difference	+ 0.26 m	+ 0.14 m	+ 0.11 m
TSF Spillway - Downstream	Base Model	230.00	229.12	228.92
	+ 20% Manning's Sensitivity	229.98	229.09	228.67
	+ 20% Rainfall Depth	230.27	229.26	229.04
	Maximum Modelled Difference	+ 0.27 m	+ 0.14 m	+ 0.12 m

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TABLE 17: TSF SPILLWAY IMPACTS – MAXIMUM FLOW RATE

Location	Model Type	Peak Flow Rate (m^3/sec)		
		PMP	0.1% AEP	1% AEP
TSF Spillway	Base Model	282.9	74.6	44.6
	+ 20% Manning's Sensitivity	246.0	71.1	43.7
	+ 20% Rainfall Depth	333.5	89.3	56.5
	Maximum Modelled Difference	+ 50.6	+ 14.7	+ 11.9

The sensitivity tests indicate that the model is not very sensitive to increases in the surface roughness, but has some sensitivity to increases in rainfall depths at both the main mine site and the TSF area.

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5 PCRP INPUTS

The PRCP requires flood risk assessments for two aspects of closure; to identify whether any mine voids will remain in the floodplain post-closure, and to assess the flood risk to any remaining infrastructure.

5.1 Mine Portals

Post closure, if there was a mine void located in a floodplain the void would need to be rehabilitated to a stable condition. A mine portal could potentially be considered as a void, and the floodplain is defined as land which is at or below the peak water level for the 0.1% AEP design storm event.

The modelling outputs presented in **Section 4** show that the mine portals are not located below the 0.1% AEP flood level and are therefore not located within the floodplain. Further, both portals are at very low risk from flooding. The North Portal and the South Portal are not subject to inundation in any events up to and including the PMF.

Flood mapping shows that the portals are clear of local flooding and are outside of the floodplain, but there are small drainage lines in the area. These drainage lines are artefacts of the original topography prior to any mine disturbance and not a definitive representation of the final landform (refer **DIAGRAM 10**). Local topography and drainage will be modified during closure, to ensure that local runoff is directed away from the portals and will aim to reconnect drainage lines with downstream watercourses.

It should also be noted that the mine portals will be capped at closure, to prevent water entering the mine workings.

5.2 TSF

Post closure, the TSF will be the only remaining piece of infrastructure, although this will be closed and capped. Preliminary design has adopted a self-shedding cover system, with a nominal gradient of 1.5%, and a modified embankment. A spillway channel will be added, to achieve the following:

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

The flood modelling presented in **Section 4** has demonstrated that the proposed spillway design (**TABLE 6**) is suitable to safely convey design events up to and including the PMF. Flooding from the downstream tributary and Cabbage Tree Creek does not affect the TSF embankment. Notwithstanding, modelled results indicated that a backwater effect was exhibited on the downstream toe of the TSF embankment, as a result of the spillway outflows. Re-alignment of the spillway channel, to properly convey catchment flows to the downstream tributary, will be required during detailed design of the spillway.

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6 SUMMARY AND CONCLUSION

Hydraulic analysis of the site was undertaken using the two dimensional (2D) finite difference program TUFLOW, with ARR **[1]** utilised to develop the rainfall estimates for input into the hydraulic model. It is understood that MMG intends to rehabilitate the site to the pre-mining topography, as much as is practically possible. As such, the pre-mining surface and the preliminary TSF closure plan, developed by ATCW in 2016, were incorporated in the hydraulic model.

The PRCP requires flood risk assessments for two aspects of closure: to identify whether any mine voids will remain in the floodplain post-closure; and to assess the flood risk to remaining infrastructure. The modelling outputs presented in **Section 4.3** show that the mine portals are not located below the 0.1% AEP flood level and are therefore not within the floodplain. Additionally, the modelling results indicated that both portals are at a low risk of flooding. The North Portal and the South Portal are not subject to inundation in any events up to and including the PMF.

The remaining infrastructure proposed to be left at the site is the rehabilitated and capped TSF. Modelled results indicate that flooding from the downstream tributary and Cabbage Tree Creek does not affect the TSF embankment. Notwithstanding, a backwater effect was exhibited on the downstream toe of the TSF embankment, due to the spillway outflows. Re-alignment of the spillway channel, to properly convey catchment flows to the downstream tributary, will be required during detailed design of the spillway. Modelling results indicated that, with only a single spillway, the TSF embankment crest should be raised to a level of 238.5 m AHD. Additionally, the maximum velocities recorded for the PMP event were some 6.2 m/s within the spillway channel. These modelled velocities have a high potential for erosion, and as such erosional velocity dampeners, re-grading of the spillway channel or a similar method of limiting velocity would potentially need to be implemented.

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[9] ATCW (2016b), 'MMG Dugald River – Tailings Storage Facility - Design Report Closure Concept – Figure 15.1' (Ref: 108003.20.Figure 15.1 – dated 22 February 2016).

[10] SGM Environmental Pty Ltd (2019), 'Tailings Storage Facility: Dugald River Mine: Column Cover trials, prepared for MMG limited.

[11] Innovyze (2019), 'Manning's n Roughness Coefficients – Open Channel', October 2019.

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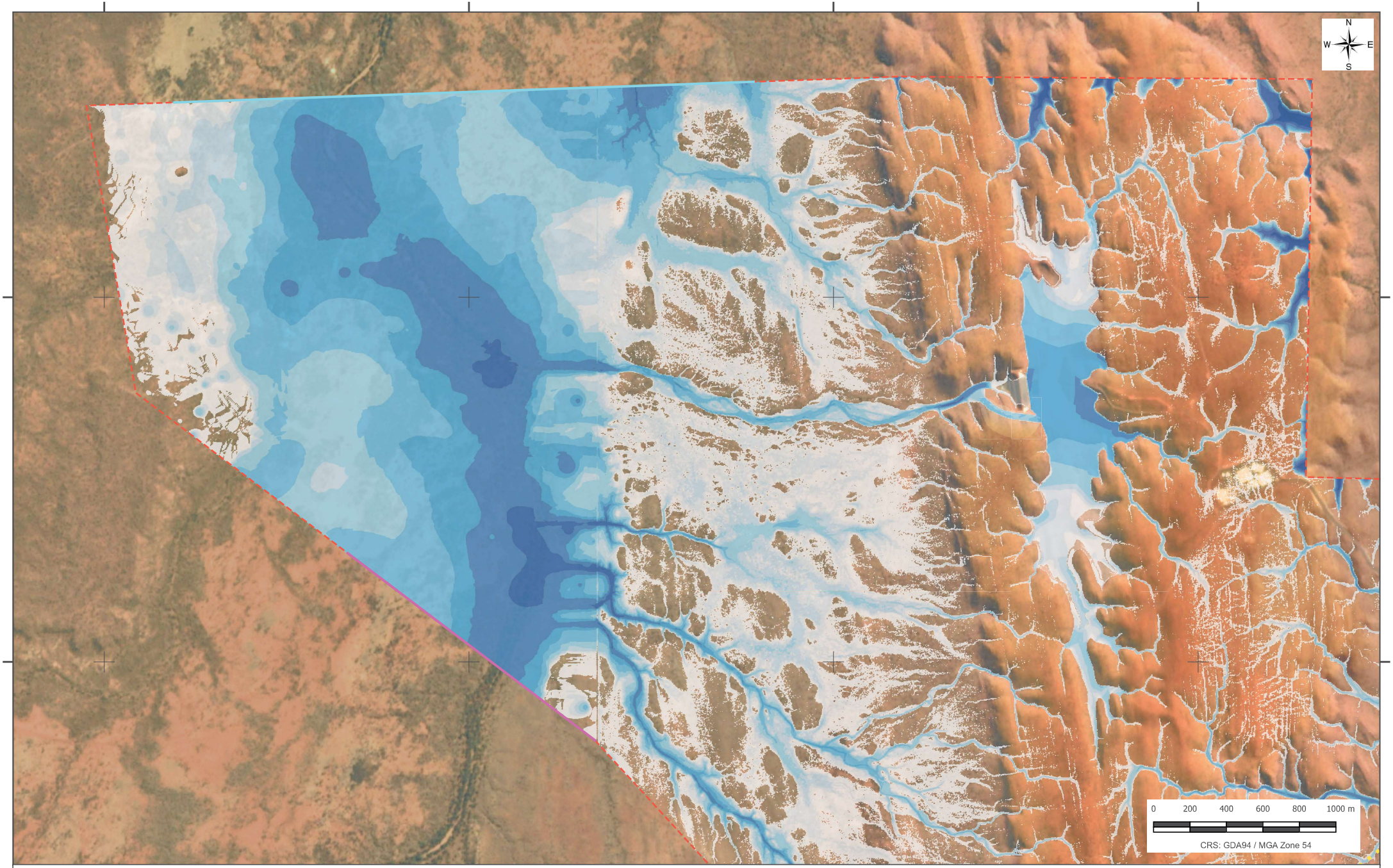
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FIGURES



LEGEND

- OUTFLOW BOUNDARY
- INFLOW BOUNDARY
- TUFLOW MODEL BOUNDARY

ELEVATION (RL m)

170	275
205	310
240	

MAXIMUM DEPTH (m)

0.3 - 0.5	1.5 - 2.5	5.0 - 7.5
0.5 - 0.8	2.5 - 3.5	> 7.5
0.8 - 1.5	5.0 - 7.5	

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DUGALD RIVER MINE
TSF PMP - MAXIMUM FLOOD DEPTH

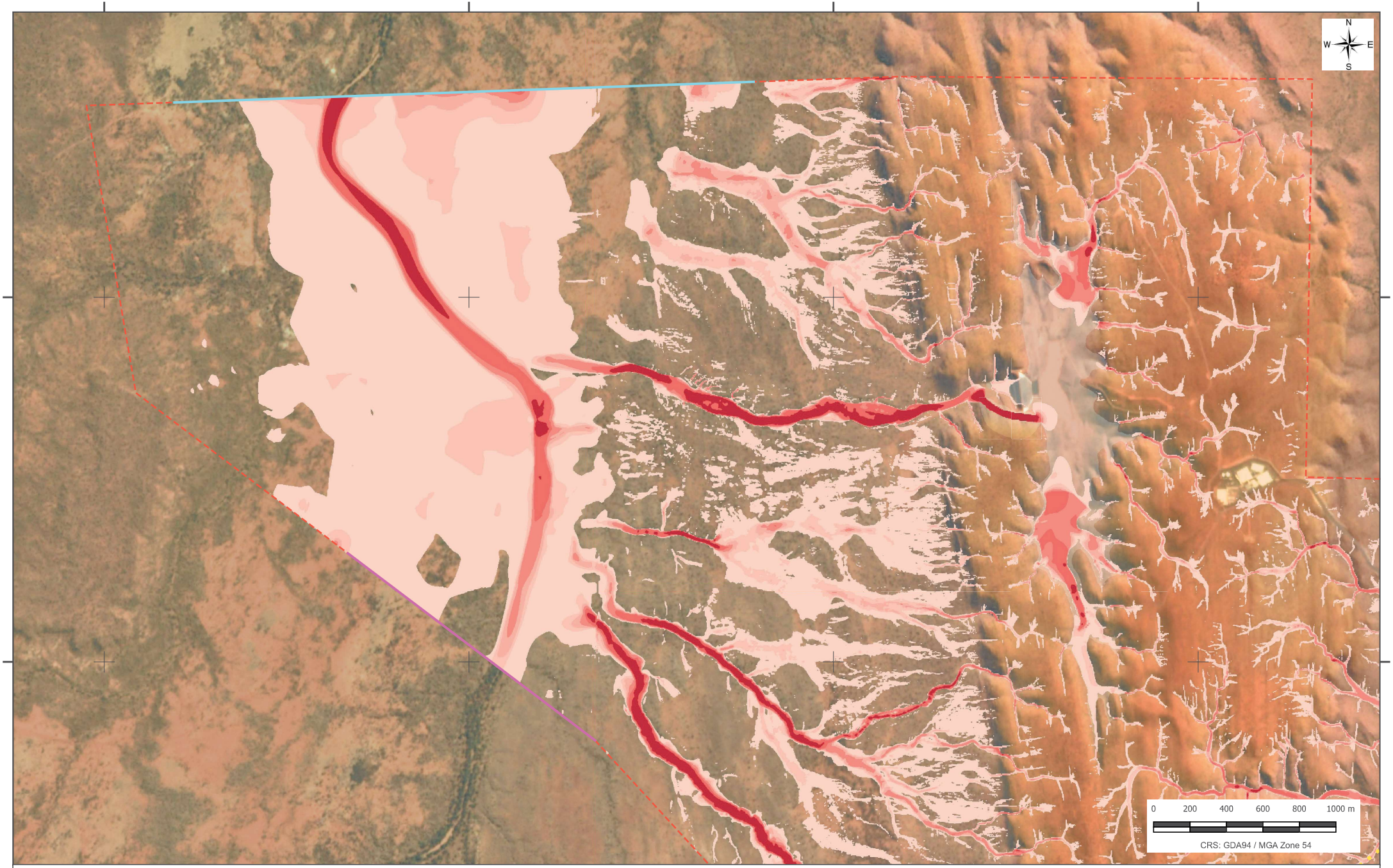
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FIGURE 001

108003-49

DATE: 2021-05-18

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LEGEND

- OUTFLOW BOUNDARY
- INFLOW BOUNDARY
- TUFLOW MODEL BOUNDARY

ELEVATION (RL m)

170	275
205	310
240	

MAXIMUM VELOCITY (m/sec)

0.3 - 0.6	0.8 - 1.0	> 2.5
0.6 - 0.8	1.0 - 1.5	
0.6 - 0.8	1.5 - 2.5	

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DUGALD RIVER MINE
TSF PMP - MAXIMUM FLOOD VELOCITY

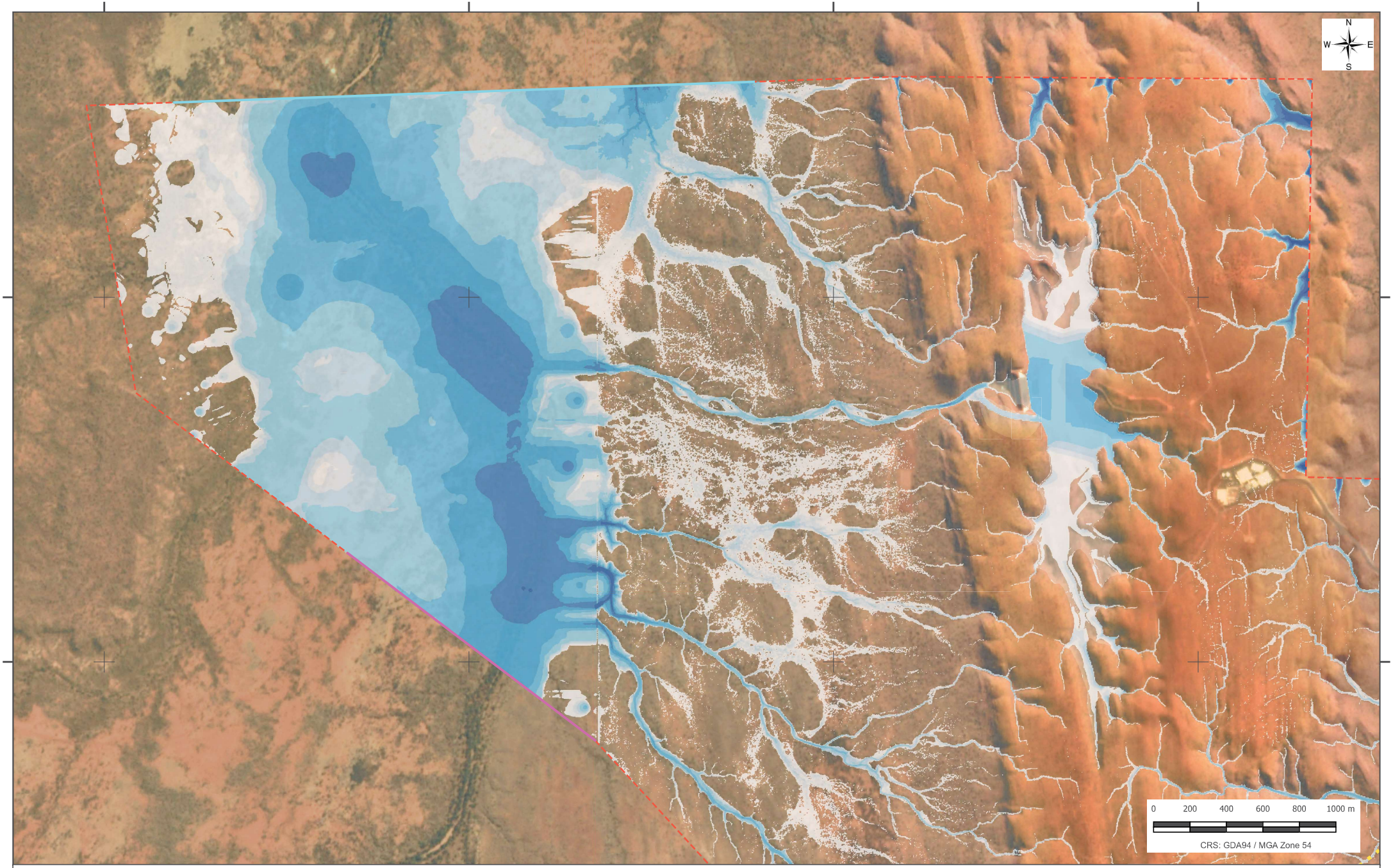
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FIGURE 002

108003-49

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LEGEND

- OUTFLOW BOUNDARY
- INFLOW BOUNDARY
- TUFLOW MODEL BOUNDARY

ELEVATION (RL m)

170	275
205	310
240	

MAXIMUM DEPTH (m)

0.3 - 0.5	1.5 - 2.5	5.0 - 7.5
0.5 - 0.8	2.5 - 3.5	> 7.5
0.8 - 1.5	5.0 - 7.5	

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DUGALD RIVER MINE
TSF 0.1% AEP - MAXIMUM FLOOD DEPTH

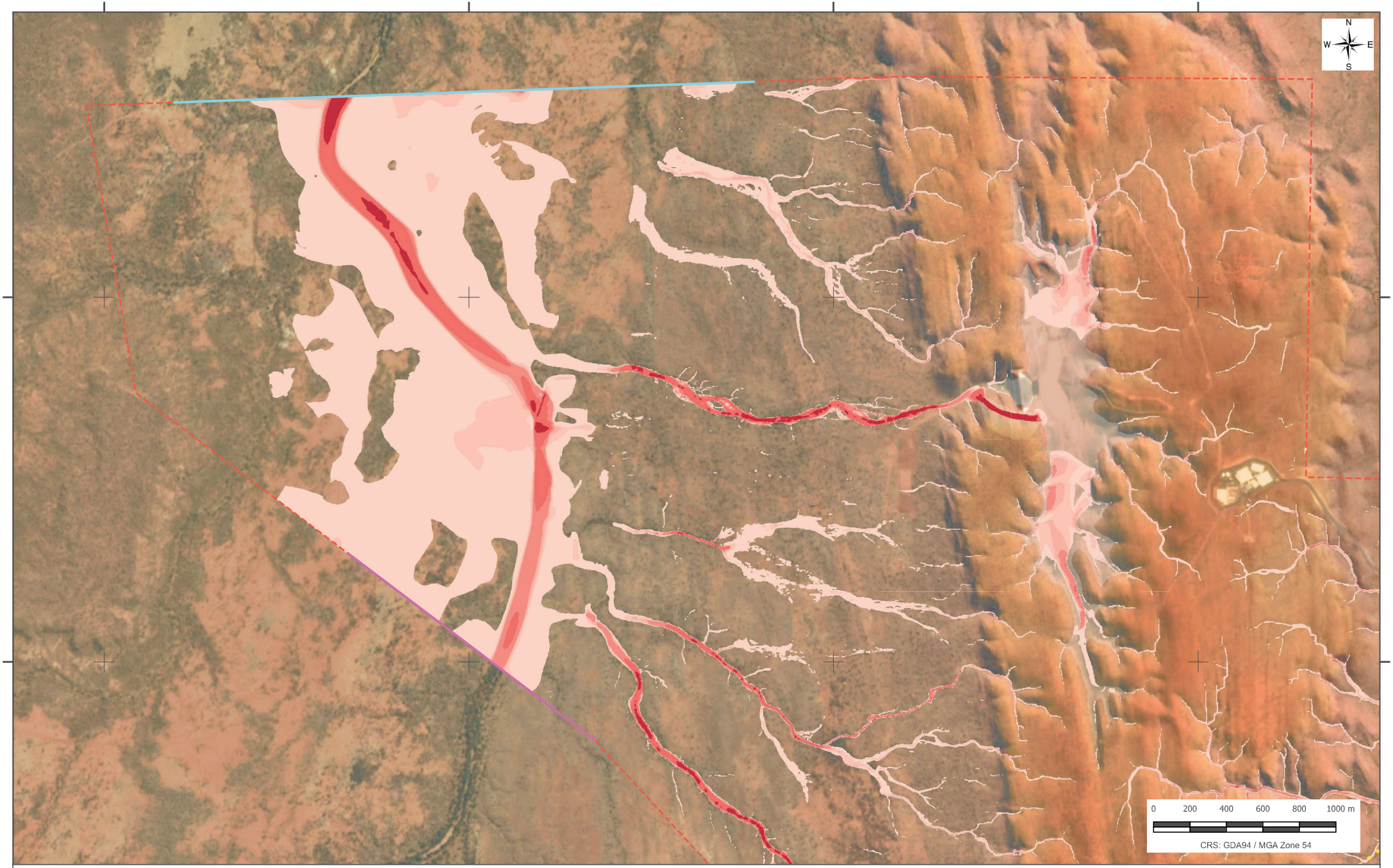
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FIGURE 003

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DATE: 2021-05-18

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LEGEND

- OUTFLOW BOUNDARY
- INFLOW BOUNDARY
- TUFLOW MODEL BOUNDARY

ELEVATION (RL m)

170 | 205 | 240 | 275 | 310

MAXIMUM VELOCITY (m/sec)

0.3 - 0.6 | 0.6 - 0.8 | 0.6 - 0.8 | 0.8 - 1.0 | 1.0 - 1.5 | 1.5 - 2.5 | > 2.5

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DUGALD RIVER MINE
TSF 0.1% AEP - MAXIMUM FLOOD VELOCITY

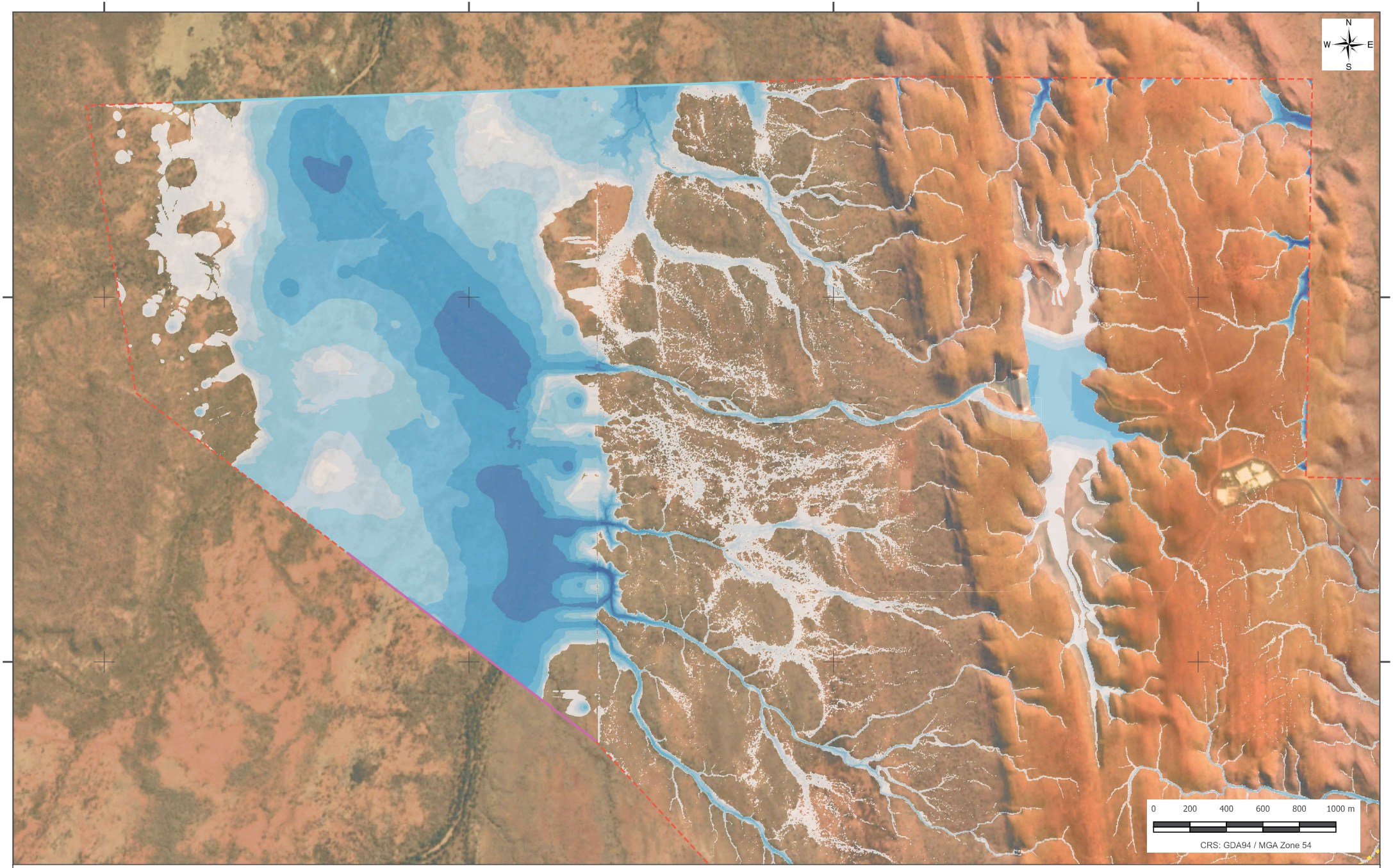
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FIGURE 004

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DATE: 2021-05-18

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LEGEND

- OUTFLOW BOUNDARY
- INFLOW BOUNDARY
- TUFLOW MODEL BOUNDARY

ELEVATION (RL m)

170	275
205	310
240	

MAXIMUM DEPTH (m)

0.3 - 0.5	1.5 - 2.5	5.0 - 7.5
0.5 - 0.8	2.5 - 3.5	> 7.5
0.8 - 1.5	5.0 - 7.5	

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DUGALD RIVER MINE
TSF 1.0% AEP - MAXIMUM FLOOD DEPTH

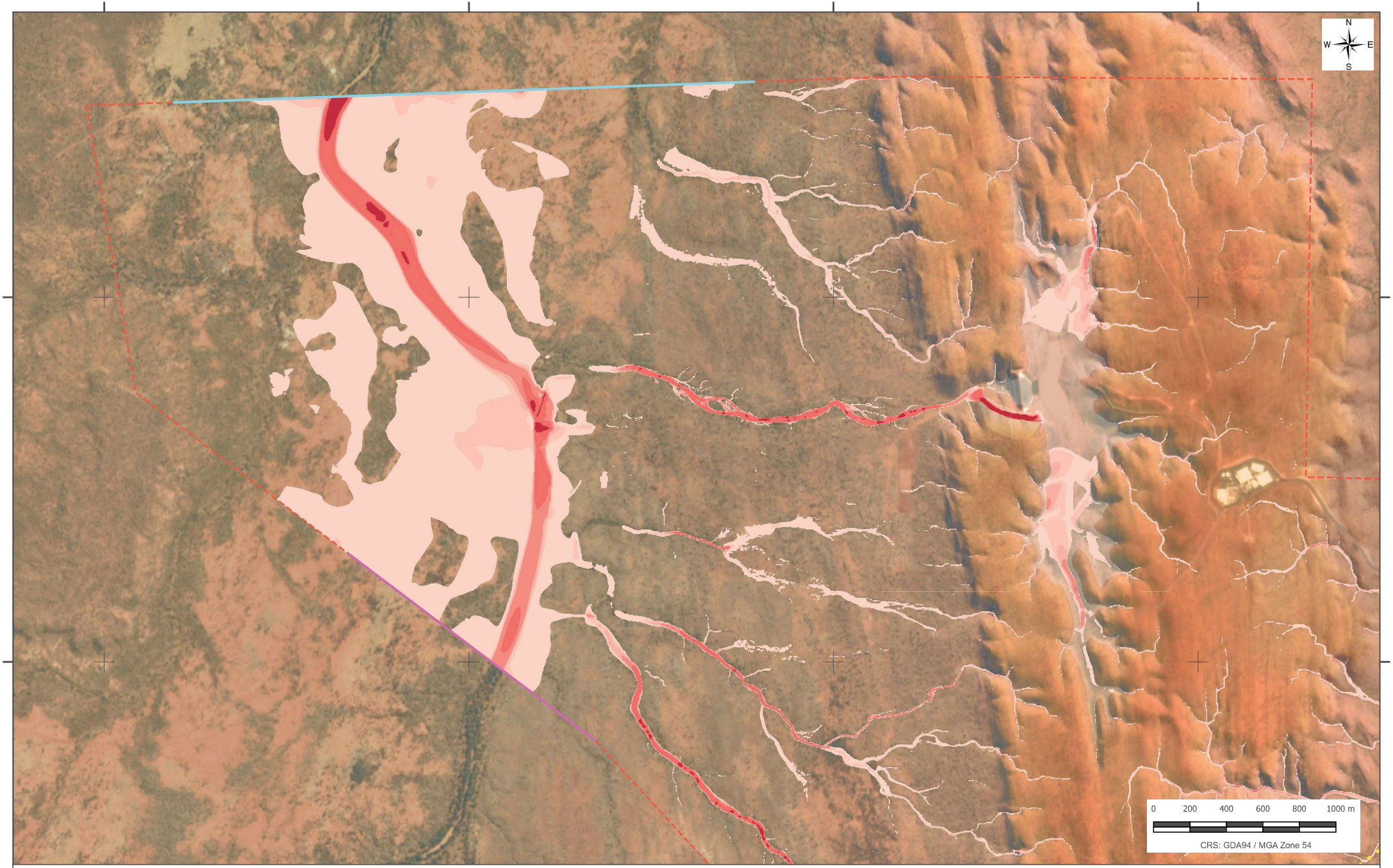
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FIGURE 005

108003-49

DATE: 2021-05-18

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LEGEND

- OUTFLOW BOUNDARY
- INFLOW BOUNDARY
- TUFLOW MODEL BOUNDARY

ELEVATION (RL m)

170	275
205	310
240	

MAXIMUM VELOCITY (m/sec)

0.3 - 0.6	0.8 - 1.0	> 2.5
0.6 - 0.8	1.0 - 1.5	
0.6 - 0.8	1.5 - 2.5	

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DUGALD RIVER MINE
TSF 1.0% AEP - MAXIMUM FLOOD VELOCITY

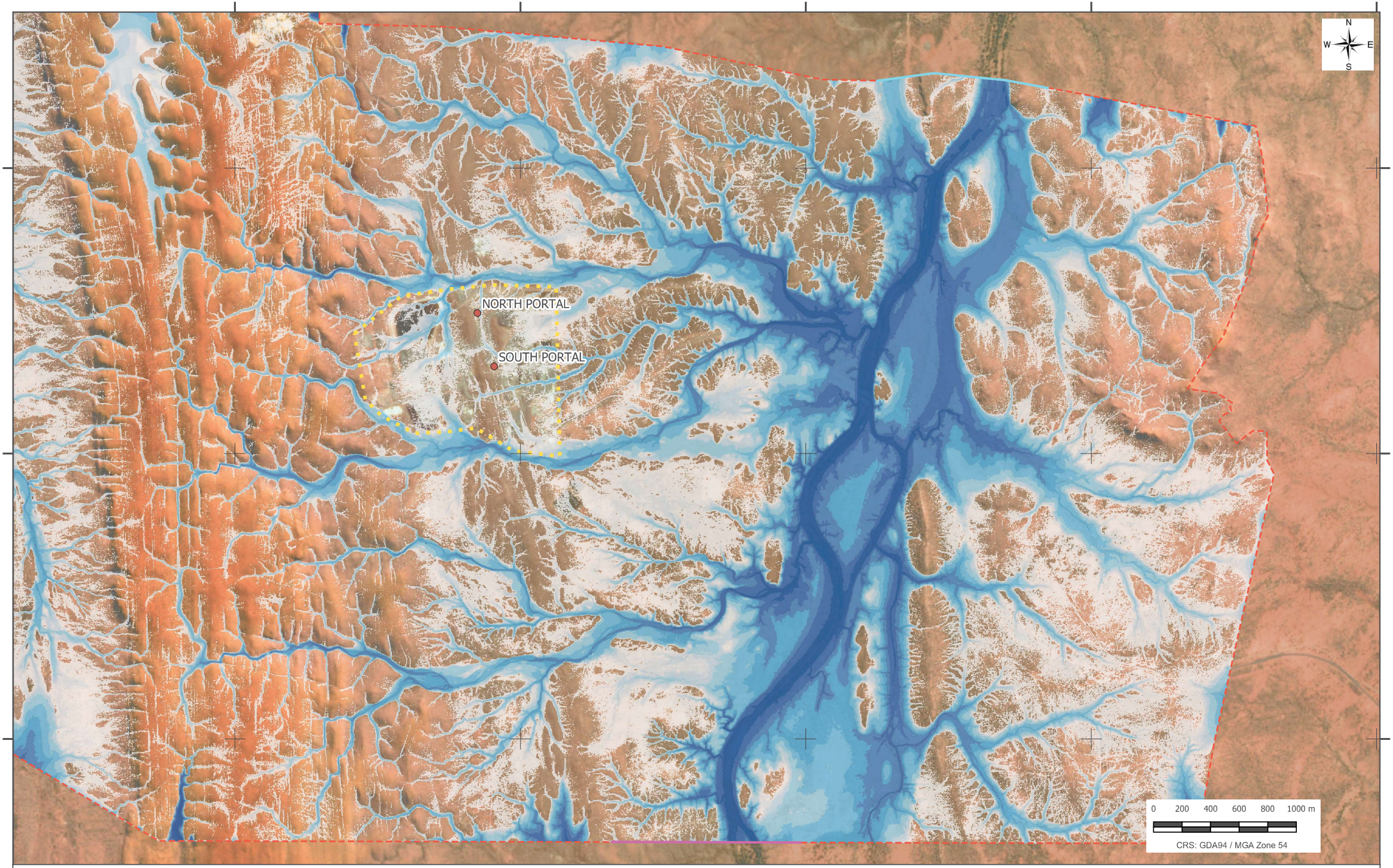
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FIGURE 006

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LEGEND

- OUTFLOW BOUNDARY
- INFLOW BOUNDARY
- TUFLOW MODEL BOUNDARY
- PA EXTENT

ELEVATION (RL m)

170	275
205	310
240	

MAXIMUM DEPTH (m)

0.3 - 0.5	1.5 - 2.5	5.0 - 7.5
0.5 - 0.8	2.5 - 3.5	> 7.5
0.8 - 1.5	5.0 - 7.5	

MMG AUSTRALIA PTY LTD

DUGALD RIVER MINE
PROCESS AREA PMP - MAXIMUM FLOOD DEPTH

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FIGURE 007

108003-49

DATE: 2021-05-18

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LEGEND

- OUTFLOW BOUNDARY
- INFLOW BOUNDARY
- TUFLOW MODEL BOUNDARY
- PA EXTENT

ELEVATION (RL m)

170 | 205 | 240 | 275 | 310

MAXIMUM VELOCITY (m/sec)

0.3 - 0.6 | 0.6 - 0.8 | 0.6 - 0.8 | 0.8 - 1.0 | 1.0 - 1.5 | 1.5 - 2.5 | > 2.5

MMG AUSTRALIA PTY LTD

DUGALD RIVER MINE
PROCESS AREA PMP - MAXIMUM FLOOD VELOCITY

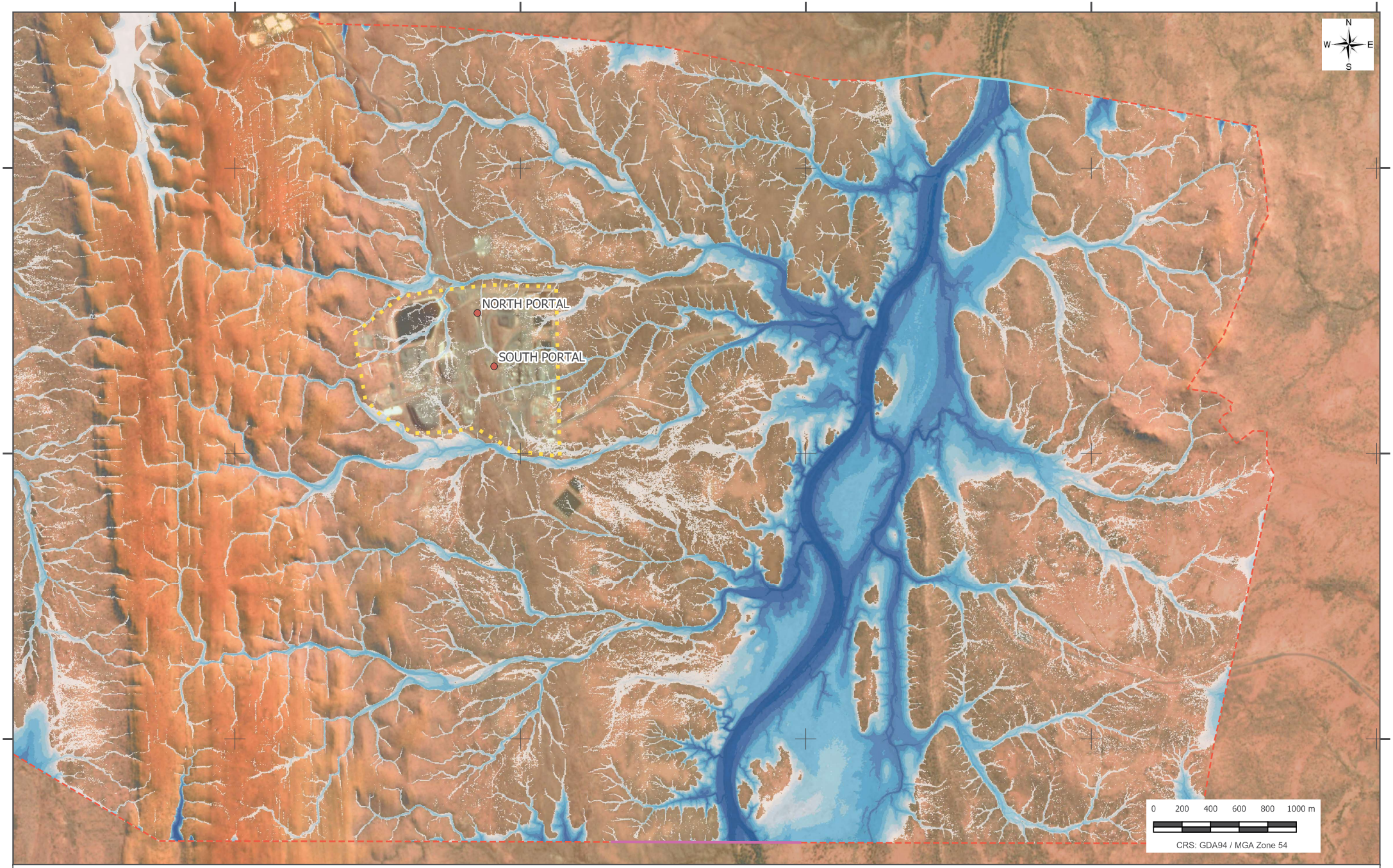
ATC WILLIAMS

FIGURE 008

108003-49

DATE: 2021-05-18

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LEGEND

- OUTFLOW BOUNDARY
- INFLOW BOUNDARY
- TUFLOW MODEL BOUNDARY
- PA EXTENT

ELEVATION (RL m)

170 275 205 310 240

MAXIMUM DEPTH (m)

0.3 - 0.5 1.5 - 2.5 5.0 - 7.5
0.5 - 0.8 2.5 - 3.5 > 7.5
0.8 - 1.5 5.0 - 7.5

MMG AUSTRALIA PTY LTD

DUGALD RIVER MINE
PROCESS AREA 0.1% AEP - MAXIMUM FLOOD DEPTH

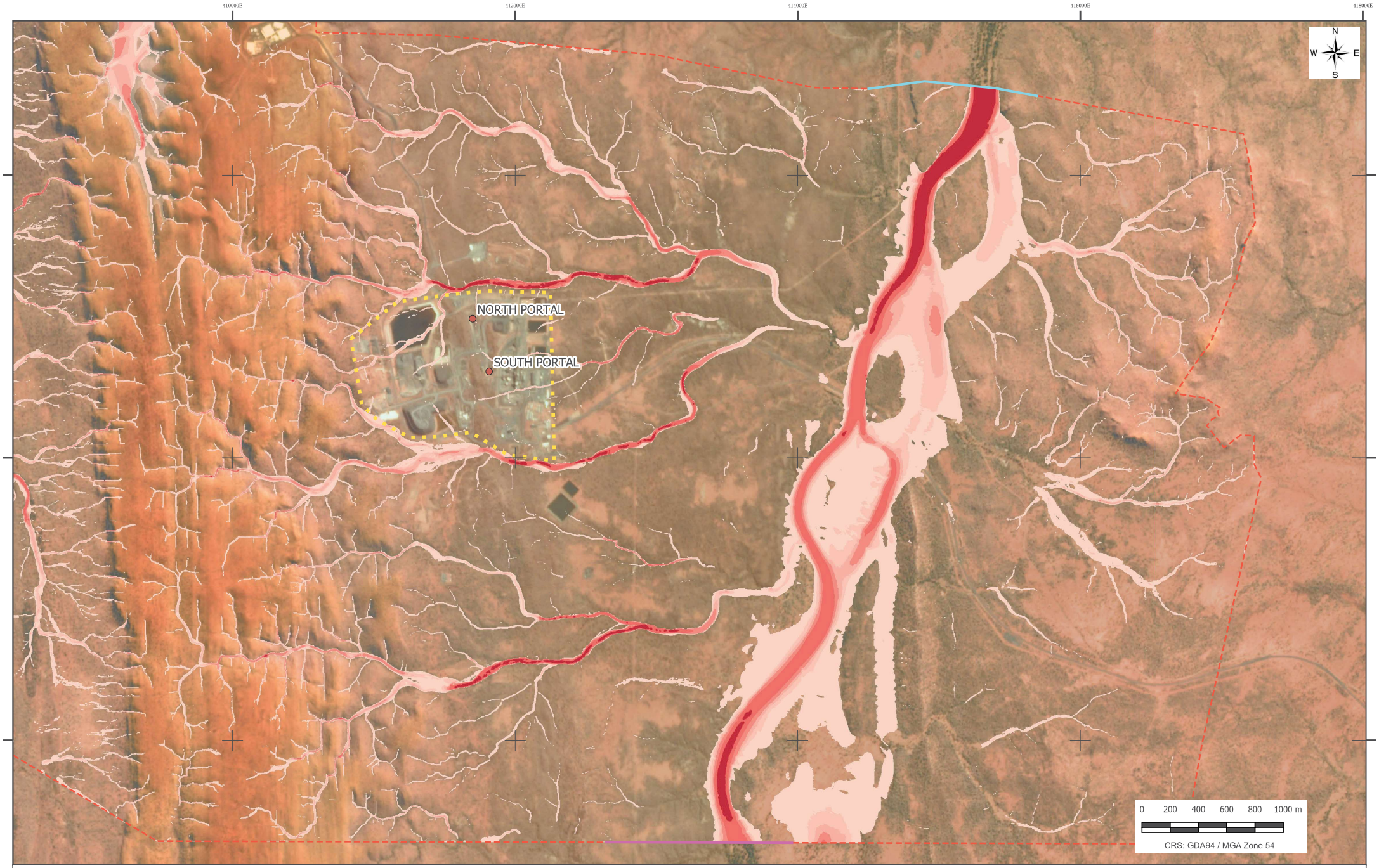
ATC WILLIAMS

FIGURE 009

108003-49

DATE: 2021-05-18

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LEGEND

- OUTFLOW BOUNDARY
- INFLOW BOUNDARY
- TUFLOW MODEL BOUNDARY
- PA EXTENT

ELEVATION (RL m)

170 275
205 310
240

MAXIMUM VELOCITY (m/sec)

0.3 - 0.6 0.8 - 1.0 > 2.5
0.6 - 0.8 1.0 - 1.5
0.6 - 0.8 1.5 - 2.5

MMG AUSTRALIA PTY LTD

DUGALD RIVER MINE
PROCESS AREA 0.1% AEP - MAXIMUM FLOOD VELOCITY

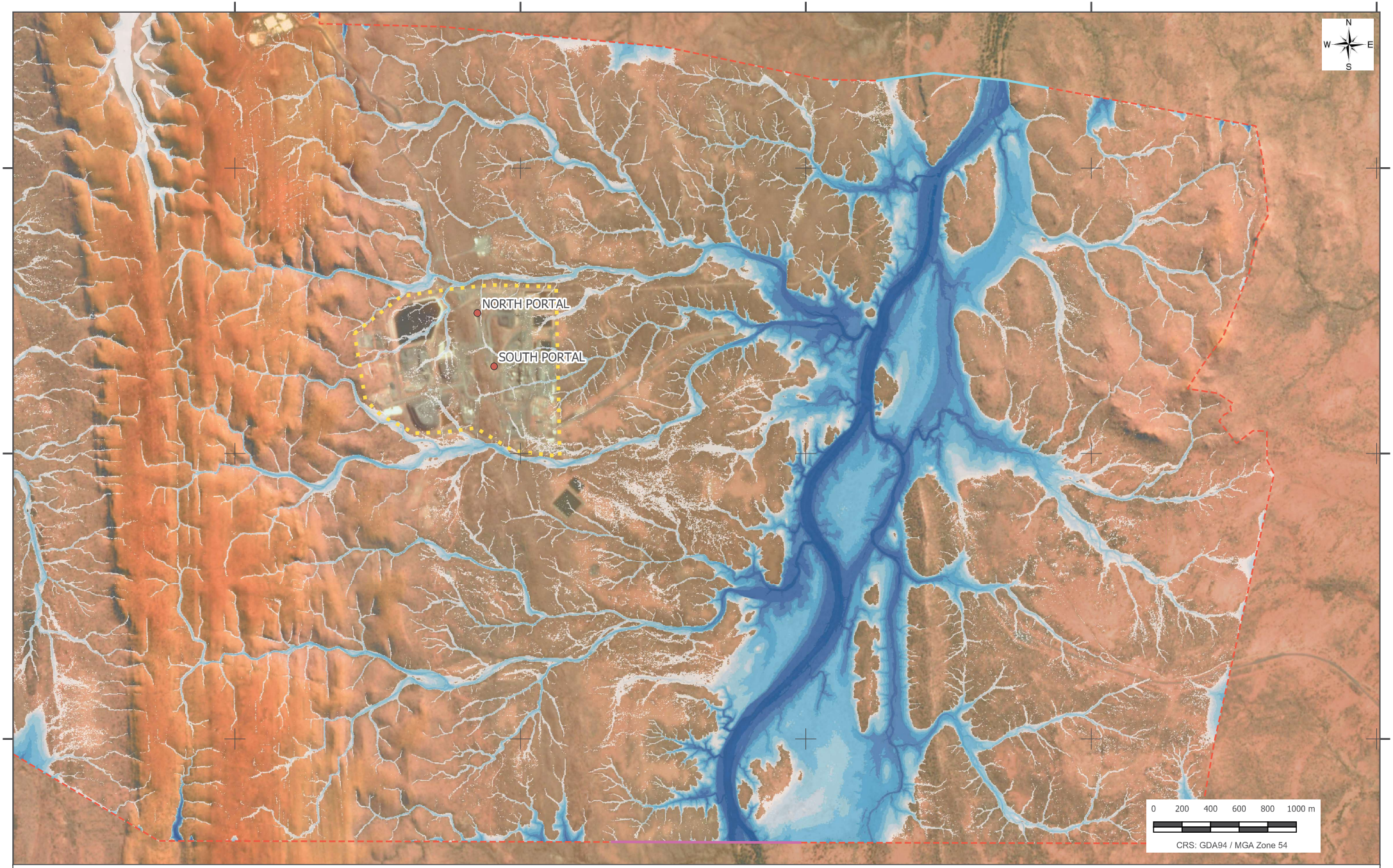
ATC WILLIAMS

FIGURE 010

108003-49

DATE: 2021-05-18

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LEGEND

- OUTFLOW BOUNDARY
- INFLOW BOUNDARY
- TUFLOW MODEL BOUNDARY
- PA EXTENT

ELEVATION (RL m)

170 275
205 310
240

MAXIMUM DEPTH (m)

0.3 - 0.5 1.5 - 2.5 5.0 - 7.5
0.5 - 0.8 2.5 - 3.5 > 7.5
0.8 - 1.5 5.0 - 7.5

MMG AUSTRALIA PTY LTD

DUGALD RIVER MINE
PROCESS AREA 1.0% AEP - MAXIMUM FLOOD DEPTH

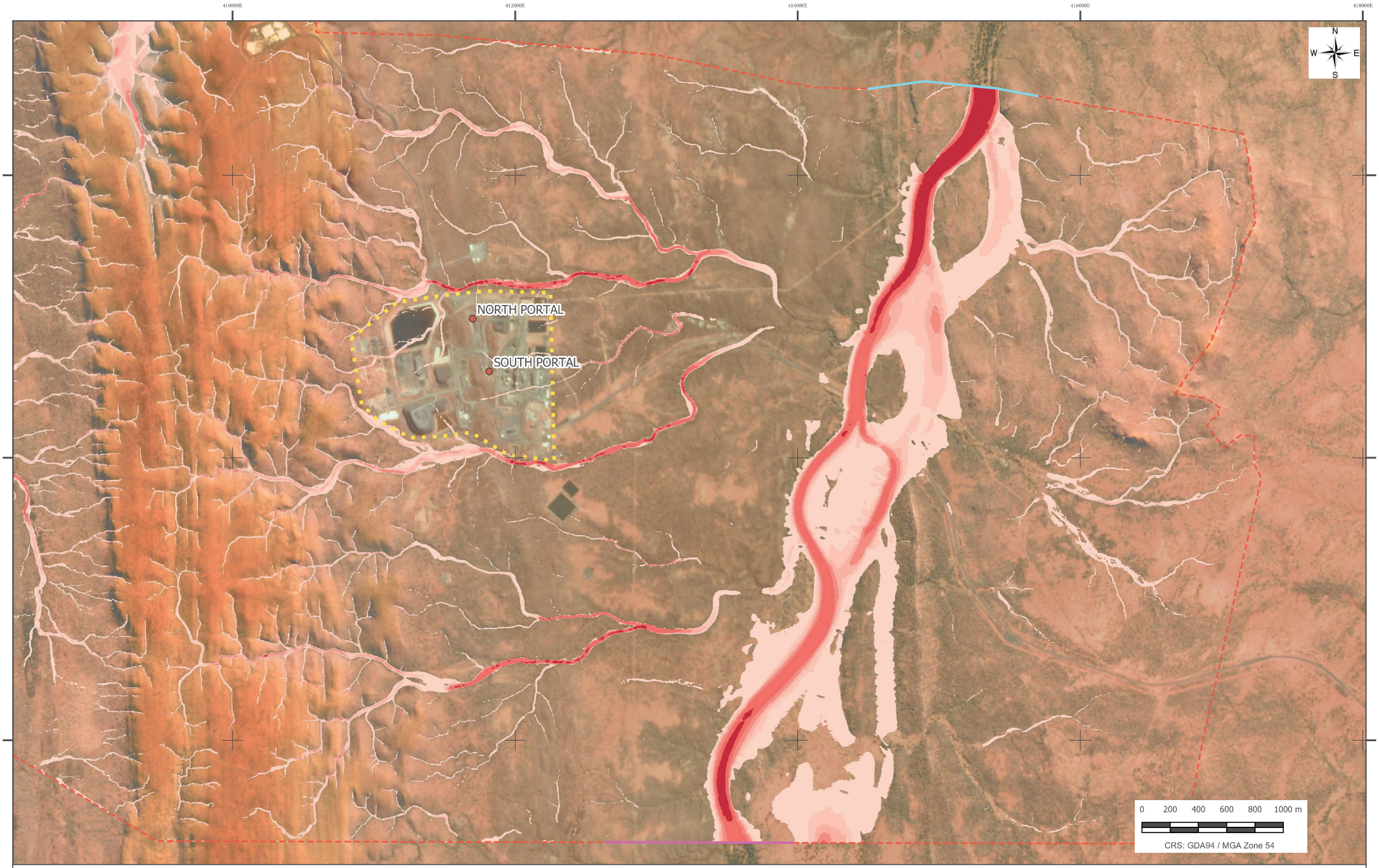
ATC WILLIAMS

FIGURE 011

108003-49

DATE: 2021-05-18

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LEGEND

- OUTFLOW BOUNDARY
- INFLOW BOUNDARY
- TUFLOW MODEL BOUNDARY
- PA EXTENT

ELEVATION (RL m)

170 275 205 310 240

MAXIMUM VELOCITY (m/sec)

0.3 - 0.6 0.8 - 1.0 > 2.5 0.6 - 0.8 1.0 - 1.5 0.6 - 0.8 1.5 - 2.5

MMG AUSTRALIA PTY LTD

DUGALD RIVER MINE
PROCESS AREA 1.0% AEP - MAXIMUM FLOOD VELOCITY

ATC WILLIAMS

FIGURE 012

108003-49

DATE: 2021-05-18

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APPENDICES

APPENDIX A PMP CALCULATIONS

TAILINGS.WATER.WASTE.

Generalised Short-Duration Method (GSDM)

LOCATION INFORMATION

Catchment Name	Dugald River Mine and TSF		*Reference: Generalised Short Duration Method (BOM, 2003)*	
Catchment Area	16.6 km²			
State	Qld			
Latitude	Longitude	Duration Limit	Prop Smooth	Prop Rough
-20.224	140148.000	6 Hrs	0%	100%

ELEVATION ADJUSTMENT FACTOR (EAF)

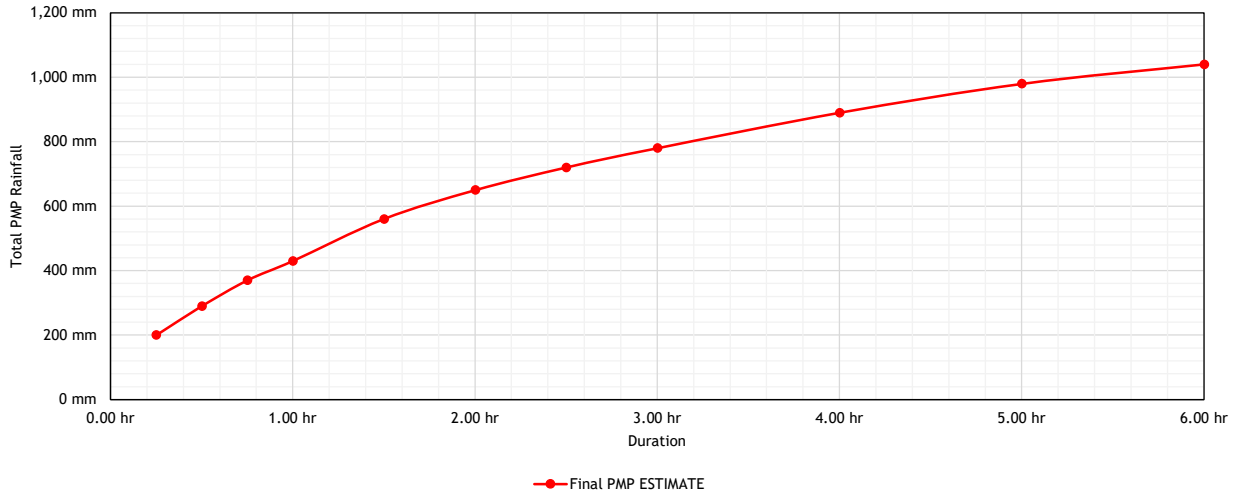
Mean Elevation at Site Location:	236 m	**EAF**	1

MOISTURE ADJUSTMENT FACTOR (MAF)

	MAF	0.960649

PMP VALUES (mm)

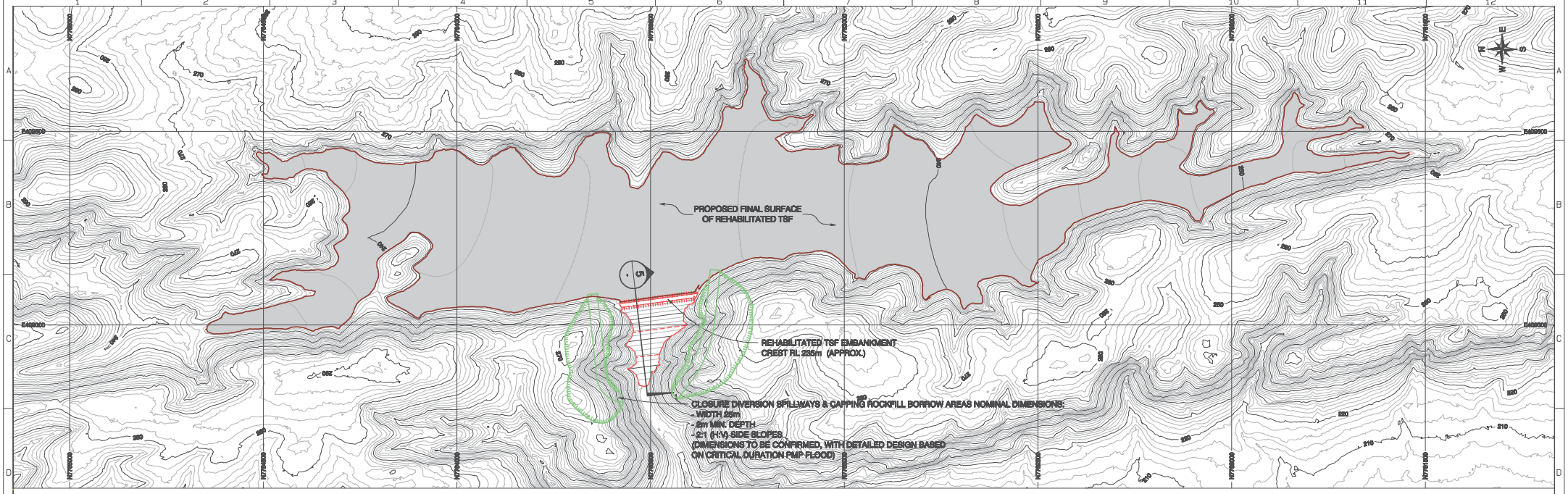
Duration (hours)	Initial Depth - Smooth (DS)	Initial Depth - Rough (DR)	PMP Estimate = (Ds x S + DR x R) x MAF x EAF	Rounded PMP Estimate (nearest 10 mm)
0.25 hr	203.1 mm	203.1 mm	195.1 mm	200 mm
0.50 hr	298.9 mm	298.9 mm	287.2 mm	290 mm
0.75 hr	381.2 mm	381.2 mm	366.2 mm	370 mm
1.00 hr	447.6 mm	447.6 mm	429.9 mm	430 mm
1.50 hr	511.2 mm	573.3 mm	550.7 mm	560 mm
2.00 hr	573.4 mm	670.2 mm	643.9 mm	650 mm
2.50 hr	610.2 mm	740.6 mm	711.5 mm	720 mm
3.00 hr	640.3 mm	807.7 mm	775.9 mm	780 mm
4.00 hr	708.8 mm	923.7 mm	887.4 mm	890 mm
5.00 hr	763.3 mm	1,014.6 mm	974.7 mm	980 mm
6.00 hr	808.6 mm	1,081.2 mm	1,038.6 mm	1040 mm



Dugald River Mine and TSF	**PMP ESTIMATES** **Short Duration** **GSDM**
ATC Williams www.atcwilliams.com.au perth@atcwilliams.com.au T +61 8 9213 1600	**Job No: 108003.49** **Date: 18/05/2021** **FIGURE 1**

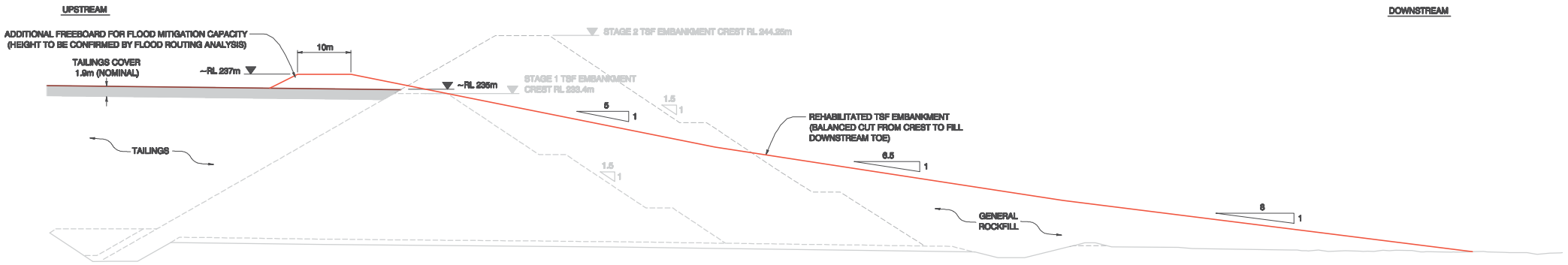
APPENDIX B DUGALD RIVER MINE TSF – CLOSURE CONCEPT

TAILINGS.WATER.WASTE.



FINAL CLOSURE PLAN

SCALE 1:10,000



SECTION 5

REHABILITATED TSF EMBANKMENT

SCALE 1:750

No.	DESCRIPTION	DATE	DRAWN	CHECKD	APPRD

SCALE AS SHOWN	
JOB No.	108003.20
DATE	22.02.16
DESIGN	CN
DRAWN	HR
CHECKED	
APPROVED	

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MMG DUGALD RIVER
TAILINGS STORAGE FACILITY

DESIGN REPORT
CLOSURE CONCEPT

FIGURE 15.1

CLIENT No.
CAD REF.
REV. 0
SHT SIZE A3
SHEET 1 OF 1

J:\2008\108003 Dugald River\18 Revised TSF Design\Terramodel\Dugald River Design Report Figures.pro (Terramodel) Thu 25 Feb 2016 15:26:52

Appendix G

Waste Rock Characterisation for the Dugald River Deposit



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For:

Minerals and Metals Group

Document No. 6412/934

Dugald River Project Qld

Assessment of the Geochemical Characteristics and ARD Potential of Waste Rock for the Dugald River Zinc, Lead & Silver Deposit

September 2010

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3: Speciation of sulphur forms in Dugald River waste rock

4: Elemental composition of Dugald River waste rock

5: Geochemical abundance indices for Dugald River waste rock

6: Water extractable elements in Dugald River waste rock

7: Acid extractable elements in Dugald River waste rock

8: Peroxide extractable elements in Dugald River waste rock

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1: Dugald River Project - Waste rock sampling program

2: Statistical summary of sulphur data for Dugald River waste rock

3: Statistical summary of ANC data for Dugald River waste rock

4: Statistical summary of NAPP data for Dugald River waste rock

5: Acid-base account plot for Dugald River waste rock

6: ARD classification plot for Dugald River waste rock

7: Acid buffer characteristics curve of Dugald River waste rock

(a) calc-silicate (#80448)

(b) mafic feldspar porphyry (#80424)

(c) lode waste (#80478)

(d) foot wall slate (#80430)

(e) foot wall limestone (#80436)

8: Sulphur speciation results for Dugald River waste rock

9: Kinetic NAG test profiles for Dugald River waste rock

(a) lode waste (#80454)

(b) lode waste (#80429)

(c) foot wall slate (#80443)

(d) hanging wall slate (#80483)

(e) foot wall slate (#80438)

10: Box plot showing the ratios of elemental concentrations in Dugald River waste rock relative to median soil composition

Figures (*continued*)

11: Statistical summary of extract assay data for water (w), acid (ac) and peroxide (ox) extractions tests on Dugald River waste rock

12: Plot of leachate pH for AARC column leach tests on Dugald River waste rock

13: Plot of sulphate concentrations in leachates from AARC column leach tests on Dugald River waste rock

14: Plot of calcium concentrations in leachates from AARC column leach tests on Dugald River waste rock

15: Statistical summary of AARC column leach assay data for samples comprising NAF Dugald River waste rock

16: Plot of Fe, Zn, Mn and Al concentrations in leachate from Column 3 containing a PAF waste mixture

Appendices (*after text*)

A: Acid forming characteristics of drill core samples from previous geochemical studies of Dugald River waste rock

B: Multi-element data and geochemical abundance indices for drill core samples from previous geochemical studies of Dugald River waste rock

- B-1 Multi-element data
- B-2 Geochemical abundance indices

C: Results of column leach tests involving Dugald River waste rock

- C-1 Acid forming characteristics of column leach samples
- C-2 Leachate composition for HW slate (Column 1)
- C-3 Leachate composition for FW limestone (Column 2)
- C-4 Leachate composition for PAF rock mixture (Column 3)
- C-5 Leachate composition for FW slate (Column 4)
- C-6 Leachate composition for HW calc-silicate (Column 5)
- C-7 Leachate composition for HW cal-silicate & mafic feldspar porphyry (Column 6)
- C-8 Leachate composition for HW mica schist (Column 7)

1.0 Introduction

This report presents the results and findings of a geochemical assessment of drill core samples representing waste rock that will be produced at the Dugald River project located near Cloncurry in the north west region of Queensland. The study was commissioned by Minerals and Metals Group (MMG) as part of environmental studies being undertaken for the project.

The project will involve conventional underground mining of a stratabound, massive zinc/lead deposit hosted within a black slate environment and copper mineralisation in the adjacent hanging wall. The Dugald River deposit is estimated to contain 53 million tons of zinc/lead ore and 3.4 Mt of copper ore which will be mined over a 23 year mine life. Ore will be processed on site using conventional flotation technology, producing zinc, lead and copper concentrates for shipment and tailings that will be discharged to a tailings storage facility located to the west of the Knapdale Ranges. There will also be approximately 7 Mt of waste rock produced, mainly during the development of the decline.

Seven waste lithologies will be intercepted during mining of the Dugald River deposit. They are calc-silicate, white mica schist, mafic feldspar porphyry, hanging wall slate, mineralized lode waste, footwall slate, and footwall limestone. Calc-silicate, white mica schist and mafic feldspar porphyry will only be intercepted if mining of the copper ore is undertaken. The results of geochemical testing carried out by AARC (2008) indicated that most waste should be non-acid forming (NAF) but that some potentially acid forming (PAF) rock may be encountered, primarily as lode waste but also within the hanging wall and foot wall slate.

Sphalerite and galena are the main primary sulphides in Dugald River ore but pyrrhotite and pyrite also occur and are likely to be the main sulphide forms in mineralised waste rock. The presence of pyrrhotite and pyrite are a potential concern given that they will be subject to oxidation processes if the rock is exposed to atmospheric conditions. The potential for acidification of sulphidic rock will depend on both the sulphide content and the magnitude of any inherent neutralising capacity within the rock. Sulphidic rock that has little acid neutralising capacity (ANC) could be a potential source of *acid rock drainage* (ARD) and it is essential that such waste is identified and managed in a manner that limits the potential for sulphide oxidation and/or formation of acid conditions.

It is expected that drainage from non-acid forming rock should remain circum-neutral, nevertheless assessment of the potential to generate drainage with elevated salinity is necessary, as calcium and magnesium sulphates may be mobilised from non-acid forming rock by the combination of oxidation and neutralisation reactions. Such drainage, commonly referred to as *Neutral Mine Drainage* may also have measurable concentrations of trace elements (*e.g.* metals and metalloids) that are sparingly soluble at circum-neutral pH.

In recognition of the likelihood of some PAF waste rock and also the potential for generation of sulphate-rich neutral mine drainage, EGi was commissioned by MMG to review the findings of previous geochemical studies and to undertake further detailed assessment of the geochemical characteristics of samples representing waste rock that will be produced during the development of the Dugald River underground

mine. The main objectives of the geochemical testing program carried out on these samples were as follows:

- To determine the range of acid forming characteristics of the major waste rock units within the Dugald River deposit and to provide sufficient data for estimating the incidence of acid generating waste rock types within the proposed mine.
- To assess the forms and reactivity of the sulphide mineralisation within major waste rock units under controlled laboratory conditions, and to make preliminary estimates of the likely geochemical behaviour and lag times for acidification to occur under field conditions.
- To assess the reactivities of any carbonate mineralisation within major rock units that might delay or mitigate the generation of ARD.
- To identify any elemental enrichments within major rock units that might be environmentally significant and assess the potential for mobilisation of environmentally important elements which could impact on the quality of pit water and waste dump seepage.
- To assess the leaching potential of environmentally important elements from both PAF and NAF waste rock types and to assess the geochemical implications for mine water chemistry and the need for long term management of ARD from the waste dump and the final pit.

This report presents the results of the laboratory testing program carried out by EGi on drill core samples supplied by MMG and presents the main findings and implications of the current and previous geochemical investigations in relation to geochemical characteristics of waste rock and need for the selective handling and disposal of materials that could be problematic in respect of acid generations or metals leaching.

2.0 Previous Geochemistry Studies

There have been two previous geochemical studies of waste rock for the Dugald River project.

The first study was of a preliminary nature carried out by AGC Woodward-Clyde[1] as part of the pre-feasibility baseline environmental studies commissioned by Minenco Pty Limited in 1991. This study involved the assessment of the acid forming potential of 18 drill core samples representing waste rock and another five samples representing ore grade material within the Zn/Pb lode. The samples were taken from seven drill holes and the lithologies represented by the waste samples were hanging wall slate (6 samples), footwall slate (8) and limestone (4).

A second more detailed investigation of waste rock geochemistry was commissioned by OZ Minerals Australia Limited in 2008. This study was carried out by AARC[2] and included static geochemical analysis of 121 drill core samples and also establishment of a series of kinetic leach column tests. The samples were taken from 12 diamond drill holes and were representative of the following lithologies: calc-silicate (23 samples), mafic feldspar porphyry (3), white mica schist (13), hanging wall slate (38), lode waste (10), footwall slate (16) and foot wall limestone (18).

The acid forming characteristics of drill core samples assessed in the 1991 and 2008 studies are summarised in Appendix A. The testing programs for both studies involved measurements of existing pH, total sulphur content, acid neutralising capacity (ANC), and net acid producing potential (NAPP). The 2008 study also included measurement of net acid generation (NAG) capacity. Overall, a total of 139 samples representing waste rock were assessed for acid forming potential.

Multi-element assays were also carried out on all samples in the 1991 study and half the samples in the 2008 study. Samples in both the 1991 and 2008 studies were analysed for As, Cd, Co, Cu, Hg, Pb, S and Zn. The 1991 samples were also assayed for Bi and Sb, whilst the 2008 samples were also assayed for Ba, Be, Cr, Mn, Ni and V. The multi-element data for the previous studies are given in Appendix B.

The preliminary findings of previous geochemical investigations were as follows:

- The initial pHs of the majority of samples were circum-neutral, suggesting that drainage from freshly mined rock will likely be neutral to alkaline.
- Most samples were enriched to some extent with sulphur, but most samples also had high to very high ANCs and were classified as non-acid forming.

1 AGC Woodward Clyde (1971). Preliminary Waste Characterisation. Report prepared for Minenco Pty Limited as part of the Dugald River Project - Prefeasibility Environmental Baseline Studies, July 1991.

2 AustralAsian Resource Consultants (2008). Waste Rock Characterisation Report, Dugald River Project. Prepared for OZ Minerals Australia Limited, September 2008.

- Sulphur contents were distributed as follows:
    - 30% low (<0.01 to 0.3 %S)
    - 20% low to moderate (0.3 to 1.0 %S)
    - 50% high to very high (> 1%S)
- ANCs were distributed as follows:
    - 14% low (<10 kg H_2SO_4/t)
    - 28% low-moderate (10 to 50 kg H_2SO_4/t)
    - 58% high to very high (>50 kg H_2SO_4/t)
- Based on the NAPP and (when available) NAG test results, 95 samples (68%) were classified as non-acid forming and 40 samples (29%) were classified as potentially acid forming. The classifications of the other four samples were uncertain, but it is EGi's evaluation of the results that two of the four were more likely to be NAF and the other two more likely PAF.
- The main lithologies in which PAF samples occurred were lode waste (8 samples), hanging wall slate (22 samples), and pyritic foot wall slate (3 samples).
- In addition to elevated sulphur contents, many of the lode, hanging wall slate and footwall slate samples were significantly enriched to varying extents in one or more environmentally important elements that include arsenic, cadmium, copper, lead, mercury and zinc.
- Based on the results of the static testing program and the expected lithological distribution of waste rock at that time it was estimated by AARC (2008) that about one-quarter of total waste mined could be PAF. AARC(2008) recommended that, where possible, PAF waste should be prioritised for disposal to underground voids, whilst PAF waste rock remaining on the surface at closure would need to be fully encapsulated within NAF waste rock with high to very high ANC (*e.g*. limestone, calc-silicate and white mica schist).

3.0 Testing Program

3.1 Sample Selection

Seventy-two drill core samples were selected by MMG for the current geochemical program. Figure 1 shows the sample locations on a long-section through the proposed underground mining area.

When combined with samples from the two previous geochemical investigations carried out by AGC-Woodward Clyde (1991) and AARC (2008) there were 211 samples representing Dugald River waste rock. The samples were distributed between the seven lithologies as follows:

	AGC-WC (1991)	AARC (2008)	EGI (2010)	Combined
• Calc-silicate	0	23	8	31
• Mafic feldspar porphyry	0	3	4	7
• White mica schist	0	13	4	17
• Hanging wall slate	6	38	8	52
• Lode waste	0	10	8	18
• Footwall slate	8	16	20	44
• Footwall limestone	4	18	20	42

The guideline on *Assessment and Management of Acid Drainage* prepared by the Queensland Government, Department of Environment and Resource Management (DERM)[3] provides minimum numbers of samples that should be collected from each rock type based on the tonnage that will be mined. The tonnages of the various waste rock units generated by the Dugald River zinc/lead underground development will be 0.46 Mt of hanging wall slate, 0.66 Mt of lode waste, 2.88 Mt of footwall slate, and 3.11 Mt of footwall limestone. The corresponding minimum sample numbers for these tonnages based on interpolation of the DERM guideline are 18, 21, 43 and 45, respectively. Therefore, over the three geochemical assessment programs the numbers of samples tested were comparable to the DERM guideline.

[3] DERM (1995). Assessment and Management of Acid Drainage. Queensland Department of Environment and Resource Management, January 1995.

The guideline indicates the minimum number of samples collected from each rock/overburden type during initial sampling should generally be as follows; <0.01 Mt = minimum of 3, <0.1 Mt = minimum of 8, < 1 Mt = minimum of 26, and <10 Mt = minimum of 80. These discrete values can be interpolated using the formula $y=25.9x^{0.48}$, where y is the minimum number of samples and x is the tonnage (Mt) of the particular rock unit.

3.2 Sample Preparation

The samples for the current geochemical program were supplied as drill core pieces, with each sample typically weighing 1-2 kg. Following inspection of the samples they were forwarded to Sydney Environmental and Soil Laboratory Pty Ltd where sample preparation was carried out. Sample preparation included crushing to less than 4 mm size by conventional jaw crusher, then milling of a 200g split to less than 75 micron using a zirconia pulverising bowl. The crushed and pup samples were subsequently returned to EGi's laboratory for geochemical analysis.

3.3 Static Testing Program

The static testing program for the 72 drill core pulps included assessment of the same range of parameters as were determined in the 1991 and 2008 geochemical studies. They were:

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

The NAPP and NAG test results were reviewed then some samples were selected for more detailed analysis to either clarify the ARD classifications, assess sulphide or carbonate reactivity, and identify elemental enrichments and their potential leachability. The detailed testing of selected drill core samples included one or more of the following:

- Sulphur forms - 15 samples
- Sequential NAG test - 2 samples
- Kinetic NAG tests - 5 samples
- Acid buffer characteristic curves - 5 samples
- Solids multi-element analyses - 15 samples
- Water extractable elements - 15 samples
- Acid extractable elements - 15 samples
- Peroxide extractable elements - 15 samples

In addition to the static testing reported herein, MMG is currently assessing commissioning long-term column leach tests involving some waste rock samples discussed in this report.

3.4 Laboratory Procedures

Existing pH and Conductivity

The pH and electrical conductivity of each sample were measured on a suspension comprising 30 g of crushed (minus 4 mm) sample in 60 mL of deionised water (*i.e.* 1:2 solid:water ratio), following at least 1 hour of equilibration.

Total Sulphur Analyses

The total sulphur content of each sample was determined by the Leco furnace method. Sulphur assays were carried out by Sydney Environmental & Soil Laboratory Pty Ltd under a quality assurance system certified as complying with ISO 9002.

Maximum Potential Acidity

The maximum potential acidity (MPA) is the amount of acid that theoretically could be generated by a sample if all the sulphur occurred as reactive pyrite and there was complete oxidation of the pyrite according to the following reaction:

$$FeS_2 + 15/4\ O_2 + 7/2\ H_2O \Rightarrow Fe(OH)_3 + 2\ H_2SO_4$$

The MPA of each sample, expressed as kg H_2SO_4/t, and was calculated from the %S content using a conversion factor of 30.6.

Acid Neutralising Capacity

The acid neutralising capacity (ANC) of each sample was determined using the Sobek Method. The method provides a direct measurement of the amount of acid that can be consumed by carbonate and other minerals within a rock sample, and involves reacting a sample with a known amount of acid at between pH 1 to 2 for approximately 1 to 2 hours. The residual acidity after reaction was back-titrated to determine the amount of acid consumed by the sample, expressed in terms of kg H_2SO_4/t.

Net Acid Producing Potential

The NAPP is the amount of acid that potentially can be produced by a sample after allowance for the ANC. It is calculated by subtracting the ANC value from the MPA value. If the NAPP is negative then it is likely that the material has sufficient inherent buffer capacity to prevent acid generation. Conversely, if the NAPP is positive then the material may be acid generating.

Net Acid Generation

NAG is a direct oxidation procedure for estimating the acid forming potential of a sample. The NAG test involved reaction of 2.5 g sample with 250 mL of 15% hydrogen peroxide to rapidly oxidise any sulphide minerals present. Both acid generation and acid neutralisation occur simultaneously during the NAG test,

hence the end result represents a direct measurement of the net amount of acid that a sample can generate. If the sample after reaction had a pH less than 4.5 (*i.e.* NAGpH<4.5) then it was considered to be acid forming and the actual amount of acidity generated was subsequently determined by titration of the mixture.

Sequential NAG Tests

With high sulphur samples the oxidation of sulphides is often not completed in a single stage NAG test, and a sequential multi-stage procedure is needed to ensure all sulphides are fully oxidised. In the sequential NAG test a 2.5 g sub-sample of tailings is reacted several times with 250 mL aliquots of 15% hydrogen peroxide. At the end of each stage, the sample is filtered to separate the solids and NAG liquor. The NAG liquor is assayed for pH and acidity, as per a standard NAG test. The solids are recovered and the oxidation process continued using another aliquot of hydrogen peroxide. The overall NAG capacity of the tailings is determined by summing the individual acid capacities from each stage.

Kinetic NAG Tests

Kinetic NAG tests were also carried out on selected tailings samples to assess the reactivity of the sulphides present and to provide an indication of the likely lag period for acid generation to occur under oxidising conditions. The kinetic NAG test is an accelerated oxidation procedure wherein a sample is reacted with hydrogen peroxide (as per the standard NAG test described in Section 2.2) and the reaction kinetics are continuously monitored by measuring the pH and temperature of the NAG solution.

Acid Buffer Characteristic Curve

An acid buffer characteristic curve was produced by slowly titrating of a sample with dilute HCl acid over a period of 16 to 24 hours. This titration method provides a far less aggressive treatment of a sample than that applied in the ANC method and hence provides a measure of the buffering provided by more soluble carbonates within a sample.

Multi-Element Analysis of Solids

The multi-element analysis of solids was carried out by Australian Laboratory Services (ALS) in Brisbane using NATA registered procedures. Mercury was assayed using an aqua regia digestion to ensure minimal volatilisation followed by analysis using inductively coupled plasma mass spectrometry. A suite of 34 other elements were assayed using a multi-acid digestion (*i.e.* hydrofluoric, nitric, perchloric and hydrochloric acids) followed by analysis using inductively coupled plasma optical spectrometry.

Water Extractable Elements

The water-soluble components within a sample were determined by extraction of 25 g of crushed (minus 4 mm) sample in 500 mL of deionised water (*i.e.* a solid:liquor ratio of 1:20) for 24 hours in accordance with the Australian Standard Leaching Procedure (ASLP). The extraction containers were agitated on an end-over-end shaker throughout the equilibration period, and at completion the pH and electrical conductivity of each

extract were recorded. The liquor fraction was then filtered through a 0.45 micron membrane filter, preserved with a few drops of high purity HNO_3 acid, then despatched to Australian Laboratory Services (ALS) in Sydney for multi-element analysis.

Acid Extractable Elements

The acid-soluble components within a sample were determined in accordance with the ASLP but using dilute sulphuric acid as the extractant. The extraction involved equilibration of 25 g of crushed (minus 4 mm) sample in 500 mL of 0.05 M H_2SO_4 (*i.e.* a solid:liquor ratio of 1:20) for 24 hours with constant agitation. The pH and electrical conductivity of each extract were recorded, then the liquor fraction was filtered through a 0.45 micron membrane filter, preserved with a few drops of high purity HNO_3 acid, then despatched to Australian Laboratory Services (ALS) in Sydney for multi-element analysis.

Peroxide Extractable Elements

Elements that may be mobilised as a consequence of sulphide oxidation were determined by reacting 2.5 g of sample with 250 mL of 15% hydrogen peroxide, as per the NAG test procedure described above. Following reaction of the sample the NAG liquor was re-adjusted to 250 mL with deionised water, then a sub-sample was filtered through a 0.45 micron membrane filter, preserved with a few drops of high purity HNO_3 acid, then despatched to Australian Laboratory Services (ALS) in Sydney for multi-element analysis. A second sub-sample was titrated as per the normal NAG procedure to determine the amount of any acidity generated during the test.

4.0 Acid Forming Potential of Dugald River Waste Rock

The acid forming characteristics of the 72 drill core samples assessed by EGi are summarised in Table 1 with the samples sorted according to the drill hole number. The same data are also presented in Table 2 with the samples sorted according to lithology and ARD classification.

As the procedures used to assess these samples were the same as those used in previous geochemical investigations by AGC-Woodward Clyde (1991) and AARC (2008), the three datasets were combined to allow a more comprehensive review. This provided an overall total of 211 samples representing waste rock that were distributed between the seven lithologies as follows:

	Sample Count	Percent of Total
• Calc-silicate	31	~ 15%
• Mafic feldspar porphyry	7	~ 3%
• White mica schist	17	~ 8%
• Hanging wall slate	52	~ 25%
• Lode waste	18	~ 9%
• Footwall slate	44	~ 21%
• Footwall limestone	44	~ 20%

4.1 Sulphur Content

The sulphur content distributions for each of the seven lithologies are shown graphically in Figure 2. The sulphur content range and median content for each lithology were as follows:

	%S Median	%S Range
• Calc-silicate	<0.01	<0.01 - 1.57
• Mafic feldspar porphyry	<0.01	<0.01 - 0.77
• White mica schist	0.03	<0.01 - 0.29
• Hanging wall slate	1.8	<0.01 - 14.4
• Lode waste	6.4	1.2 - 16.6
• Footwall slate	1.1	0.45 - 14.6
• Footwall limestone	1.0	0.1 - 2.12

The sulphur contents of samples representing calc-silicate, mafic feldspar porphyry and white mica schist were generally low, with 87% of the samples from these three lithologies containing less than 0.1 %S, and only a few samples exceeding 0.3 %S.

In contrast, the sulphur contents of samples representing lode waste, hanging wall and footwall slate, and footwall limestone were typically in the moderate to high range. Not surprisingly, sulphur enrichment is particularly high in lode waste. The median sulphur content for lode waste samples was 6.4 %S. Furthermore, one-third of the lode samples had sulphur contents exceeding 10 %S.

On average, the extent of sulphur enrichment in hanging wall and footwall slate was less than for lode waste but nevertheless still significant. The median sulphur contents for the two slate lithologies were 4.1 and 1.8 %S, respectively and approximately one-third of the slate samples had sulphur contents exceeding 2 %S.

Almost all of the footwall limestone samples were also enriched but concentrations were typically confined to between 0.5 to 1.5 %S. The median sulphur content for limestone samples was 1.0 %S.

4.2 Acid Neutralising Capacity

The ANC distributions for each of the seven lithologies are shown graphically in Figure 3. The median, range and percentage of samples with ANCs in the high to very high range (*i.e.* ANC exceeding 100 kg H_2SO_4/t) were as follows:

	Median (kg H_2SO_4/t)	Range (kg H_2SO_4/t)	Percent with ANC>100 kg H_2SO_4/t
• Calc-silicate	169	9 - 688	81 %
• Mafic feldspar porphyry	79	21 - 401	43 %
• White mica schist	32	9 - 252	24 %
• Hanging wall slate	31	5 - 455	27 %
• Lode waste	13	5 - 398	28 %
• Footwall slate	108	11 - 548	55 %
• Footwall limestone	235	10 - 552	90 %

The results indicate wide ranging ANC values for all lithologies. As might be expected, the majority of footwall limestone samples had high to very high ANCs, as did most of the calc-silicate samples and more than half of the footwall slate samples.

The neutralising capacities of the hanging wall slate and the white mica schist samples were, on average, noticeably lower with median ANCs for the two lithologies of 31 and 32 kg H_2SO_4/t, respectively. Nevertheless around one-quarter of the samples from each lithology had ANCs exceeding 100 kg H_2SO_4/t.

The ANCs of lode waste samples were bi-modal in distribution. Thirteen of the 18 lode waste samples had low ANCs in the range 5 to 34 kg H_2SO_4/t. The other five lode waste samples had very high ANCs between 208 and 398 kg H_2SO_4/t.

4.3 Net Acid Producing Potential

The calculation of NAPP represents the balance between a samples acid potential and neutralisation capacity. This balance is sometimes also referred to as an acid-base account. The acid potential is related to the presence of sulphides, and in this study was indirectly determined from the total sulphur content, assuming that all sulphur occurred as pyrite. This is a conservative assumption, hence the acid potential can be regarded as the maximum potential acidity (MPA) that could be produced by a sample.

The NAPP represents the net acidity after allowance for the neutralising capacity within a sample, as determined directly using the standard Sobek method (as discussed Section 3.4). The difference between the two components represents the net acid producing potential or NAPP, which. The NAPP is expressed in terms of weight of acid generation per unit weight of rock (kg H_2SO_4/t) and may be positive or negative depending on the relative magnitudes of the respective acid and neutralising potentials.

The NAPP distributions for each of the seven lithologies are shown graphically in Figure 4. The median, range and percentage of samples with positive NAPPs were as follows:

	Median (kg H_2SO_4/t)	Range (kg H_2SO_4/t)	Percent with +ve NAPP
• Calc-silicate	-161	-688 to -9	0 %
• Mafic feldspar porphyry	-72	-401 to -21	0 %
• White mica schist	-31	-246 to 0	0 %
• Hanging wall slate	10	-423 to 421	58 %
• Lode waste	104	-187 to 500	78 %
• Footwall slate	-71	-512 to 390	20 %
• Footwall limestone	-195	-513 to 18	2 %

The results indicate that with samples representing calc-silicate, mafic feldspar porphyry, white mica schist and footwall limestone the neutralising capacity exceeds the acid potential of contained sulphides, in many cases by a large amount (*i.e.* samples were strongly NAPP negative).

The NAPPs of samples representing lode waste and hanging wall and footwall slate varies widely from strongly negative through to strongly positive. The majority of footwall slate samples were NAPP negative, lode waste samples were predominantly NAPP positive, whilst hanging wall slate samples relatively evenly divided.

Figure 5 shows an acid-base account plot for the combined data set. The acid-base account plot illustrates the relationship between the sulphur content (and hence MPA) of a sample and its ANC. This type of plot not only provides an indication of the acid forming potential of a sample but also illustrates the relative balance between the two parameters.

4.4 ARD Classification

The ARD classifications of the 18 waste rock samples previously tested by AGC-Woodward Clyde (1991) were based solely on NAPP values. For all other samples, the ARD classifications were assigned on the basis of both the NAPP value (as discussed above) and the sample's net acid generation (NAG) capacity. The latter was determined directly by reaction of the sample with hydrogen peroxide. A sample is considered to have a positive NAG capacity if it acidifies to pH 4.5 or less, in which case the amount of acid generated[4] is determined by titration. Because the NAPP and NAG values are determined independently of each other, the combination of the NAPP and NAG results provides greater certainty to the classification.

The ARD classification criteria were as follows:

- ***Non-Acid Forming*** *(NAF)* - A sample was considered to be NAF if it had a negative NAPP and the sample did not acidify to any significant extent when oxidised with peroxide in the NAG test (*i.e.* NAG=0 or NAGpH≥4.5). Although sulphides may be present in such samples, the inherent ANC is generally sufficient to neutralise any acid that might have been produced by sulphide oxidation.

- ***Potentially Acid Forming*** *(PAF)* - A sample was considered to be PAF if the NAPP and NAG were both positive. The exposure of such rock to atmospheric conditions is likely to result in sulphide oxidation, which in turn could result in tailings acidification.

- **Uncertain** *(UC)* - With some samples there was a disparity between the NAPP and NAG test results, and in such cases an *uncertain* (UC) classification was assigned. A disparity may occur if the NAPP is negative but the sample acidifies to less than pH 4.5 in the NAG test, or when the NAPP is positive but it does not acidify under NAG test conditions. The former may occur when the ANC within a sample is not readily available, and the latter may occur when some sulphur occurs as sulphate or as sulphides that do not generate acid when oxidised. The ARD classification considered most likely was indicated in brackets *e.g.* UC(NAF) or UC(PAF).

Figure 6 shows an ARD classification plot for the combined dataset, excluding the 18 samples from the AGC-Woodward Clyde (1991) study which did not include NAG testing. The ARD classification plot illustrates the concurrence of the NAPP and NAG test results. Clearly, the majority of samples plot either in the upper left quadrate *(i.e.* negative NAPP and NAGpH≥4.5) signifying samples were NAF, or in the lower right quadrate (positive NAPP and NAGpH<4.5) signifying samples were PAF. There were only five samples (four from the AARC study and one sample in the current EGi study) that could not be definitively classified due to conflicting NAPP and NAG test results. Tentative classifications were assigned as follows:

- AARC (2008) White mica schist (DR342, 272.5-273m) likely PAF (*but low capacity only*)
- AARC (2008) Hanging wall slate (DR346, 410-410.5m) likely NAF
- AARC (2008) Hanging wall slate (DR315, 84.5-85m) likely PAF
- AARC (2008) Footwall slate (DR342, 424-425m) likely PAF
- EGi (2010) Lode waste (DR379 631-631.5m) likely NAF (*based on seq NAG test*)

[4] Note: A sample may have a positive, zero or negative NAPP, but the NAG value can only be positive if acidification (i.e. NAGpH≤4.5) occurs, or zero if there is no acidification in the NAG test.

The last three samples on this list typically had high sulphur contents, high ANCs and strong positive NAPPs but they did not acidify when oxidised with peroxide in the NAG test. With the two AARC (2008) samples it is possible that the absence of acidification in the single-stage NAG tests was associated incomplete sulphide oxidation, which is a common occurrence with samples where the sulphur content and ANC are both high. As this possibility could not be confirmed, both samples were conservatively classified as PAF based on the positive NAPP results.

In the case of the one *uncertain* sample in the current study a follow-up sequential NAG test was carried out by EGi to verify the classification. Ten sequential stages of oxidation were carried to ensure complete sulphide oxidation. In all stages the pH of the NAG liquor remained circum-neutral. Therefore, although the classification remains uncertain, the results of the sequential NAG test suggest that the sample was more likely to be NAF.

After allowing for these tentative classifications, the NAF/PAF distributions for each of the seven lithologies were as follows:

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

The main points to note in relation to acid forming characteristics are as follows:

Calc-silicate
- negligible sulphur and high to very high ANC
- virtually all likely to be NAF and most will have a large excess of neutralising capacity due to high carbonate content.

Mafic feldspar porphyry
- low sulphur and moderate to high ANC
- a relatively small number of samples tested but results suggest waste rock from this lithology will be NAF, most with a considerable excess of neutralising capacity.

White mica schist
- low sulphur and variable ANC (from low to high)
- results suggest waste rock from this lithology will predominantly be devoid of sulphur and hence will be NAF, but there is a possibility of some material with low ANC (<10 kg H2SO4/t) which has slightly elevated sulphur (~0.3 %S) that could be PAF, albeit with a low capacity for acid generation.

Hanging wall slate

- moderate to high sulphur content and variable ANC
- results indicate a major portion of waste rock from this lithology will be PAF, some with a very high capacity for acid generation. There will also be some NAF rock, which is primarily distinguished by having high to very high ANC.

Lode waste

- high to very sulphur content and variable ANC
- majority of mineralised waste within the lode will be PAF with a very high capacity for acid generation. Only lode waste with very high ANC (*i.e.* >200 kg H_2SO_4/t) will be NAF.

Footwall slate

- moderate to high sulphur content and moderate to high ANC
- results suggest that footwall slate will be predominantly NAF but some footwall slate with low ANC is likely to be PAF.

Footwall limestone

- moderate sulphur content and moderate to high ANC
- results suggest virtually all footwall limestone is likely to be NAF and will have a large excess of neutralising capacity.

5.0 Reactivity of Carbonate Mineralisation within Dugald River Waste Rock

Many of drill core samples tested had high acid neutralising capacities. This was particularly the case for samples representing calc-silicate and footwall limestone, but also included samples from each other lithologies. Overall, approximately 54% of samples had ANCs greater than 100 kg H_2SO_4/t, and around half of these had ANCs exceeding 200 kg H_2SO_4/t.

In this study and the previous geochemical studies of Dugald River waste rock the ANCs of drill core samples were determined using the Sobek method. As described in Section 3.4, the Sobek method involves measurement of acid consumption by a sample under relatively strong acid conditions, typically around pH 1 to 2. The method therefore represents an aggressive treatment of the sample and accounts for buffer capacity provided not only by the more readily-available carbonate minerals such as calcite and dolomite but also less reactive forms such as ferroan dolomite, siderite, and some clay minerals.

The following five samples were selected for further testing to define the reactivity of the mineralisation responsible for the ANC under circum-neutral and weak acid conditions:

MMG / EGi Codes	Lithology	Sulphur (%S)	ANC (kg H_2SO_4/t)
80448 / 40886	Calc-silicate	1.57	210
80424 / 40862	Mafic feldspar porphyry	0.77	79
80478 / 40916	Lode waste	2.38	219
80430 / 40868	Footwall slate	1.15	120
80436 / 40874	Footwall limestone	1.06	462

Each sample was slowly titrated with dilute H_2SO_4 over a period of about 18 to 24 hours to produce an acid buffer characteristic curve (ABCC). The slow acid addition represents a milder treatment of a sample than that applied in the standard Sobek method. One advantage of the buffer curve is that it can be used to identify if there is any carbonate mineralisation that can buffer the sample at around neutral pH, which is usually required to produce a substantial lag phase and which is essential for maintaining low metal solubilities.

The buffer curves for the five samples are given in Figures 7(a) to 7(e), respectively. All five samples produced well defined plateaus indicating strong pH buffering at near neutral pH, and confirming the presence of readily available carbonates[5] as the dominant source of the high ANC. In each case, the starting

[5] As a general rule, calcite and limestone are typically readily available for neutralisation and can maintain pH-neutral conditions up until almost all the ANC is consumed. Dolomite is also usually reactive, however the reactivity may decline when there is significant iron substitution, such as with ferroan dolomite. In contrast, magnesite and siderite are usually poorly reactive at circum-neutral pH, and significant dissolution of these carbonates often only occurs under laboratory conditions when the pH drops below about 4. Furthermore, iron carbonate (siderite) does not

pH was greater than pH 8, indicating that fresh rock similar to the test samples should be a potential source of alkaline drainage.

The readily-available buffer capacity was quantified as the amount of acid required to lower the pH of a unit weight of sample to 4.5, which generally marks the end of the buffer plateau and is the pH used in the NAG test to differentiate NAF and PAF materials. The readily-available buffer capacities were as follows:

MMG / EGi Codes	Lithology	Start pH	ANC (kg H_2SO_4/t)	Readily Available (kg H_2SO_4/t)	% Readily Available
80448 / 40886	Calc-silicate	8.6	210	208	99%
80424 / 40862	Mafic feldspar porphyry	8.4	79	100	100%
80478 / 40916	Lode waste	9.4	219	210	96%
80430 / 40868	Footwall slate	9.5	120	116	97%
80436 / 40874	Footwall limestone	9.4	462	475	100%

This comparison confirms that virtually all of the ANCs of the five samples resulted from carbonate forms that were readily-available under circum-neutral to weak acidic conditions. Such forms could be expected to provide effective buffering of sulphide derived acidity if such material were exposed to atmospheric conditions.

contribute to the ANC of a sample. This is because the dissolution of $FeCO_3$ during the acidification stage of the ANC method is negated by the re-precipitation of iron hydroxide during the back-titration step of the method.

6.0 Sulphur Speciation and Reactivity within Dugald River Waste Rock

6.1 Sulphur Speciation

In this study the calculation of NAPP was based on total sulphur assays, assuming that the sulphur occurs as pyrite. This represents a conservative approach in that some sulphur can occur as sulphate, which is non-acid generating, and/or as other metal-sulphides that generate less acidity than pyrite when oxidised. For example, monosulphides such as sphalerite (ZnS) and galena (PbS) typically do not contribute significantly to the acid forming potential as both sulphides generate little or no free acid when oxidised. The oxidation of sphalerite by oxygen occurs without generating hydrogen ions according to the reaction:

$$ZnS + 2\,O_2 \Rightarrow Zn^{2+} + SO_4^{2-}$$

Consequently, sphalerite and galena (which would be expected to occur mainly within mineralised lode waste) are generally not regarded as acid generating, although the oxidation of these sulphide minerals does release zinc and lead, respectively.

A preliminary assessment of sulphur forms within Dugald River waste rock was carried out based on selective extraction methods. Fifteen samples with elevated sulphur contents were selected by EGi and analysed by ALS (Brisbane) for the following:

- Total sulphur - Measured using a Leco sulphur analyser.
- Sulphate-sulphur - Sample leached with hot HCl to remove acid-soluble sulphates. The amount of sulphate within the leachate is then determined by ICPAES. The acid leachable fraction is generally considered to be sulphate, although the method isn't always specific as some mono-sulphides can dissolve to varying extents.
- Sulphide-sulphur - Calculated as the difference between Total-S and Sulphate-S values.
- Cr Reducible S - Sample reacted with hot acidic $CrCl_2$ to reduce (non-sulphate) inorganic sulphur forms to H_2S which are trapped in zinc acetate solution for assay. Chromium reducible sulphur is generally deemed to occur specifically as pyritic-S forms but may include some elemental-S if present in a sample.

The sulphur speciation results are given in Table 3 and shown graphically in Figure 8. The samples included:

- 6 lode waste samples (5 PAF / 1 UC),
- 2 hanging wall slate (1 PAF / 1 NAF),
- 6 footwall slate (3 PAF / 3 NAF), and
- 1 footwall limestone sample (NAF)

Overall, the results indicate that sulphate-S typically represents a relatively small fraction of the total sulphur content in Dugald River waste rock. There was one lode waste sample where sulphate-S was 35% of total sulphur, but in most other cases sulphate-S represented less than 10% of total sulphur. This means that sulphide-sulphur, indirectly calculated as the difference between the total and sulphate-S values, accounted for the vast majority of the sulphur present in Dugald River waste samples tested.

As a further check, measurements were also made of chromium reducible sulphur, which directly quantifies sulphidic-sulphur forms. The chromium reducible sulphur contents of the 15 samples were essentially the same as the sulphide-S contents calculated by difference from the total-S and sulphate-S assays. This similarity adds veracity to the finding that sulphur is most likely to occur as sulphide.

6.2 Sulphur Reactivity

The kinetic NAG procedure was used to gain an insight into the reactivity of sulphides within Dugald River waste rock and to obtain a quick, qualitative assessment of the likely lag time for acidification of PAF waste rock to occur under field conditions. The kinetic NAG test is similar to the standard NAG test where a sample is oxidised with hydrogen peroxide, except that the pH and temperature of the NAG liquor are constantly recorded during the reaction phase of the test. The reaction kinetics are then extrapolated to the field situation using correlations previously derived from an extensive database comprising results of kinetic NAG tests, leach column tests, and field observations across a wide range of rock types.

Although kinetic NAG testing is not a replacement for column leach tests where reactions occur at real time, the profiles obtained by the accelerated procedure provide a qualitative estimate of the lag period to the extent that acidification of PAF rock is likely to occur rapidly (weeks to months), within the short term (many months to one or two years), or medium to long term (several years).

Five PAF samples were selected for kinetic NAG testing as follows:

MMG / EGi Codes	Lithology	%S	ANC	NAPP	ARD Class
80454 / 40892	Lode waste	10.46	34	286	PAF
80429 / 40867	Lode waste	3.32	19	83	PAF
80443 / 40881	Footwall slate	7.88	21	220	PAF
80438 / 40876	Footwall slate	1.66	11	40	PAF
80483 / 40921	Hanging wall slate	1.99	9	52	PAF

The kinetic NAG test reaction profiles for the five samples are given in Figures 9(a) to 9(e), respectively.

Lode Waste Rock –High Sulphur

The two lode waste samples (Figures 9a and 9b) exhibited similar reactivities under NAG test conditions. The pH profiles for both samples were indicative of high rates of sulphide oxidation and there was no evidence of any circum-neutral buffering which normally indicates a lag. The starting pHs were relatively low at 4.0 and 4.8, respectively, and both liquors rapidly acidified to around pH 3 within 8 and 9 minutes,

respectively. There was some buffering between pH 3 to 2 (as indicated by a small plateau in the pH curve) presumably associated with their respective ANCs of 34 and 19 kg H_2SO_4/t, but with ongoing oxidation both samples eventually acidified to less than pH 1 within about one and a half hours. The pH minimums corresponded with rapid increases in temperature, with the NAG liquors effectively boiling primarily as a consequence of catalytic decomposition[6] of the peroxide.

Overall, the acidification patterns exhibited by the two high sulphur lode waste samples under NAG test conditions are consistent with such material exhibiting high reactivity and, based on previous laboratory and field testing of waste rock at other sites with similar reaction profiles, it is likely that lode waste similar to the two test samples would exhibit little, if any, lag period if exposed to atmospheric conditions in the field. The results suggest that acidification would likely occur within months rather than years[7].

Footwall Slate –High Sulphur

The high sulphur footwall slate sample also reacted strongly in the kinetic NAG test (Figure 9c). As was the case with the high sulphur lode waste samples there was no initial circum-neutral pH plateau that normally signifies a significant lag, but the rate of acidification was slower than for the lode waste samples even though the sulphur content was equally high at 7.88 %S. It took approximately 49 minutes for the pH of the NAG liquor to acidify to pH 3 from a starting point of pH 5.2, roughly 5-times longer than for the lode waste samples. There was again some buffering between pH 3 to 2, and the pH minimum of less than 1 occurred after about 100 minutes (similar to the lode samples) corresponding with a sharp increase in temperature.

The reason for the slower rate of acidification of the footwall slate sample is not clear. The ANC of the slate sample was relatively low at 21 kg H_2SO_4/t and comparable to the neutralization capacities of the two lode waste samples. It is possible that the slower rate of acidification relate to differences in the forms of sulphides present. This aspect will be examined further when the sulphur speciation data become available.

The reaction kinetics exhibited by the footwall slate sample under NAG test conditions suggests that such material might respond slower than the lode waste in the field if exposed to atmospheric conditions. However, given the high sulphide content and the limited availability of inherent neutralisation capacity it is expected that any lag period would be relatively short. Based on the reaction kinetics exhibited in the NAG test it is expected that any field lag would be less than a year, and possibly no more than several months.

6 The temperature of the NAG solution also provides an insight into sulphide reactivity. Some of the initial temperature rise may be attributed to the oxidation of pyrite, which is an exothermic (heat generating) process. However, as the oxidation process continues and soluble metals are released, there is an increasing tendency for the hydrogen peroxide to catalytically decompose, a process that is also exothermic. This markedly accelerates the heating of the NAG solution. The main catalyst for peroxide decomposition is likely to be dissolved iron that is released during pyrite oxidation.

7 The lag times provided in this report should be used as a guide only and are based on correlations previously derived by EGi from comparison of kinetic NAG profiles with results from real time testing of the same materials (*e.g.* leach column tests) and field observations at actual mine sites.

Footwall and Hanging Wall Slate – Moderate to High Sulphur

The kinetic NAG test results for the hanging wall and footwall slate samples with moderate to high sulphur contents are given in Figures 9d and 9e, respectively. The profiles for the two samples were very similar, reflecting the fact that they also had similar acid forming characteristics. As noted above, the respective sulphur contents were moderately high at 1.66 and 1.99 %S, the ANCs were relatively low at 11 and 9 kg H_2SO_4/t, and the NAPPs were comparable at 40 and 52 kg H_2SO_4/t.

The pHs were initially between above 5 but again there were no pH plateaus to suggest that such materials could produce circum-neutral drainage for any length of time if exposed to atmospheric conditions. The pHs of both NAG liquors decreased steadily with time, reaching pH 3 within 83 and 36 minutes, respectively. This rate of pH decrease would suggest a field lag of the order of months to a year, rather than several years. The initial rapid pH decreases were followed by more gradual declines to around pH 1.5, but unlike the high sulphur samples discussed above, there accompanying temperature rises were relatively modest, peaking at around 40 ^{o}C after nearly 5 to 6 hour of reaction time.

Summary of Implications for Field Behaviour

Overall, the results of the kinetic NAG tests suggest that sulphidic lode waste and PAF slate from the hanging wall and footwall adjoining the lode which has a low ANC and a sulphur content exceeding 1.5 %S will be highly reactive and could acidify within several months of exposed to atmospheric conditions.

However, it should be noted that only a limited number of samples with moderate to very high sulphur contents were subjected to kinetic NAG testing. The lag period for PAF waste rock that contains substantially less than 1.5 %S and/or has an ANC substantially above the ANCs of the test samples could extend for much longer, with the onset of acidic conditions delayed beyond a year and possibly for several years.

Some long-term column leach tests were carried out as apart of the AARC (2008) geochemical study (see Section 9) and further column testing is planned for samples from the current study. These column tests will provide more information on sulphide reactivity and lag time under real-time condition.

7.0 Elemental Composition of Dugald River Waste Rock

Multi-element scans were run on 15 drill core samples from the current study. They included three samples representing hanging wall slate and two samples from each of the other lithologies. As a general rule, one of the chosen samples from each lithology had a sulphur content towards the top of the concentration range for that lithology, whilst the other sample had a sulphur content that was typically around mid-range. The samples selected were as followed:

MMG / EGi Codes	Lithology	%S	ANC	NAPP	NAG	ARD Class
80466 / 40904	Calc-silicate	0.47	62	-48	0	NAF
80448 / 40886	Calc-silicate	1.57	210	-161	0	NAF
80442 / 40880	Mafic feldspar porphyry	0.01	72	-72	0	NAF
80424 / 40862	Mafic feldspar porphyry	0.77	79	-56	0	NAF
80467 / 40905	White mica schist	0.05	11	-9	0	NAF
80449 / 40887	White mica schist	0.29	9	0	6	PAF
80428 / 40866	Hanging wall slate	0.94	158	-129	0	NAF
80483 / 40921	Hanging wall slate	1.99	9	52	43	PAF
80437 / 40875	Hanging wall slate	4.81	286	-139	0	NAF
80478 / 40916	Lode waste	2.38	219	-146	0	NAF
80454 / 40892	Lode waste	10.46	34	286	138	PAF
80430 / 40868	Footwall slate	1.15	120	-84	0	NAF
80438 / 40876	Footwall slate	1.66	11	40	37	PAF
80436 / 40874	Footwall limestone	1.06	462	-429	0	NAF
80486 / 40924	Footwall limestone	1.69	107	-55	0	NAF

The elemental compositions of the 15 Dugald River waste rock samples are given in Table 4. The samples were assayed for a suite of 35 elements that included: Al, As, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, Ga, Hg, In, K, La, Li, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, S, Sb, Se, Sn, Sr, Th, Ti, U, V, and Zn.

Multi-element assays were also carried out as part of AGC-Woodward Clyde (1991) and AARC (2008) geochemical studies of Dugald River waste rock. All samples in the 1991 study and half the samples in the 2008 studies were assayed for a limited range of elements of environmental significance which included: As, Cd, Co, Cu, Hg, Pb, S and Zn. The 2008 samples were also assayed for Ba, Be, Cr, Mn, Ni and V, whilst the 1991 samples were also assayed for Bi[8] and Sb. The assay data from previous studies are given in Appendix B-1.

To provide some relativity to the multi-element data, the compositions of the rock solids were compared to typical background compositions reported for soil. The ratios of the concentrations in Dugald River rock relative to background soil are presented graphically in Figure 10. Those elements that occur substantially

[8] The bismuth contents of all of the samples in the AGC-Woodward Clyde (1991) study were at or below the analytical detection limit of 5 mg/kg, which is relatively high in comparison to concentrations typically found in background soils. As such, the Bi results were not included in this review of elemental enrichments in Dugald waste rock.

above the ratio=1 line in Figure 10 are elevated in comparison to typical soil, whilst elements that occur below the line are deficient relative to typical soil

Geochemical Abundance Indices (GAIs) were also calculated for each sample to provide an indication of elemental enrichments that may have environmental significance. Each GAI was calculated as follows:

$GAI = \log_2 [C / (1.5*S)]$

where C is the concentration of the element in the sample and S is the median soil[9] content for that element. The GAI are truncated to integer increments (0 through to 6, respectively) where a GAI of 0 indicates the element is present at a concentration similar to, or less than, median soil abundance and a GAI of 6 indicates approximately a 100-fold, or greater, enrichment above median soil abundance. The enrichment ranges for the GAI are as follows:

Little or No Enrichment

GAI=0	< 3 times median soil

Slightly Enrichment

GAI=1	3 to <6 times median soil
GAI=2	6 to <12 times median soil

Significant Enrichment

GAI=3	12 to <24 times median soil
GAI=4	24 to <48 times median soil
GAI=5	48 to <96 times median soil
GAI=6	≥ 96 times median soil

The GAIs for the 15 Dugald River waste rock samples assayed in the current study are given in Table 5, and GAIs for samples from previous studies are given in Appendix B-2. The main purpose of the GAI is to provide an indication of any elemental enrichments that may be of environmental importance. As a general rule, a GAI of 3 or above is considered significant and such an enrichment may warrant further examination.

Samples representing calc-silicate, mafic feldspar porphyry and white mica schist were relatively free of significant (GAI≥3) enrichments. For these lithologies, the only significant enrichment identified was sulphur in one calc-silicate sample.

However, many samples representing hanging wall slate, footwall slate and lode waste were significantly (GAI≤3) enriched with one or more of a range of environmentally important elements. In addition to sulphur, the implications of which have already been discussed in Section 4, many samples from these lithologies were significantly enriched with arsenic, cadmium and zinc, and there were small numbers of samples enriched with copper, lead, mercury, and selenium.

[9] References for median soil data were: (1) Bowen, H.J.M. (1979) Environmental Chemistry of the Elements. Academic Press, London. (2) Berkman, D.A. (1976) Field Geologists' Manual, The Australian Institute of Mining and Metallurgy, Parkville, Victoria, Australia

A summary of the significant enrichments in each lithology (apart from sulphur) is given below:

- Calc-silicate none
- Mafic feld. porphyry none
- White mica schist none
- Hanging wall slate As (11/28) Zn (6/28) Cd (5/28) Hg (3/28) Cu (9/28) Se (1/3)
- Lode waste As (4/6) Zn (2/6) Cd (5/6) Hg (4/6) Pb (2/6) Se (1/2), Mn (1/6), Bi (1/2)
- Footwall slate As (8/21) Zn (4/21) Cd (6/21) Hg (1/21) Pb (2/21) Cu (1/21)
- Footwall limestone As (3/14) Zn (2/4)

(ratios shown are the number samples significantly enriched compared to the total assayed)

The enriched elements listed above form an elemental association that is commonly reported for a hydrothermal base metal deposit, hence their occurrence within the lode waste and the hanging wall and footwall slate adjoining the lode is expected. However, they are all regarded as environmentally important because of their potential toxicological effects on humans and/or aquatic life. Biological systems are particularly sensitive to metals such as zinc and copper, and there are obvious health implications in relation to elevated concentrations of mercury, cadmium and lead.

Zinc, copper and cadmium are usually highly mobile under acidic conditions and it is likely that significant concentrations of these metals would occur in any acidic drainage produced by PAF waste that is exposed to atmospheric conditions.

There may also be potential for leaching of arsenic, although the solubility of arsenic is often difficult to predict as its solubility and geochemical behaviour in geological systems is often controlled by adsorption or co-precipitation reactions involving other elements (*e.g.* iron at lower pHs and calcium at higher pHs).

The potential for leaching of environmentally important elements from Dugald River waste rock is considered further in Section 8.

8.0 Solute Leaching from Dugald River Waste Rock

Batch extraction tests were carried out on the 15 samples selected for multi-element analysis (see Section 7) to assess the potential for mobilisation of potentially hazardous elements from Dugald River waste rock. Three extractants were used, namely deionised water, 0.05M sulphuric acid, and hydrogen peroxide. The extractions with water and sulphuric acid were based on the Australian Standard leaching Procedure (ASLP) and involved leaching of crushed (≤4 mm) material at a solid:liquor ratio of 1:20 on an end-over-end shaker for a period of 18 hours. The peroxide extractions were based on the single-stage NAG test and involved over-night oxidation and leaching of pulverised sample at a solid:liquor ratio of 1:100.

The main objectives of the extraction tests were as follows:

- Deionised water - To provide an indication of the likely solubility of elements in freshly mined rock at the existing pH of the material.
- Dilute Acid - To assess the potential for elemental release from NAF waste rock that may be subject to acidic conditions imposed from some other source (*i.e.* overlying PAF rock).
- Peroxide - To assess elements that could potentially be released from the same rock following an extended period of exposure to atmospheric conditions resulting in significant sulphide oxidation. Depending on the particular rock type, the oxidation process may result in formation of *acidic rock drainage* (*e.g.* PAF lode waste) or generation of *neutral mine drainage* (*e.g.* NAF calc-silicate or footwall limestone with elevated sulphur and high to very high ANC).

The compositions of extracts from tests involving deionised water, dilute acid and peroxide are given in Tables 6 to 8, respectively. A statistical summary of the results for elements that are generally regarded as environmentally important is also presented graphically in Figure 11. This figure illustrates the concentration range, 20-80 percentile band, and average concentrations for Al, As, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Sb, Se, Sn, and Zn. Because the peroxide extractions were carried out at one-fifth the solid:liquor ratio than was used for the water and acid extractions, a five-times adjustment factor was applied to peroxide results to provide a more realistic comparison of extraction methods in Figure 11.

Water Extractions

Regardless of the ARD classifications, the water extracts of all 15 waste rock samples were circum-neutral to alkaline, with pHs of 7.4 to 8.5, respectively. The pH values are consistent with the samples containing some reactive carbonate, and in most cases having moderate to high ANCs.

Overall, there was little difference in the chemical compositions of the water extracts. The only differences of any substance was that the two NAF calc-silicate samples produced extracts with markedly higher concentrations of calcium (48 and 221 mg/L) and sulphate (113 and 549 mg/L) compared to extracts from

other samples. The elevated calcium and sulphate concentrations suggests the presence of some readily-soluble gypsum or anhydrite within the calc-silicate.

One of the hanging wall slate samples also had slightly elevated concentrations of calcium (22 mg/L) and sulphate (49 mg/L), but for all other extracts the concentrations were relatively low, with calcium ranging from <1 to 11 mg/L and sulphate ranging from <1 to 20 mg/L. There was also minimal release of magnesium (<1 to 2 mg/L), potassium (<1 to 4 mg/L) or sodium (<1 to 2 mg/L).

Overall, the concentrations of environmentally important elements in the water extracts were consistently low and commonly less than the analytical detection limits. Mercury and cadmium were consistently below the detection limit of 0.0001 mg/L, cobalt, chromium, copper, lead, nickel, antimony and tin were below or close to the 0.001 mg/L detection limit, and selenium was below the 0.01 mg/L detection limit. Arsenic was also low, with all but two extracts containing less than 0.006 mg/L.

Only the lode waste samples exhibited some minor leaching of metals. The water extract of one of the load samples contained 0.42 mg/L of zinc and 0.33 mg/L of barium. There were also traces of nickel (0.006 mg/L) and lead (0.004 mg/L), whilst the other lode extract had a trace of arsenic (0.016 mg/L).

Such results from the water extractions suggest that the potential for leaching by natural rainfall of environmentally important elements such as As, Cd, Co, Cr, Cu, Hg, Mn, Ni, Pb, Se, Sn, and Zn will be inconsequential for freshly mined rock similar to the samples tested.

Acid Extractions

The dilute acid extraction involved 0.05M H_2SO_4. This strength has a pH of 1.6, an acidity equivalent to 5000 mg $CaCO_3$/L, and a sulphate concentration of approximately 4,800 mg/L. From an ARD perspective, a pH of 1.6 represents an extreme case but the acidity[10] and sulphate concentration are of a magnitude commonly observed in ARD from actively oxidising PAF rock. The total amount of acid added to each sample was equivalent to 98 kg H_2SO_4/t.

As expected, there was some neutralisation of acid by some of the samples, in particular those with high ANCs. Three of the four samples with ANCs exceeding 200 kg H_2SO_4/t produced extracts of pH 5.3 to 5.4, while the fourth sample raised the pH to 3.3. It is expected that some neutralisation would also have occurred with most of the other 11 samples that had lower ANCs, but overall pHs remained low at between pH 1.5 to 2.1.

A defining feature of the acid extractions was that there was significant release of calcium as a direct consequence of the neutralisation processes. Calcium concentrations ranged from 20 to 164 mg/L in the acid extracts for samples with relatively low ANCs (i.e. ≤34 kg H2SO4/t), and from 393 to 874 mg/L for the higher ANC samples. The latter range equates to ANC equivalent of 19 to 43 kg H_2SO_4/t if it is assumed that

[10] In most cases the acidity of ARD predominantly results from dissolved iron and aluminium, with free acid (H_2SO_4) usually a minor contributor.

the calcium was derived from calcite[11] dissolution and there was no re-precipitation[12] of the calcium into other forms.

In addition to calcium, there was significant release of iron, aluminium and manganese from most samples. The concentrations of iron in the acid extracts ranged from 4 to 60 mg/L (average 25 mg/L), aluminium from 0.3 to 22 mg/L (average 8 mg/L), and manganese from 2.8 to 137 mg/L (average24 mg/L). Concentrations of iron and aluminium were greatest in extracts of low pH, which is consistent with the solubilities of both these elements being highly pH-dependent.

Mercury, tin and selenium remained below their respective detection limits of 0.0001, 0.001 and 0.1 mg/L. The concentration ranges for most of the environmentally important elements were generally higher in the acid extracts compared to the water extraction results, typically by an order-of-magnitude as illustrated in Figure 11.

Notwithstanding this general increase, the concentrations in most cases were still comparatively low and indicative of only limited elemental release despite the low pH condition imposed on the samples. For example, concentrations of cadmium and antimony were less than 0.01 mg/L, and the concentrations of arsenic, cobalt, chromium, copper and nickel were less than 0.1 mg/L.

However, there was a significant release of zinc from one of the lode waste samples (as per the water extract) producing concentration of 5.8 mg/L in the acid extract. For all other samples the zinc concentrations were much lower, typically around 0.1 to 0.3 mg/L.

Peroxide Extractions

As noted above, the results of the water leach tests provide an indication of the initial solubility of elements in freshly mined rock. However geochemical changes are likely to occur if sulphidic rock is exposed to conditions in which oxidation can occur, which could alter the potential for leaching of metals and other environmentally important elements. The purpose of the peroxide extractions, which followed the same procedure as the NAG test, was to highlight those elements that could potentially be released from Dugald River waste rock during an extended period of exposure to atmospheric conditions.

It should be noted that only four of the samples tested were classified as PAF. They included lode waste sample, one white mica schist, one hanging wall slate and one footwall slate. The pHs of these samples after reaction ranged from 2.3 to 3.5. Some of the NAF samples also had significant sulphide contents, but the ANCs were generally high to very high and the pH of the peroxide extracts were invariably circum-neutral at between pH 6.2 to 9.2.

[11] In the case of calc-silicate it is likely that some of the calcium derived from other sources (*e.g*. dissolution of gypsum or anhydrite) as calcium concentration was also relatively high in the corresponding water extracts.

[12] It is likely that some calcium re-precipitated as gypsum in some extracts given that the sulphate concentrations at the end of the test where generally lower than at the start, particularly in the case of samples with higher ANCs where carbonate dissolution was greatest. This being the case, the amounts of ANC dissolution would have been higher than those indicated by dissolved calcium.

It should also be noted that the composition of a peroxide extract at the end of the 18 hour reaction period should not be regarded as necessarily representative of the drainage quality that might be produced by such a material under field conditions as the concentrations of various elements are fundamentally influenced by the configuration of the test procedure, including the soil:liquor ratio, the extent of oxidation, and the degree of any acidification that might occur. Rather, the intent of the peroxide test was to highlight elements that might be released in significant amounts as a consequence of sulphide oxidation. To this end, and to provide a more apt comparison of the peroxide, water and acid leach results in Figure 11, the elemental concentrations in the peroxide extracts were multiplied by five to adjust for the different solid:liquor ratio that was used in the peroxide (NAG test) extraction.

This comparison suggests that the elements which had a higher propensity for release under oxidising conditions included zinc, lead, nickel, manganese, copper, cobalt, and to a lesser extent arsenic. However, significant releases of these elements were almost exclusively confined to the four PAF samples that acidified during the peroxide extraction. With the NAF samples the concentrations in the peroxide extracts were typically at trace values only. Elements that showed little or no propensity for release regardless of pH included mercury, tin, chromium, selenium and antimony.

9.0 Column Leach Testing of Dugald River Waste Rock

MMG is currently assessing commissioning long-term column leach tests involving some waste rock samples discussed in this report. The results of such testing would complement the findings of previous column leach tests that were commissioned by AARC in August 2008 and operated for either 44 weeks or 68 weeks.

The main objective of the column tests is to quantify the longer-term geochemical behaviour of different waste rock lithologies at real time under conditions that are conducive to sulphide oxidation and metals leaching. The column leach testing program will also provide data on rates of sulphide oxidation and acidification of PAF waste rock such as occurs within the vicinity of the lode and in the adjoining hanging wall and footwall slate, and more accurate water quality data for drainages that could emerge from PAF and NAF waste rock stockpiled at the surface.

The column tests commissioned by AARC involved composites of drill core samples representing the following waste rock types:

- Column 1 - hanging wall slate (uncertain),
- Column 2 - footwall limestone (NAF),
- Column 3 - PAF waste mixture (comprising lode waste and pyritic/mineralised footwall slate)
- Column 4 - footwall slate (NAF),
- Column 5 - calc-silicate (NAF),
- Column 6 - calc-silicate & mafic feldspar porphyry mix (NAF),
- Column 7 - mica schist (NAF),

The acid forming characteristics of the samples are detailed in Appendix C-1. Briefly, the samples exhibited the following characteristics:

- The PAF waste mixture had a very high acid forming potential. The sulphur content was 9.47 %S, and the NAPP was corresponding high at 254 kg H_2SO_4/t.
- The hanging wall slate was borderline with respect to ARD potential and the ARD classification was uncertain. It contained 2.39 %S and had a small positive NAPP of 2 kg H2SO4/t, but it did not acidify when reacted in the NAG test.
- All other samples were classified as NAF They had substantially lower sulphur contents (0.02 to 0.96 %S) and high to very high ANCs (80 to 222 kg H_2SO_4/t).

The column tests were undertaken by ALS Brisbane, generally in accordance with the *Free Draining Leach Column Procedure* outlined in the AMIRA P387A Project ARD Test Handbook[13]. Each column comprised 2.5 kg of crushed core (nominally less than 10 mm[14]) and was leached under free-draining conditions with deionised water on a monthly leach cycle.

The monthly leachate collections were assayed for pH, EC, alkalinity/acidity and sulphate concentration. A multi-element scan was also run on every second collection. The leachate assay results for the column tests are tabulated in Appendix C. Plots of leachate pH, sulphate and calcium concentration through time are also given in Figures 12 to 14, respectively.

NAF Waste Samples

The five NAF samples produced circum-neutral leachates (Figure 12) throughout the 44 week test period and the major ion chemistries were dominated by sulphate (Figure 13) and calcium (Figure 14). The average pH, alkalinity, sulphate concentration and calcium concentration for the five NAF columns during the test period were as follows:

Column Test	Lithology	Average pH	Average Alk (mg/L)	Average SO_4 (mg/L)	Average Ca (mg/L)
Column 2	Footwall limestone	7.8	30	44	17
Column 4	Footwall slate	7.6	21	46	18
Column 5	HW Calc-silicate	8.7	54	6	7
Column 6	HW Calc-sil / Mafic porphyry	8.6	39	8	7
Column 7	HW Mica schist	8.4	27	4	7

Figure 15 shows a statistical summary of the combined leachate quality results for the five NAF leach column tests. The results are consistent with the findings of the water extraction tests reported in Section 8. Apart from occasional trace concentrations of zinc (up to 0.2 mg/L) and manganese (up to 0.35 mg/L) there was no evidence of significant release of environmentally important elements from any of the NAF waste rock samples during the 12 month period. Mercury and cadmium were consistently below or close to the analytical detection limit of 0.0001 mg/L, antimony, arsenic, chromium, cobalt, copper, lead nickel and tin were below or close to the 0.001 mg/L detection limit, and selenium was below the 0.01 mg/L detection limit.

The concentrations reported for zinc ranged up to 0.2 mg/L but around half of leachate collections contained less than the 0.005 mg/L detection limit and the average zinc concentration across all of the NAF samples

[13] EGi was a contributing author of the AMIRA handbook and the column leach procedure described was developed by EGi and is currently used in EGi's laboratory. This column set-up will also be employed for the planned new column tests involving Dugald waste rock.

[14] The nominal minus 10 mm size material used by ALS for the 2.5 kg column tests was larger than the nominal minus 4 mm specified in the handbook.

was less than 0.02 mg/L. Similarly for manganese, concentrations ranged up to 0.35 mg/L but the average overall was only 0.06 mg/L.

PAF Waste Mixture

Column 3 contained a mixture of drill core samples representing PAF lode waste and PAF mineralised and pyritic footwall slate. The acid forming characteristics of the sample were typical of the lode waste samples included in the current study in that it had a high sulphur content (9.47 %S), a low to moderate ANC (36 kg H_2SO_4/t) and a high NAPP (254 kg H_2SO_4/t). The static NAG test also confirmed that the sample had a high acid potential under oxidising conditions.

The initial leachate draining from the column was pH neutral, similar to what was observed in the water extraction tests that were carried out on this type of waste rock. Leachate pH remained neutral for the first 12 weeks, but thereafter steadily decreased with time (see Figure 12). When the column test was stopped at 68 weeks the pH of leachate had decreased to 4.4.

There was considerable variability in the concentration of sulphate in column leachate during the test, but overall there was a general upward trend with time. The average concentration for the 68 week test period was 99 mg/L. This average is around twice that recorded for leachates from the columns containing the footwall slate (Column 2) and footwall limestone (Column 3), and more than an order-of-magnitude greater than for leachates from the other NAF columns. However, the sulphate concentrations *per se* were relatively low in comparison to what often occurs in acid rock drainage from highly pyritic rock. With such materials it is not uncommon to find sulphate concentrations in the order of several thousand mg/L. Indeed, sulphate concentrations of that magnitude were recorded in an identical column leach test involving process tailings from the Dugald River project that was carried out by EGi[15] in 2008-9. The reason for the relatively low sulphate concentrations in leach from the PAF waste sample is not known, but it is probable that the particle size and rock strength of the test material (nominally < 10 mm) were factors affecting the exposed surface area of sulphides.

The acidification of the PAF waste mix was accompanied by increased leaching of iron, zinc, manganese and aluminium as illustrated in Figure 16. The maximum concentrations recorded during the column test were 18.1, 9.4, 6.3, and 0.47 mg/L, respectively.

However, there was only trace leaching of other environmentally important elements, with many elements occurring in leachate at concentrations below or close to the limits of analytical detection. For example, mercury was less than the detection limit of 0.0001 mg/L, arsenic, chromium, lead antimony and tin were less than 0.001 mg/L, and selenium was less than 0.01 mg/L. The average and range of concentrations recorded for environmentally important elements were as follows:

15 EGi (2009). Geochemistry and column leach testing of tailings. Dugald River Zinc Project, Queensland. Final Report. Prepared for Oz Minerals Australia Limited by Environmental Geochemistry International Pty Ltd. Document No. 6412/877, July 2009.

The Dugald tailings sample had a sulphur content of 7.9 %S and was strongly acid generating with a NAG capacity of 86 kg H_2SO_4/t. Under column leach testing the tailings acidified to around pH 3.5 within the first few months of leaching and over the course of the 52 week column test the concentration of sulphate in leachate ranged from 1640 to 5720 mg/L and averaged 3080 mg/L.

Element	Average	Range
Al	0.19	(0.02 - 0.47)
As	<0.001	
Cd	0.005	(0.0002 - 0.009)
Co	0.015	(0.003 - 0.04)
Cr	<0.001	
Cu	0.01	(<0.001 - 0.03)
Fe	8.3	(<0.05 - 18.1)
Hg	<0.0001	(<0.0001 - 0.0004)
Mn	2.4	(0.41 - 6.3)
Ni	0.06	(0.01 - 0.14)
Pb	0.015	(<0.001 - 0.03)
Sb	<0.001	
Se	<0.01	
Sn	<0.001	
Zn	4.02	(0.10 - 9.4)

Hanging Wall Slate

Column 1 contained a composite of drill core interval representing both NAF and PAF hanging wall slate. Static testing of the sample indicated a sulphur content of 2.39 %S (which equates to a maximum acid potential of 73 kg H_2SO_4/t), and an ANC of 71 kg H_2SO_4/t. These results mean that the acid-base characteristics of the sample were evenly balanced, with a NAPP of only 2 kg H_2SO_4/t. The sample didn't acidify when reacted in a single addition NAG test, but the acid-base account denotes it was borderline with respect to ARD potential.

The overall pH profile for the hanging wall slate sample (see Figure 12) was comparable to that profile exhibited by the PAF waste mix, despite having a much lower sulphur content (albeit still relatively high) and about double the ANC. The initial leachate from the column was circum-neutral but after the first few months there was an overall downward trend in pH, with values less than 5 recorded for the last two collections at weeks 64 and 68. A lag period of only a few months is unusual for rock which has an ANC of 71 kg H_2SO_4/t, which normally would be considered to be in the moderate to high range and would normally be expected to provide a lag of at least a year and probably several years. The absence of such an extended lag suggests that the ANC within the slate was not readily available for reaction with acid produced by sulphide oxidation.

The decrease in pH was again accompanied by increases in the concentrations of iron, zinc, manganese and aluminium, but not to the same extent as reported for the PAF waste mix. By the end of the test the concentrations of these metals had increased to 10.4, 0.50, 0.51 and 0.19 mg/L, respectively. Other environmentally important elements were either below detection or occurred at trace concentrations only.

10.0 Summary and Implications for Dugald River Waste Rock Management

This report presents the results and findings of geochemical analysis of drill core samples representing waste rock lithologies that will be mined during development and operation of the Dugald River project. The geochemical program involved static testing of 72 drill core samples selected by MMG to assess their potential for generation of acid rock drainage, and also the potential for metals leaching under both acidic and neutral drainage conditions. In addition to the 72 samples tested by EGi, data from previous geochemical studies carried out by AARC (2008) and AGC-Woodward Clyde (1991) were compiled into a single geochemical database to enhance the evaluation of acid generation and metals leaching characteristics of the different waste rock types.

Main Findings

Overall, results for 211 samples were assessed. They included 31 samples representing calc-silicate, 7 mafic feldspar porphyry, 17 white mica schist, 52 hanging wall slate, 18 lode waste, 44 footwall slate, and 42 footwall limestone. The results for these samples suggest that:

- Waste rock from the calc-silicate, mafic feldspar porphyry, white mica schist lithologies associated with the mining of copper ore, and also waste rock from the footwall limestone lithology will be non-acid forming (NAF), with the calc-silicate and footwall limestone likely to have high to very high neutralisation capacity.
- Waste rock from within the lode zone will almost invariably be potentially acid forming (PAF) and have a high to very high capacity for acid generation if exposed to atmospheric conditions. It is also likely that some slate waste rock from the adjoining hanging wall and footwall will be pyritic and strongly PAF. Approximately 54% of the hanging wall slate samples tested, and 20% of the footwall slate samples tested were classified as PAF.

Elemental analyses of selected samples were also carried out to identify any enrichments that might be environmentally significant in terms of impacting on the quality of mine water and waste dump seepage. No significant metal or metalloid enrichments were identified in the calc-silicate, mafic feldspar porphyry and white mica schist but many of the hanging wall slate, footwall slate and lode waste samples were highly enriched with one or more of a range of environmentally important elements on comparison to concentrations typically occurring in background soils. The most prevalent enrichments were arsenic, cadmium and zinc. There was also less frequent enrichment with copper, lead, mercury, and selenium.

The enriched elements listed above form an elemental association that is commonly reported for a hydrothermal base metal deposit, hence their occurrence within the lode waste and the hanging wall and footwall slate adjoining the lode is expected. However, they are all regarded as environmentally important in terms of water quality, human health and/or aquatic life.

A series of batch extraction tests were carried out on selected samples to assess the potential for mobilisation of environmentally important elements under both acidic and neutral mine drainage conditions. Also, the results of column leach tests previously commissioned by AARC were reviewed to identify elements that might be released from different waste rock lithologies when exposed to atmospheric conditions. Elements that exhibited a higher propensity for release under oxidising conditions included zinc, lead, nickel, manganese, copper, cobalt, and to a lesser extent arsenic. However, significant releases of these elements were almost exclusively confined to PAF waste once acidification had occurred. With the NAF rock producing neutral drainage, the concentrations of environmentally important elements were typically at trace values only. Elements that showed little or no propensity for release regardless of pH included mercury, tin, chromium, selenium and antimony.

Implications for Waste Rock Management

The results of this and previous studies suggest that most lode waste and some pyritic slate in the hanging wall and footwall adjoining the lode will have a high acid generating potential and consequently a high level of management will be required to limit sulphide oxidation and minimise the risk of ARD generation occurring if such material is brought to the surface and exposed to atmospheric conditions. Clearly, highly PAF waste should be preferentially used as underground fill where possible. For PAF waste that needs to be stockpiled temporarily at the surface, or permanently placed within a dump, it is recommended that mining and handling procedures are developed that will allow selective placement of PAF waste in a manner that minimises rainfall infiltration (to limit leaching) and oxygen ingress (to limit oxidation). Prevention or control of acid rock drainage within stockpiles or dumps of pyritic waste rock will require adoption of strategies that involve one or more of the following:

- In-situ neutralisation of acid generation via blending of PAF rock with other materials that are non-acid forming, in particular high carbonate materials such as the footwall limestone or hanging wall calc-silicate;
- Minimisation of pyrite oxidation processes within dumped PAF waste via:
    - isolation and encapsulation of PAF rock within cells within the core of a dump or stockpile,
    - prevention of convective air movement by constructing dumps in small, compacted lifts,
    - construction of intermediate or final barrier layers which limit oxygen diffusion;
- Minimisation of acid drainage migration via:
    - controls on surface drainage,
    - incorporation of layers of low hydraulic conductivity.

The two key ingredients for pyrite oxidation are water and oxygen. Whilst it is generally best practice to divert surface waters away from dumps, and to place final cappings that minimise rainwater ingress, such measures are unlikely to produce a dump in which the moisture content is low enough to prevent sulphide oxidation. In the wet-dry climatic setting that occurs at the Dugald River site, the only practical mechanism for controlling sulphide oxidation will be to limit the movement of atmospheric oxygen into stockpiled material. This can generally be achieved by either burial and isolation of PAF rock within cells within the core of a

dump, or by construction of an outer cover that incorporates a layer with a low air-filled porosity which will act as a barrier to inward gaseous movement.

It is essential that all PAF rock is excluded from the area under the outer slope of dumps where convective air movement tends to be greatest. PAF rock should also be excluded from the base layer and from existing drainage lines so that the under-drainage is not in contact with sulphidic mineralised rock. To the extent possible, limestone or calc-silicate should be placed in drainage lines to impart some alkalinity to drainage prior to emergence at the dump toe.

As it is expected that PAF waste will be a relatively small percentage of total waste, there should also be opportunities for blending with high carbonate NAF rock prior to encapsulation within cells within the dump core. Ideally, blending would involve co-dumping of high carbonate rock such as limestone or calc-silicate with PAF rock to create an overall blend that is non-acid forming. Even if a NAF blend cannot be achieved, the high ANC of the blend would be expected to provide a very long lag which would prevent acidification pending possible future use as underground fill.

It is essential that no PAF rock is unduly exposed to atmospheric conditions, and intermediate barrier layers of NAF rock should be used to encapsulate PAF lifts prior to the wet season. Progressive encapsulation of PAF rock using intermediate cover layers would reduce leaching of PAF rock during dump construction, and in the longer term such layers would also provide a source of alkalinity to any pore water moving down into PAF rock zones within a dump.

It is essential that any stockpiled waste rock remaining at the surface at mine closure has a final cover layer comprising only NAF material. Such a cover would serve as a revegetation layer and provide circum-neutral surface runoff. The design of the final cover can be developed as mining proceeds and the NAF/PAF schedule for waste rock is refined, but under the climatic conditions prevailing at the River site a *Store and Release* cover system would likely provide the necessary level of control on rainfall infiltration to prevent significant leaching of any PAF rock encapsulated within cells within the dump core.

Tables

TABLE 1: Acid Forming Characteristics of Dugald River waste rock - Samples arranged by drill hole

MMG Sample ID	EGi Code	Hole No.	From (m)	To (m)	Interval (m)	Lithology	EC	Existing pH	Total %S	MPA	ANC	ANC/MPA Ratio	NAPP	NAG	NAGpH	ARD Class
80421	40859	DR315	284.0	284.5	0.5	Footwall slate	331	8.3	0.90	28	220	8	-193	0	7.8	NAF
80422	40860	DR315	304.0	304.5	0.5	Footwall limestone	216	8.1	0.68	21	456	22	-435	0	8.3	NAF
80423	40861	DR322	104.0	104.5	0.5	Calc-silicate	221	8.4	0.01	0	261	853	-261	0	8.8	NAF
80424	40862	DR322	150.0	150.5	0.5	Mafic feldspar porphyry	315	8.5	0.77	24	79	3	-56	0	8.9	NAF
80425	40863	DR322	288.0	288.5	0.5	Footwall slate	416	8.3	0.80	24	82	3	-57	0	7.9	NAF
80426	40864	DR322	310.0	310.5	0.5	Footwall limestone	239	8.2	0.88	27	467	17	-440	0	8.5	NAF
80427	40865	DR324	300.0	300.5	0.5	Hanging wall slate (Si Ab alt)	325	8.5	0.42	13	81	6	-68	0	7.8	NAF
80428	40866	DR324	405.0	405.5	0.5	Hanging wall slate (non sulphide)	176	8.4	0.94	29	158	5	-129	0	8.1	NAF
80429	40867	DR324	423.0	423.5	0.5	Lode (mineralised waste)	212	7.8	3.32	102	19	0.2	83	73	2.2	PAF
80430	40868	DR324	456.0	456.5	0.5	Footwall slate	245	7.9	1.15	35	120	3	-84	0	9.3	NAF
80431	40869	DR324	485.0	485.5	0.5	Footwall limestone	335	8.6	1.53	47	307	7	-260	0	8.2	NAF
80432	40870	DR330	101.5	102.0	0.5	Calc-silicate	346	8.4	0.01	0	134	437	-133	0	8.7	NAF
80433	40871	DR331	197.0	197.5	0.5	Footwall slate	512	8.5	1.18	36	170	5	-134	0	8.3	NAF
80434	40872	DR331	240.0	240.5	0.5	Footwall limestone	146	8.2	1.06	32	451	14	-418	0	9.6	NAF
80435	40873	DR336	382.0	382.5	0.5	Footwall limestone	235	8.3	0.71	22	215	10	-194	0	8.1	NAF
80436	40874	DR337	401.0	401.5	0.5	Footwall limestone	315	8.2	1.06	32	462	14	-429	0	8.9	NAF
80437	40875	DR339	188.0	188.5	0.5	Hanging wall slate (Si Ab alt)	142	8.1	4.81	147	286	1.9	-139	0	8.1	NAF
80438	40876	DR339	241.0	241.5	0.5	Footwall slate	117	8.9	1.66	51	11	0.2	40	37	2.4	PAF
80439	40877	DR339	248.0	248.5	0.5	Lode (mineralised waste)	145	8.2	2.05	63	237	4	-175	0	8.1	NAF
80440	40878	DR339	271.0	271.5	0.5	Footwall limestone	129	7.9	1.28	39	363	9	-323	0	8.0	NAF
80441	40879	DR343	133.0	133.5	0.5	Calc-silicate	139	7.8	0.01	0	82	268	-82	0	9.4	NAF
80442	40880	DR343	416.0	416.5	0.5	Mafic feldspar porphyry	146	8.4	0.01	0	72	235	-72	0	8.6	NAF
80443	40881	DR343	521.0	521.5	0.5	Footwall slate	235	7.6	7.88	241	21	0.1	220	260*	2.0	PAF
80444	40882	DR343	544.0	544.5	0.5	Footwall limestone	246	7.8	0.82	25	229	9	-204	0	7.7	NAF
80445	40883	DR345	351.0	351.5	0.5	Footwall slate	415	7.7	0.57	17	60	3	-42	0	7.8	NAF
80446	40884	DR345	364.0	364.5	0.5	Footwall limestone	329	8.6	0.85	26	199	8	-173	0	7.9	NAF
80447	40885	DR346	449.0	449.5	0.5	Footwall slate	346	8.7	1.61	49	119	2.4	-70	0	7.6	NAF
80448	40886	DR355	435.0	435.5	0.5	Calc-silicate	352	8.5	1.57	48	210	4	-161	0	9.5	NAF

TABLE 1: *Continued*

MMG Sample ID	EGi Code	Hole No.	From (m)	To (m)	Interval (m)	Lithology	EC	Existing pH	Total %S	MPA	ANC	ANC/MPA Ratio	NAPP	NAG	NAGpH	ARD Class
80449	40887	DR355	501.0	501.5	0.5	Schist	146	8.2	0.29	9	9	1	0	6	3.5	PAF
80450	40888	DR355	576.0	576.5	0.5	Lode (mineralised waste)	216	8.4	11.75	360	7	0	352	297*	2.0	PAF
80451	40889	DR355	636.0	636.5	0.5	Footwall slate	315	8.0	2.18	67	148	2	-82	0	7.5	NAF
80452	40890	DR355	660.0	660.5	0.5	Footwall limestone	429	7.8	0.39	12	152	13	-140	0	7.6	NAF
80453	40891	DR356	52.0	52.5	0.5	Hanging wall slate (Si Ab alt)	276	7.9	0.38	12	392	34	-380	0	7.9	NAF
80454	40892	DR356	181.0	181.5	0.5	Lode (mineralised waste)	186	7.4	10.46	320	34	0	286	348*	2.0	PAF
80455	40893	DR356	215.0	215.5	0.5	Footwall slate	345	7.6	0.87	27	136	5	-109	0	7.8	NAF
80456	40894	DR356	261.0	261.5	0.5	Footwall limestone	329	8.4	1.87	57	435	8	-377	0	7.9	NAF
80457	40895	DR356	263.0	263.5	0.5	Hanging wall slate (non sulphide)	307	7.8	1.07	33	455	14	-423	0	7.5	NAF
80458	40896	DR364	150.0	150.5	0.5	Schist	212	8.3	0.08	2	15	6	-13	0	4.7	NAF
80459	40897	DR364	278.0	278.5	0.5	Footwall slate	246	8.5	0.59	18	140	8	-122	0	7.8	NAF
80460	40898	DR364	306.0	306.5	0.5	Footwall limestone	197	8.6	0.89	27	462	17	-435	0	7.9	NAF
80461	40899	DR366	178.0	178.5	0.5	Footwall limestone	176	8.7	1.32	40	385	10	-345	0	7.6	NAF
80462	40900	DR368	245.0	245.5	0.5	Footwall limestone	203	8.5	0.77	24	516	22	-492	0	8.2	NAF
80463	40901	DR373	338.0	338.5	0.5	Calc-silicate	211	8.3	0.04	1	143	117	-141	0	7.8	NAF
80464	40902	DR373	638.0	638.5	0.5	Footwall slate	242	8.7	1.11	34	111	3	-77	0	8.9	NAF
80465	40903	DR373	671.0	671.5	0.5	Footwall limestone	403	8.6	0.83	25	302	12	-276	0	8.2	NAF
80466	40904	DR379	531.0	531.5	0.5	Calc-silicate	179	8.5	0.47	14	62	4	-48	0	8.4	NAF
80467	40905	DR379	575.0	575.5	0.5	Schist	245	8.7	0.05	2	11	7	-9	0	6.3	NAF
80468	40906	DR379	584.0	584.5	0.5	Hanging wall slate (non sulphide)	225	8.9	0.89	27	159	6	-132	0	7.6	NAF
80469	40907	DR379	631.0	631.5	0.5	Lode (mineralised waste)	312	8.1	13.94	427	398	0.9	28	0*	7.3	UC (NAF)
80470	40908	DR379	671.0	671.5	0.5	Footwall slate	345	8.4	1.56	48	40	0.8	7	3*	3.6	PAF
80471	40909	DR379	715.0	715.5	0.5	Footwall limestone	332	8.3	0.92	28	192	7	-163	0	8.0	NAF
80472	40910	DR388	478.0	478.5	0.5	Footwall slate	199	8.5	0.84	26	103	4.0	-77	0	7.6	NAF
80473	40911	DR388	513.0	513.5	0.5	Footwall limestone	227	8.6	1.22	37	446	12	-409	0	7.7	NAF
80474	40912	DR393	335.0	335.5	0.5	Calc-silicate	235	8.3	0.74	23	212	9	-189	0	7.8	NAF
80475	40913	DR393	358.0	358.5	0.5	Mafic feldspar porphyry	246	8.2	0.01	0	187	612	-187	0	7.5	NAF
80476	40914	DR393	698.0	698.5	0.5	Footwall slate	255	8.9	0.91	28	60	2.2	-32	0	7.6	NAF

TABLE 1: *Continued*

MMG Sample ID	EGi Code	Hole No.	From (m)	To (m)	Interval (m)	Lithology	EC	Existing pH	Total %S	MPA	ANC	ANC/MPA Ratio	NAPP	NAG	NAGpH	ARD Class
80477	40915	DR395	674.0	674.5	0.5	Mafic feldspar porphyry	142	8.4	0.01	0	169	551	-168	0	7.7	NAF
80478	40916	DR395	769.0	769.5	0.5	Lode (mineralised waste)	222	8.3	2.38	73	219	3	-146	0	7.8	NAF
80479	40917	DR395	932.0	932.5	0.5	Footwall slate	315	8.5	1.13	35	144	4	-109	0	7.6	NAF
80480	40918	DR405	212.0	212.5	0.5	Footwall slate	329	8.4	0.66	20	43	2.1	-23	0	7.9	NAF
80481	40919	DR405	234.0	234.5	0.5	Footwall limestone	276	7.6	0.10	3	127	41	-123	0	7.2	NAF
80482	40920	DR406	216.0	216.5	0.5	Calc-silicate	155	7.7	0.01	0	196	642	-196	0	7.4	NAF
80483	40921	DR406	481.0	481.5	0.5	Hanging wall slate (non sulphide)	242	7.8	1.99	61	9	0.1	52	43	2.4	PAF
80484	40922	DR408	839.0	839.5	0.5	Lode (mineralised waste)	235	7.9	6.12	187	5	0.0	182	219*	2.3	PAF
80485	40923	DR408	889.0	889.5	0.5	Footwall slate	246	8.7	2.12	65	94	1.5	-30	0	7.5	NAF
80486	40924	DR412	36.0	36.5	0.5	Footwall limestone	196	8.3	1.69	52	107	2.1	-55	0	7.6	NAF
80487	40925	DR414	337.0	337.5	0.5	Hanging wall slate (Si Ab alt)	331	8.4	0.01	0	190	621	-190	0	7.3	NAF
80488	40926	DR414	421.0	421.5	0.5	Schist	342	8.2	0.05	2	10	6	-8	0	7.2	NAF
80489	40927	DR414	564.5	565.0	0.5	Lode (mineralised waste)	309	8.6	1.90	58	16	0.3	42	38	2.4	PAF
80490	40928	DR414	599.5	600.0	0.5	Footwall slate	311	8.7	0.98	30	88	2.9	-58	0	7.8	NAF
80491	40929	DR417	58.0	58.5	0.5	Footwall slate	316	8.6	1.18	36	548	15	-512	0	7.7	NAF
80492	40930	DR417	123.0	123.5	0.5	Footwall limestone	321	8.5	0.97	30	444	15	-414	0	7.2	NAF

KEY

Existing pH = pH of 1:2 extract
EC = Electrical Conductivity of 1:2 extract (µS/cm)
MPA = Maximum Potential Acidity (kg H_2SO_4/t)
ANC = Acid Neutralising Capacity (kg H_2SO_4/t)

NAPP = Net Acid Producing Potential (kg H_2SO_4/t)
NAG = Net Acid Generation capacity to pH 7.0 (kg H_2SO_4/t)
NAGpH = pH of NAG liquor
** note: NAG values with asterisk are from sequential NAG tests*

NAF = Non-Acid Forming
PAF = Potentially Acid Forming
UC = Uncertain Classification
(likely classification given in brackets)

TABLE 2: Acid Forming Characteristics of Dugald River waste rock - Samples arranged by lithology

MMG Sample ID	EGi Code	Hole No.	From (m)	To (m)	Interval (m)	Lithology	EC	Existing pH	Total %S	MPA	ANC	ANC/MPA Ratio	NAPP	NAG	NAGpH	ARD Class
80423	40861	DR322	104.0	104.5	0.5	Calc-silicate	221	8.4	0.01	0	261	853	-261	0	8.8	NAF
80482	40920	DR406	216.0	216.5	0.5	Calc-silicate	155	7.7	0.01	0	196	642	-196	0	7.4	NAF
80474	40912	DR393	335.0	335.5	0.5	Calc-silicate	235	8.3	0.74	23	212	9	-189	0	7.8	NAF
80448	40886	DR355	435.0	435.5	0.5	Calc-silicate	352	8.5	1.57	48	210	4	-161	0	9.5	NAF
80463	40901	DR373	338.0	338.5	0.5	Calc-silicate	211	8.3	0.04	1	143	117	-141	0	7.8	NAF
80432	40870	DR330	101.5	102.0	0.5	Calc-silicate	346	8.4	0.01	0	134	437	-133	0	8.7	NAF
80441	40879	DR343	133.0	133.5	0.5	Calc-silicate	139	7.8	0.01	0	82	268	-82	0	9.4	NAF
80466	40904	DR379	531.0	531.5	0.5	Calc-silicate	179	8.5	0.47	14	62	4	-48	0	8.4	NAF
80475	40913	DR393	358.0	358.5	0.5	Mafic feldspar porphyry	246	8.2	0.01	0	187	612	-187	0	7.5	NAF
80477	40915	DR395	674.0	674.5	0.5	Mafic feldspar porphyry	142	8.4	0.01	0	169	551	-168	0	7.7	NAF
80442	40880	DR343	416.0	416.5	0.5	Mafic feldspar porphyry	146	8.4	0.01	0	72	235	-72	0	8.6	NAF
80424	40862	DR322	150.0	150.5	0.5	Mafic feldspar porphyry	315	8.5	0.77	24	79	3	-56	0	8.9	NAF
80458	40896	DR364	150.0	150.5	0.5	White mica schist	212	8.3	0.08	2	15	6	-13	0	4.7	NAF
80467	40905	DR379	575.0	575.5	0.5	White mica schist	245	8.7	0.05	2	11	7	-9	0	6.3	NAF
80488	40926	DR414	421.0	421.5	0.5	White mica schist	342	8.2	0.05	2	10	6	-8	0	7.2	NAF
80449	40887	DR355	501.0	501.5	0.5	White mica schist	146	8.2	0.29	9	9	1.0	0	6	3.5	PAF
80457	40895	DR356	263.0	263.5	0.5	Hanging wall slate (non sulphide)	307	7.8	1.07	33	455	14	-423	0	7.5	NAF
80453	40891	DR356	52.0	52.5	0.5	Hanging wall slate (Si Ab alt)	276	7.9	0.38	12	392	34	-380	0	7.9	NAF
80487	40925	DR414	337.0	337.5	0.5	Hanging wall slate (Si Ab alt)	331	8.4	0.01	0	190	621	-190	0	7.3	NAF
80437	40875	DR339	188.0	188.5	0.5	Hanging wall slate (Si Ab alt)	142	8.1	4.81	147	286	1.9	-139	0	8.1	NAF
80468	40906	DR379	584.0	584.5	0.5	Hanging wall slate (non sulphide)	225	8.9	0.89	27	159	6	-132	0	7.6	NAF
80428	40866	DR324	405.0	405.5	0.5	Hanging wall slate (non sulphide)	176	8.4	0.94	29	158	5	-129	0	8.1	NAF
80427	40865	DR324	300.0	300.5	0.5	Hanging wall slate (Si Ab alt)	325	8.5	0.42	13	81	6	-68	0	7.8	NAF
80483	40921	DR406	481.0	481.5	0.5	Hanging wall slate (non sulphide)	242	7.8	1.99	61	9	0.1	52	43	2.4	PAF

TABLE 2: *Continued*

MMG Sample ID	EGi Code	Hole No.	From (m)	To (m)	Interval (m)	Lithology	EC	Existing pH	Total %S	MPA	ANC	ANC/MPA Ratio	NAPP	NAG	NAGpH	ARD Class
80439	40877	DR339	248.0	248.5	0.5	Lode (mineralised waste)	145	8.2	2.05	63	237	4	-175	0	8.1	NAF
80478	40916	DR395	769.0	769.5	0.5	Lode (mineralised waste)	222	8.3	2.38	73	219	3	-146	0	7.8	NAF
80469	40907	DR379	631.0	631.5	0.5	Lode (mineralised waste)	312	8.1	13.94	427	398	0.9	28	0*	8.4	UC (NAF)
80489	40927	DR414	564.5	565.0	0.5	Lode (mineralised waste)	309	8.6	1.90	58	16	0.3	42	38	2.4	PAF
80429	40867	DR324	423.0	423.5	0.5	Lode (mineralised waste)	212	7.8	3.32	102	19	0.2	83	73	2.2	PAF
80484	40922	DR408	839.0	839.5	0.5	Lode (mineralised waste)	235	7.9	6.12	187	5	0.0	182	219*	2.0	PAF
80454	40892	DR356	181.0	181.5	0.5	Lode (mineralised waste)	186	7.4	10.46	320	34	0.1	286	348*	2.0	PAF
80450	40888	DR355	576.0	576.5	0.5	Lode (mineralised waste)	216	8.4	11.75	360	7	0.0	352	352*	2.0	PAF
80491	40929	DR417	58.0	58.5	0.5	Footwall slate	316	8.6	1.18	36	548	15	-512	0	7.7	NAF
80421	40859	DR315	284.0	284.5	0.5	Footwall slate	331	8.3	0.90	28	220	8	-193	0	7.8	NAF
80433	40871	DR331	197.0	197.5	0.5	Footwall slate	512	8.5	1.18	36	170	5	-134	0	8.3	NAF
80459	40897	DR364	278.0	278.5	0.5	Footwall slate	246	8.5	0.59	18	140	8	-122	0	7.8	NAF
80455	40893	DR356	215.0	215.5	0.5	Footwall slate	345	7.6	0.87	27	136	5	-109	0	7.8	NAF
80479	40917	DR395	932.0	932.5	0.5	Footwall slate	315	8.5	1.13	35	144	4	-109	0	7.6	NAF
80430	40868	DR324	456.0	456.5	0.5	Footwall slate	245	7.9	1.15	35	120	3	-84	0	9.3	NAF
80451	40889	DR355	636.0	636.5	0.5	Footwall slate	315	8.0	2.18	67	148	2.2	-82	0	7.5	NAF
80464	40902	DR373	638.0	638.5	0.5	Footwall slate	242	8.7	1.11	34	111	3	-77	0	8.9	NAF
80472	40910	DR388	478.0	478.5	0.5	Footwall slate	199	8.5	0.84	26	103	4	-77	0	7.6	NAF
80447	40885	DR346	449.0	449.5	0.5	Footwall slate	346	8.7	1.61	49	119	2.4	-70	0	7.6	NAF
80490	40928	DR414	599.5	600.0	0.5	Footwall slate	311	8.7	0.98	30	88	3	-58	0	7.8	NAF
80425	40863	DR322	288.0	288.5	0.5	Footwall slate	416	8.3	0.80	24	82	3	-57	0	7.9	NAF
80445	40883	DR345	351.0	351.5	0.5	Footwall slate	415	7.7	0.57	17	60	3	-42	0	7.8	NAF
80476	40914	DR393	698.0	698.5	0.5	Footwall slate	255	8.9	0.91	28	60	2.2	-32	0	7.6	NAF
80485	40923	DR408	889.0	889.5	0.5	Footwall slate	246	8.7	2.12	65	94	1.5	-30	0	7.5	NAF
80480	40918	DR405	212.0	212.5	0.5	Footwall slate	329	8.4	0.66	20	43	2.1	-23	0	7.9	NAF
80470	40908	DR379	671.0	671.5	0.5	Footwall slate	345	8.4	1.56	48	40	0.8	7	2	3.6	PAF
80438	40876	DR339	241.0	241.5	0.5	Footwall slate	117	8.9	1.66	51	11	0.2	40	37	2.4	PAF
80443	40881	DR343	521.0	521.5	0.5	Footwall slate	235	7.6	7.88	241	21	0.1	220	260*	2.0	PAF

TABLE 2: *Continued*

MMG Sample ID	EGi Code	Hole No.	From (m)	To (m)	Interval (m)	Lithology	EC	Existing pH	Total %S	MPA	ANC	ANC/MPA Ratio	NAPP	NAG	NAGpH	ARD Class
80462	40900	DR368	245.0	245.5	0.5	Foot wall limestone	203	8.5	0.77	24	516	22	-492	0	8.2	NAF
80426	40864	DR322	310.0	310.5	0.5	Foot wall limestone	239	8.2	0.88	27	467	17	-440	0	8.5	NAF
80422	40860	DR315	304.0	304.5	0.5	Foot wall limestone	216	8.1	0.68	21	456	22	-435	0	8.3	NAF
80460	40898	DR364	306.0	306.5	0.5	Foot wall limestone	197	8.6	0.89	27	462	17	-435	0	7.9	NAF
80436	40874	DR337	401.0	401.5	0.5	Foot wall limestone	315	8.2	1.06	32	462	14	-429	0	8.9	NAF
80434	40872	DR331	240.0	240.5	0.5	Foot wall limestone	146	8.2	1.06	32	451	14	-418	0	9.6	NAF
80492	40930	DR417	123.0	123.5	0.5	Foot wall limestone	321	8.5	0.97	30	444	15	-414	0	7.2	NAF
80473	40911	DR388	513.0	513.5	0.5	Foot wall limestone	227	8.6	1.22	37	446	12	-409	0	7.7	NAF
80456	40894	DR356	261.0	261.5	0.5	Foot wall limestone	329	8.4	1.87	57	435	8	-377	0	7.9	NAF
80461	40899	DR366	178.0	178.5	0.5	Foot wall limestone	176	8.7	1.32	40	385	10	-345	0	7.6	NAF
80440	40878	DR339	271.0	271.5	0.5	Foot wall limestone	129	7.9	1.28	39	363	9	-323	0	8.0	NAF
80465	40903	DR373	671.0	671.5	0.5	Foot wall limestone	403	8.6	0.83	25	302	12	-276	0	8.2	NAF
80431	40869	DR324	485.0	485.5	0.5	Foot wall limestone	335	8.6	1.53	47	307	7	-260	0	8.2	NAF
80444	40882	DR343	544.0	544.5	0.5	Foot wall limestone	246	7.8	0.82	25	229	9	-204	0	7.7	NAF
80435	40873	DR336	382.0	382.5	0.5	Foot wall limestone	235	8.3	0.71	22	215	10	-194	0	8.1	NAF
80446	40884	DR345	364.0	364.5	0.5	Foot wall limestone	329	8.6	0.85	26	199	8	-173	0	7.9	NAF
80471	40909	DR379	715.0	715.5	0.5	Foot wall limestone	332	8.3	0.92	28	192	7	-163	0	8.0	NAF
80452	40890	DR355	660.0	660.5	0.5	Foot wall limestone	429	7.8	0.39	12	152	13	-140	0	7.6	NAF
80481	40919	DR405	234.0	234.5	0.5	Foot wall limestone	276	7.6	0.10	3	127	41	-123	0	7.2	NAF
80486	40924	DR412	36.0	36.5	0.5	Foot wall limestone	196	8.3	1.69	52	107	2.1	-55	0	7.6	NAF

KEY

Existing pH = pH of 1:2 extract
EC = Electrical Conductivity of 1:2 extract (µS/cm)
MPA = Maximum Potential Acidity (kg H_2SO_4/t)
ANC = Acid Neutralising Capacity (kg H_2SO_4/t)

NAPP = Net Acid Producing Potential (kg H_2SO_4/t)
NAG = Net Acid Generation capacity to pH 7.0 (kg H_2SO_4/t)
NAGpH = pH of NAG liquor
** note: NAG values with asterisk are from sequential NAG tests*

NAF = Non-Acid Forming
PAF = Potentially Acid Forming
UC = Uncertain Classification
(likely classification given in brackets)

TABLE 3: Speciation of sulphur forms in Dugald River waste rock

MMG Sample ID	EGi Code	Hole No.	From (m)	To (m)	Lithology	SESL Lab	ALS Lab				ARD Class
						Total-S (%S)	Total-S (%S)	Sulphate-S (%S)	Sulphide-S (%S)	Cr Reducible-S (%S)	
80429	40867	DR324	423.0	423.5	Lode (mineralised Waste)	3.32	3.95	0.05	3.90	3.41	PAF
80437	40875	DR339	188.0	188.5	Hanging Wall Slate	4.81	4.47	0.29	4.18	4.33	NAF
80438	40876	DR339	241.0	241.5	Footwall Slate	1.66	1.62	0.16	1.46	1.64	PAF
80443	40881	DR343	521.0	521.5	Footwall Slate	7.88	7.67	1.46	6.21	6.81	PAF
80447	40885	DR346	449.0	449.5	Footwall Slate	1.61	2.11	0.07	2.04	1.88	NAF
80450	40888	DR355	576.0	576.5	Lode (mineralised Waste)	11.75	11.5	1.64	9.86	8.94	PAF
80451	40889	DR355	636.0	636.5	Footwall Slate	2.18	2.13	0.17	1.96	1.76	NAF
80454	40892	DR356	181.0	181.5	Lode (mineralised Waste)	10.46	9.48	1.42	8.06	8.42	PAF
80469	40907	DR379	631.0	631.5	Lode (mineralised Waste)	13.94	21.1	0.28	20.82	19.7	UC (NAF)
80470	40908	DR379	671.0	671.5	Footwall Slate	1.56	1.55	0.12	1.43	1.32	PAF
80483	40921	DR406	481.0	481.5	Hanging Wall Slate	1.99	2.16	0.13	2.03	1.92	PAF
80484	40922	DR408	839.0	839.5	Lode (mineralised Waste)	6.12	6.55	2.31	4.24	5.97	PAF
80485	40923	DR408	889.0	889.5	Footwall Slate	2.12	1.86	0.09	1.77	1.88	NAF
80486	40924	DR412	36.0	36.5	Footwall Limestone	1.69	1.72	0.02	1.70	1.68	NAF
80489	40927	DR414	564.5	565.0	Lode (mineralised Waste)	1.90	2.03	0.22	1.81	1.64	PAF

KEY

Total-S: by Leco furnace
Sulphate-S: by HCl leach method
Sulphide-S: by difference of total-S and SO4-S
Cr-Reducible-S: by reaction with hot acidic CrCl2

NAF = Non-Acid Forming
PAF = Potentially Acid Forming
UC = Uncertain Classification
(likely classification given in brackets)

TABLE 4: Elemental composition of Dugald River waste rock

MMG Code		80466	80448	80442	80424	80467	80449	80428	80483	80437	80478	80454	80430	80438	80436	80486
EGi Code		40904	40886	40880	40862	40905	40887	40866	40921	40875	40916	40892	40868	40876	40874	40924
Hole		DR379	DR355	DR343	DR322	DR379	DR355	DR324	DR406	DR339	DR395	DR356	DR324	DR339	DR337	DR412
From (m)		531.0	435.0	416.0	150.0	575.0	501.0	405.0	481.0	188.0	769.0	181.0	456.0	241.0	401.0	36.0
To (m)		531.5	435.5	416.5	150.5	575.5	501.5	405.5	481.5	188.5	769.5	181.5	456.5	241.5	401.5	36.5
Lithology		Calc Silicate	Calc Silicate	Mafic Feldspar Porphyry	Mafic Feldspar Porphyry	White Mica Schist	White Mica Schist	Hanging Wall Slate	Hanging Wall Slate	Hanging Wall Slate	Lode Waste	Lode Waste	Footwall Slate	Footwall Slate	Footwall Limestone	Footwall Limestone
Parameter		NAF	NAF	NAF	NAF	NAF	PAF	NAF	PAF	NAF	NAF	PAF	NAF	PAF	NAF	NAF
S	%	0.53	2.52	0.01	0.65	0.05	0.26	0.93	1.51	4.12	2.32	8.22	0.94	1.34	1.48	2.04
Al	%	6.16	5.34	7.12	7.41	11.05	8.69	6.3	7.61	4.33	6.58	5.65	5.46	7.17	3.19	5.66
Ca	%	3.59	9.09	2.29	2.09	0.35	0.25	4.48	0.39	9.01	9.21	0.14	4.86	0.82	10.55	3.52
Fe	%	3.84	5.63	10.15	6.05	4.85	0.86	2.41	3	8.07	5.36	7.26	2.68	2.31	1.85	3.52
K	%	2.64	4.16	2.39	1.41	4.09	4.34	4.75	5.02	2.86	5.4	4.49	3.93	4.93	1.12	2.26
Mg	%	0.96	1.14	2.48	4.38	1.28	0.61	2.08	0.78	4.14	0.98	0.35	1.19	0.96	4.84	3.11
Na	%	0.57	0.19	2.79	2.28	0.34	0.25	0.2	0.59	0.17	0.28	0.13	0.28	0.79	0.77	0.3
Ti	%	0.332	0.222	0.747	0.295	0.54	0.356	0.198	0.243	0.11	0.313	0.124	0.232	0.155	0.078	0.169
As	mg/kg	1.3	0.4	1.5	4.9	3.7	0.7	234	72.3	11	572	167.5	80.2	683	19	1.2
Ba	mg/kg	510	840	370	180	850	1030	500	1300	480	350	80	750	1110	540	360
Be	mg/kg	2.5	1.1	1.06	4.26	2.44	5.43	1.77	1.84	1.38	4.23	1.66	1.91	2.79	1.04	2.23
Bi	mg/kg	0.22	0.08	0.08	0.06	0.1	0.24	0.33	0.55	0.88	0.08	3.55	0.61	0.26	0.29	0.32
Cd	mg/kg	0.17	0.02	0.02	0.02	0.08	0.02	0.19	0.13	0.06	0.24	62.4	0.68	0.08	1.74	0.08
Co	mg/kg	14.2	17	21.2	23.8	14	3.3	6.9	11.1	8.5	12	44.4	12.5	12.8	6.1	25.5
Cr	mg/kg	47	37	17	51	77	57	37	78	35	49	44	38	49	20	36
Cu	mg/kg	159	2	9.1	4.2	25.3	8.5	24.1	44.8	324	25.8	39.9	52.4	33.4	13.2	162.5
Ga	mg/kg	19.2	15	21.6	24.1	29.3	27.9	17.9	21.2	11.9	14.85	15.05	15.95	21.8	8.36	16.5
Hg	mg/kg	0.005	0.005	0.005	0.017	0.005	0.005	0.018	0.012	0.009	0.005	1.055	0.009	0.006	0.072	0.005
In	mg/kg	0.079	0.041	0.063	0.025	0.077	0.061	0.026	0.02	0.006	0.012	0.144	0.053	0.01	0.042	0.012
La	mg/kg	84	31.4	42	132	46.9	66.6	45.5	68.5	23.7	34.4	19.9	31	81.2	27.1	81.8
Li	mg/kg	31.8	25.7	40.8	43.1	42.2	57.1	31.3	21.2	32.8	51.3	34.4	64.8	46.8	62.1	54.2
Mn	mg/kg	989	2100	824	1450	875	289	3380	336	5190	13600	1060	1560	1780	649	1020
Mo	mg/kg	1.26	3.52	0.84	0.4	0.54	0.59	7.7	4.67	8.92	5.48	8.4	4.11	8.5	4.07	3.22
Nb	mg/kg	11.8	7.1	6.6	10.9	17.4	7.7	7.3	7	3.9	10.2	3.1	9	5.7	2.1	4.3
Ni	mg/kg	21.4	22.6	35.5	31.7	40.7	27.8	17.7	43.1	82.9	32.3	30.3	21.6	25.3	14.8	36.9
P	mg/kg	790	470	680	650	850	650	830	620	740	1490	620	1150	1020	370	1020
Pb	mg/kg	4.8	5.1	0.7	3.2	5.7	5.8	22.4	39.6	17.6	51.7	433	23.5	73.4	73.3	6.7
Sb	mg/kg	0.52	0.53	0.74	0.46	0.27	0.6	3.48	2.4	1.04	0.42	8.69	0.51	0.26	1.62	0.79
Se	mg/kg	2	2	3	2	2	2	2	4	5	3	5	2	2	1	2
Sn	mg/kg	3.8	2.8	3.7	7.1	3.5	4.7	1.6	1.3	1.3	0.8	1.7	4.7	1.6	1.2	0.6
Sr	mg/kg	119.5	132.5	87.3	36.5	31.1	46.8	77.4	123	44.6	1405	48	156.5	108.5	236	34.4
Th	mg/kg	19.4	11.7	2.2	16.1	20.7	19.1	13.4	18.8	8.2	9.4	13.1	12.4	19.5	7.1	12.7
U	mg/kg	4.7	6.9	0.6	6.2	5.1	19	7	12.5	8.9	15.2	8.6	5.9	11.1	4.3	6.4
V	mg/kg	80	84	309	88	104	82	90	117	79	103	77	57	84	35	62
Zn	mg/kg	125	39	28	27	61	23	149	87	31	165	4.14%	463	38	520	17

* Underlined values indicate concentration below the analytical detection limit.

TABLE 5: Geochemical abundance indices for Dugald River waste rock

MMG Code	80466	80448	80442	80424	80467	80449	80428	80483	80437	80478	80454	80430	80438	80436	80486	Median Soil Content
EGi Code	40904	40886	40880	40862	40905	40887	40866	40921	40875	40916	40892	40868	40876	40874	40924	
Lithology	Calc Silicate	Calc Silicate	Mafic Feldspar Porphyry	Mafic Feldspar Porphyry	White Mica Schist	White Mica Schist	Hanging Wall Slate	Hanging Wall Slate	Hanging Wall Slate	Lode Waste	Lode Waste	Footwall Slate	Footwall Slate	Footwall Limestone	Footwall Limestone	
Parameter	NAF	NAF	NAF	NAF	NAF	PAF	NAF	PAF	NAF	NAF	PAF	NAF	PAF	NAF	NAF	
S	2	4	0	2	0	1	3	3	5	4	6	3	3	3	4	0.07 %
Al	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.1 %
Ca	0	2	0	0	0	0	0	0	2	2	0	1	0	2	0	1.5 %
Fe	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4 %
K	0	0	0	0	0	1	1	1	0	1	1	0	1	0	0	1.4 %
Mg	0	0	1	2	0	0	1	0	2	0	0	0	0	2	2	0.5 %
Na	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0.5 %
Ti	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5 %
As	0	0	0	0	0	0	4	3	0	5	4	3	6	1	0	6 mg/kg
Ba	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	500 mg/kg
Be	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6 mg/kg
Bi	0	0	0	0	0	0	0	0	1	0	3	1	0	0	0	0.2 mg/kg
Cd	0	0	0	0	0	0	0	0	0	0	6	0	0	1	0	0.4 mg/kg
Co	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	8 mg/kg
Cr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	70 mg/kg
Cu	1	0	0	0	0	0	0	0	2	0	0	0	0	0	1	30 mg/kg
Ga	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20 mg/kg
Hg	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0.06 mg/kg
In	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1 mg/kg
La	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	40 mg/kg
Li	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25 mg/kg
Mn	0	0	0	0	0	0	1	0	1	3	0	0	0	0	0	1000 mg/kg
Mo	0	0	0	0	0	0	1	0	1	0	1	0	1	0	0	2 mg/kg
Nb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10 mg/kg
Ni	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50 mg/kg
P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	800 mg/kg
Pb	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	35 mg/kg
Sb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5 mg/kg
Se	1	1	2	1	1	1	1	2	3	2	3	1	1	0	1	0.4 mg/kg
Sn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4 mg/kg
Sr	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	250 mg/kg
Th	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9 mg/kg
U	0	1	0	1	0	2	1	2	1	2	1	0	1	0	1	2 mg/kg
V	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	90 mg/kg
Zn	0	0	0	0	0	0	0	0	0	0	6	1	0	1	0	90 mg/kg

Median soil data from:

Bowen, H.J.M. (1979) Environmental Chemistry of the Elements. Academic Press, London.

Berkman, D.A. (1976) Field Geologists' Manual, The Australian Institute of Mining and Metallurgy, Vic.

* Geochemical Abundance Indices (GAI)

GAI=0 represents <3 times median soil content

GAI=1 represents 3 to 6 times

GAI=2 represents 6 to 12 times

GAI=3 represents 12 to 24 times

GAI=4 represents 24 to 48 times

GAI=5 represents 48 to 96 times

GAI=6 represents more than 96 times

TABLE 6: Water extractable elements in Dugald River waste rock

MMG Code		80466	80448	80442	80424	80467	80449	80428	80483	80437	80478	80454	80430	80438	80436	80486	
EGi Code		40904	40886	40880	40862	40905	40887	40866	40921	40875	40916	40892	40868	40876	40874	40924	
Hole		DR379	DR355	DR343	DR322	DR379	DR355	DR324	DR406	DR339	DR395	DR356	DR324	DR339	DR337	DR412	
From (m)		531.0	435.0	416.0	150.0	575.0	501.0	405.0	481.0	188.0	769.0	181.0	456.0	241.0	401.0	36.0	
To (m)		531.5	435.5	416.5	150.5	575.5	501.5	405.5	481.5	188.5	769.5	181.5	456.5	241.5	401.5	36.5	Blank
Lithology		Calc Silicate	Calc Silicate	Mafic Feldspar Porphyry	Mafic Feldspar Porphyry	White Mica Schist	White Mica Schist	Hanging Wall Slate	Hanging Wall Slate	Hanging Wall Slate	Lode Waste	Lode Waste	Footwall Slate	Footwall Slate	Footwall Limestone	Footwall Limestone	
Parameter		NAF	NAF	NAF	NAF	NAF	PAF	NAF	PAF	NAF	NAF	PAF	NAF	PAF	NAF	NAF	
pH		7.7	8.5	7.4	8.4	8.3	8.1	7.9	7.9	7.8	8.4	8.2	8.5	8.3	8.2	8.2	5.9
EC	µS/cm	81	145	213	146	95	86	83	142	107	167	123	115	111	92	107	1
Ag	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Al	mg/L	0.2	0.1	0.3	0.5	0.4	0.6	0.3	0.04	0.2	0.2	0.02	0.3	0.3	0.2	0.2	<0.01
As	mg/L	<0.001	<0.001	<0.001	<0.001	0.004	<0.001	0.006	<0.001	0.002	0.02	<0.001	0.003	0.01	0.002	0.002	<0.001
B	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ba	mg/L	0.003	0.007	0.02	0.002	0.04	0.005	0.02	0.03	0.008	0.3	0.02	0.03	0.02	0.04	0.02	0.002
Be	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ca	mg/L	48	221	5	6	4	5	8	22	6	9	<1	6	5	6	11	<1
Cd	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Cl	mg/L	1	2	1	2	2	<1	2	2	2	2	2	1	2	2	2	1
Co	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cr	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cu	mg/L	0.001	0.002	<0.001	0.003	0.002	0.002	0.002	0.001	<0.001	0.003	0.002	0.002	0.003	0.002	0.001	0.004
F	mg/L	<0.1	<0.1	<0.1	0.1	<0.1	0.2	<0.1	<0.1	0.1	0.2	<0.1	0.1	<0.1	<0.1	<0.1	<0.1
Fe	mg/L	<0.05	0.1	<0.05	0.3	0.1	0.06	<0.05	<0.05	<0.05	<0.05	0.3	<0.05	<0.05	<0.05	<0.05	<0.05
Hg	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
K	mg/L	3	2	4	1	3	3	3	3	3	1	<1	2	2	2	3	<1
Mg	mg/L	<1	<1	<1	2	<1	<1	2	2	<1	<1	<1	<1	<1	2	1	<1
Mn	mg/L	0.007	0.04	0.002	0.02	0.02	0.01	0.02	0.2	0.01	0.04	0.03	0.006	0.01	0.002	0.005	<0.001
Mo	mg/L	<0.001	0.004	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001
Na	mg/L	2	<1	<1	1	1	<1	1	1	2	<1	<1	2	2	1	2	<1
Ni	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	0.006	<0.001	<0.001	<0.001	<0.001	<0.001
P	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Pb	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	<0.001	<0.001	<0.001	<0.001	<0.001
Sb	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	0.002	<0.001	0.001	<0.001	<0.001	0.003	<0.001	<0.001
Se	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Si	mg/L	0.8	0.4	0.9	0.7	1.0	1.2	0.8	0.4	0.9	0.6	0.2	1.2	1.0	0.8	1.2	<0.05
Sn	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SO4	mg/L	113	549	<1	4	<1	2	11	49	5	6	5	2	4	3	20	<1
Sr	mg/L	0.2	0.4	0.008	0.006	0.02	0.007	0.03	0.1	0.02	0.09	0.004	0.04	0.01	0.06	0.02	<0.001
Th	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
U	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zn	mg/L	<0.005	<0.005	<0.005	0.011	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.4	<0.005	0.009	<0.005	<0.005	<0.005

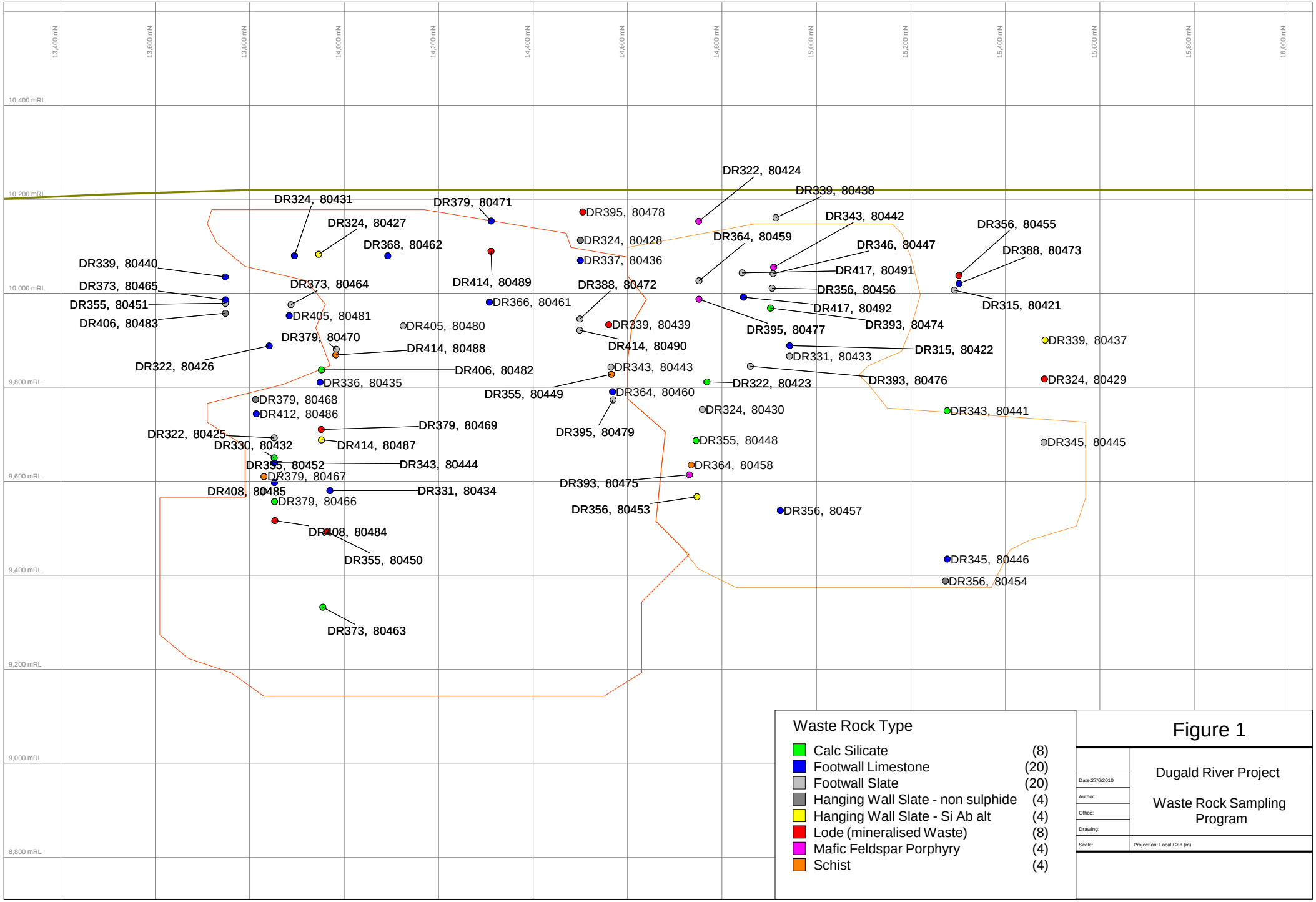
TABLE 7: Acid extractable elements in Dugald River waste rock

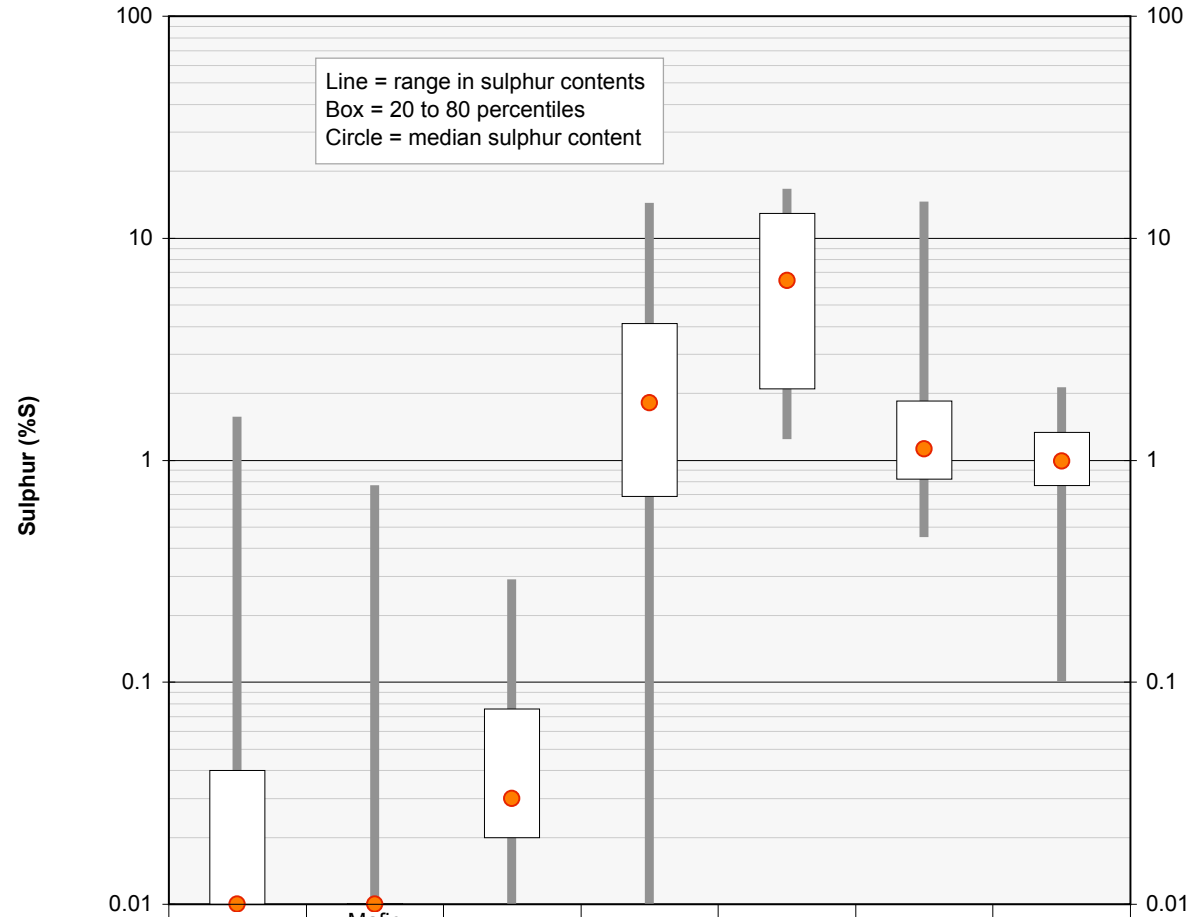
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EGi Code		40904	40886	40880	40862	40905	40887	40866	40921	40875	40916	40892	40868	40876	40874	40924	
Hole		DR379	DR355	DR343	DR322	DR379	DR355	DR324	DR406	DR339	DR395	DR356	DR324	DR339	DR337	DR412	
From (m)		531.0	435.0	416.0	150.0	575.0	501.0	405.0	481.0	188.0	769.0	181.0	456.0	241.0	401.0	36.0	
To (m)		531.5	435.5	416.5	150.5	575.5	501.5	405.5	481.5	188.5	769.5	181.5	456.5	241.5	401.5	36.5	Blank
Lithology		Calc Silicate	Calc Silicate	Mafic Feldspar Porphyry	Mafic Feldspar Porphyry	White Mica Schist	White Mica Schist	Hanging Wall Slate	Hanging Wall Slate	Hanging Wall Slate	Lode Waste	Lode Waste	Footwall Slate	Footwall Slate	Footwall Limestone	Footwall Limestone	
Parameter		NAF	NAF	NAF	NAF	NAF	PAF	NAF	PAF	NAF	NAF	PAF	NAF	PAF	NAF	NAF	
pH		1.5	5.4	1.8	1.9	1.4	1.6	1.9	1.5	3.3	5.3	1.5	2.1	1.7	5.3	1.6	1.61
EC	µS/cm	18,110	2,410	10,510	11,550	21,020	21,280	9,230	20,620	3,220	2,680	22,210	5,520	21,210	3,510	13,390	23,110
Ag	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Al	mg/L	22	0.6	20	13	10	11	2	8	3	0.5	3	8	11	0.3	8	0.05
As	mg/L	0.008	0.001	0.02	0.01	0.02	0.007	0.03	0.06	0.01	0.03	0.006	0.01	0.04	0.003	0.007	0.01
B	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Ba	mg/L	0.05	0.02	0.14	0.05	0.03	0.06	0.02	0.03	0.07	0.04	0.02	0.05	0.03	0.07	0.03	0.001
Be	mg/L	0.005	0.001	0.001	0.008	0.002	0.01	0.001	0.004	0.005	0.002	<0.001	0.008	0.004	<0.001	0.009	<0.001
Ca	mg/L	393	639	874	709	96	84	759	164	653	652	20	707	96	724	782	<1
Cd	mg/L	<0.0001	<0.0001	0.0001	<0.0001	0.0004	<0.0001	0.0002	0.0003	0.0001	0.0003	0.005	0.0004	0.0002	0.0004	0.0003	<0.0001
Cl	mg/L	<1	1	2	3	<1	<1	<1	<1	2	4	<1	1	<1	2	<1	<1
Co	mg/L	0.007	0.004	0.02	0.01	0.02	0.004	0.006	0.03	0.004	0.004	<0.001	0.007	0.004	0.003	0.03	<0.001
Cr	mg/L	0.04	0.002	0.01	0.03	0.02	0.02	0.01	0.08	0.03	0.004	0.004	0.03	0.04	0.003	0.03	0.005
Cu	mg/L	0.04	0.004	0.01	0.08	0.03	0.01	0.01	0.03	0.007	0.002	0.002	0.03	0.02	0.03	0.09	0.01
F	mg/L	1.2	0.3	0.8	0.5	3.7	<5.9	0.4	1.8	0.8	0.9	0.7	1.0	3.3	0.3	0.9	<0.1
Fe	mg/L	23	4	39	59	21	11	60	25	23	11	17	19	15	14	28	1
Hg	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
K	mg/L	8	2	32	9	7	10	5	6	7	2	1	11	7	5	13	<1
Mg	mg/L	10	6	32	261	7	6	260	11	113	17	2	15	6	225	109	<1
Mn	mg/L	4	31	11	20	1	1	58	4	40	137	3	34	2	6	17	0.001
Mo	mg/L	0.003	0.003	<0.001	0.001	<0.001	<0.001	0.002	0.005	0.003	0.003	<0.001	0.002	0.003	<0.001	0.003	<0.001
Na	mg/L	14	1	2	2	2	<1	1	2	2	1	<1	4	3	1	2	<1
Ni	mg/L	0.01	0.002	0.03	0.02	0.02	0.03	0.01	0.1	0.02	0.009	0.01	0.02	0.02	0.01	0.06	<0.001
P	mg/L	16	<1	27	9	27	20	4	11	8	<1	3	12	23	<1	18	<1
Pb	mg/L	0.01	<0.001	0.005	0.02	0.06	0.04	0.05	0.1	0.05	0.004	0.3	0.04	0.4	0.03	0.03	0.001
Sb	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.002	0.003	0.002	<0.001	0.002	<0.001	<0.001	0.007	<0.001	<0.001
Se	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Si	mg/L	16	2	27	12	13	12	2	8	3	1	2	8	12	1	10	<0.50
Sn	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SO4	mg/L	4880	2640	3870	4400	4830	4770	4270	4950	2420	3120	4770	2600	4930	2610	4370	4870
Sr	mg/L	0.3	0.5	0.4	0.08	0.09	0.05	0.3	0.3	0.2	3.2	0.07	0.4	0.07	1.2	0.3	<0.001
Th	mg/L	0.05	<0.001	0.002	0.04	0.03	0.06	0.02	0.03	0.004	<0.001	0.006	0.02	0.13	<0.001	0.009	<0.001
U	mg/L	0.009	0.004	<0.001	0.01	0.02	0.05	0.004	0.02	0.008	0.001	0.003	0.007	0.05	0.001	0.04	<0.001
Zn	mg/L	0.05	0.03	0.09	0.1	0.2	0.09	0.2	0.2	0.09	0.07	5.8	0.3	0.2	0.2	0.1	<0.005

TABLE 8: Peroxide extractable elements in Dugald River waste rock

MMG Code		80466	80448	80442	80424	80467	80449	80428	80483	80437	80478	80454	80430	80438	80436	80486
EGi Code		40904	40886	40880	40862	40905	40887	40866	40921	40875	40916	40892	40868	40876	40874	40924
Hole		DR379	DR355	DR343	DR322	DR379	DR355	DR324	DR406	DR339	DR395	DR356	DR324	DR339	DR337	DR412
From (m)		531.0	435.0	416.0	150.0	575.0	501.0	405.0	481.0	188.0	769.0	181.0	456.0	241.0	401.0	36.0
To (m)		531.5	435.5	416.5	150.5	575.5	501.5	405.5	481.5	188.5	769.5	181.5	456.5	241.5	401.5	36.5
Lithology		Calc Silicate	Calc Silicate	Mafic Feldspar Porphyry	Mafic Feldspar Porphyry	White Mica Schist	White Mica Schist	Hanging Wall Slate	Hanging Wall Slate	Hanging Wall Slate	Lode Waste	Lode Waste	Footwall Slate	Footwall Slate	Footwall Limestone	Footwall Limestone
Parameter		NAF	NAF	NAF	NAF	NAF	PAF	NAF	PAF	NAF	NAF	PAF	NAF	PAF	NAF	NAF
NAGpH		8.5	9.2	8.5	8.8	6.2	3.5	8.2	2.4	8.3	7.9	2.3	8.9	2.4	8.7	7.6
Ag	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001
Al	mg/L	1.31	1.48	1.84	0.11	0.53	6.91	0.15	6.29	0.07	0.31	5.87	0.44	11.4	0.04	0.92
As	mg/L	0.004	<0.001	0.004	<0.001	0.006	<0.001	<0.001	0.016	<0.001	0.001	0.02	0.001	0.146	<0.001	0.002
B	mg/L	0.06	0.06	<0.05	0.09	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.3	<0.05
Ba	mg/L	0.007	0.01	0.011	0.017	0.063	0.152	0.042	0.138	0.037	0.055	0.101	0.081	0.188	0.108	0.063
Be	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	0.005	<0.001	0.002	<0.001	<0.001	0.001	<0.001	0.004	<0.001	<0.001
Ca	mg/L	63	384	6	40	12	26	94	45	271	101	3	78	31	70	132
Cd	mg/L	0.0107	<0.0001	<0.0001	<0.0001	<0.0001	0.0003	<0.0001	0.0014	<0.0001	<0.0001	0.675	<0.0001	0.0013	<0.0001	<0.0001
Cl	mg/L	<1	<1	<1	1	<1	<1	<1	<1	3	<1	<1	<1	<1	<1	<1
Co	mg/L	0.005	<0.001	0.003	<0.001	0.001	0.038	<0.001	0.166	<0.001	<0.001	0.308	<0.001	0.164	<0.001	0.003
Cr	mg/L	0.005	0.004	0.002	0.007	0.004	0.008	0.002	0.008	<0.001	0.002	0.009	0.003	0.006	0.002	0.002
Cu	mg/L	0.018	0.002	0.019	0.006	0.008	0.118	0.002	0.632	0.003	0.003	0.546	0.002	0.523	0.002	0.019
F	mg/L	<0.1	0.2	<0.1	0.2	0.1	1.8	0.3	0.3	0.4	1	0.3	0.6	0.5	0.2	0.1
Fe	mg/L	5.41	0.09	0.86	0.12	0.72	0.21	0.11	52.6	0.06	0.1	184	<0.05	33.6	0.06	1.75
Hg	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
K	mg/L	9	5	34	11	9	15	6	8	11	3	6	8	12	8	8
Mg	mg/L	<1	<1	<1	<1	2	2	4	5	8	<1	2	<1	5	2	1
Mn	mg/L	0.158	0.003	0.031	0.007	0.077	0.416	0.024	1.11	0.028	0.059	8.24	0.007	1.29	0.002	0.039
Mo	mg/L	0.008	0.057	<0.001	0.004	0.008	0.009	0.048	<0.001	0.041	0.015	0.001	0.042	<0.001	0.049	0.031
Na	mg/L	2	<1	1	2	<1	<1	<1	1	1	<1	<1	1	3	2	1
Ni	mg/L	0.005	<0.001	0.004	<0.001	0.001	0.339	<0.001	0.598	<0.001	<0.001	0.329	<0.001	0.274	<0.001	0.009
P	mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Pb	mg/L	0.048	<0.001	0.008	0.002	0.003	0.012	<0.001	0.179	<0.001	<0.001	2.56	<0.001	0.364	<0.001	0.005
Sb	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	0.004	<0.001
Se	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.02	<0.01	0.03	<0.01	<0.01	<0.01	<0.01
Si	mg/L	4.91	3.45	6.69	5.06	2.47	10.3	1.18	7.77	0.45	0.93	6.93	1.65	14.5	2.96	1.33
Sn	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SO4	mg/L	181	826	10	98	14	129	224	626	652	247	1720	190	540	178	321
Sr	mg/L	0.153	0.667	0.008	0.012	0.016	0.041	0.063	0.106	0.055	0.347	0.01	0.079	0.054	0.223	0.078
Th	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.021	<0.001	<0.001	0.013	<0.001	0.058	<0.001	<0.001
U	mg/L	<0.001	<0.001	0.002	<0.001	<0.001	0.019	<0.001	0.027	<0.001	<0.001	0.019	<0.001	0.099	<0.001	<0.001
Zn	mg/L	6.19	<0.005	0.024	0.01	0.028	0.164	0.016	0.928	0.005	0.018	364	<0.005	0.725	0.006	0.022

Figures

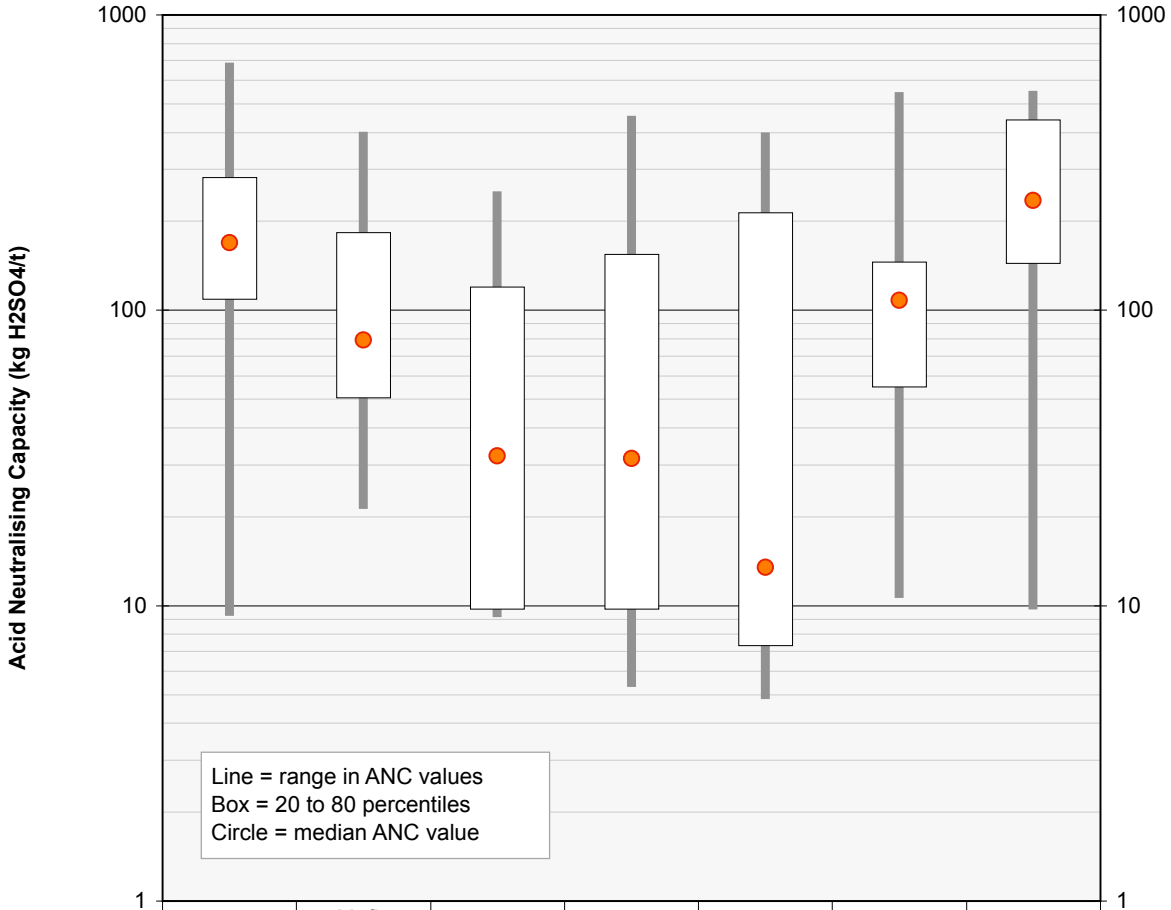

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DR345, 80445
DR330, 80432
DR414, 80487
DR355, 80452
DR343, 80444
DR364, 80458
DR379, 80467
DR393, 80475
DR408, 80485
DR331, 80434
DR379, 80466
DR356, 80453
DR356, 80457
DR408, 80484
DR355, 80450
DR345, 80446
DR356, 80454
DR373, 80463
Waste Rock Type
Calc Silicate (8)
Footwall Limestone (20)
Footwall Slate (20)
Hanging Wall Slate - non sulphide (4)
Hanging Wall Slate - Si Ab alt (4)
Lode (mineralised Waste) (8)
Mafic Feldspar Porphyry (4)
Schist (4)
Figure 1
Dugald River Project
Waste Rock Sampling Program
Date:27/6/2010
Author:
Office:
Drawing:
Scale:
Projection: Local Grid (m)



	Calc-silicate	Mafic feldspar porphyry	White mica schist	Hanging wall slate	Lode (waste)	Footwall slate	Footwall limestone
80 percentile	0.04	0.01	0.08	4.13	12.92	1.84	1.34
maximum	1.57	0.77	0.29	14.4	16.6	14.6	2.12
minimum	0.01	0.01	0.01	0.01	1.24	0.45	0.1
20 percentile	0.01	0.01	0.02	0.69	2.10	0.82	0.77
median	0.01	0.01	0.03	1.82	6.44	1.12	0.99

FIGURE 2: Statistical summary of sulphur data for Dugald River waste rock

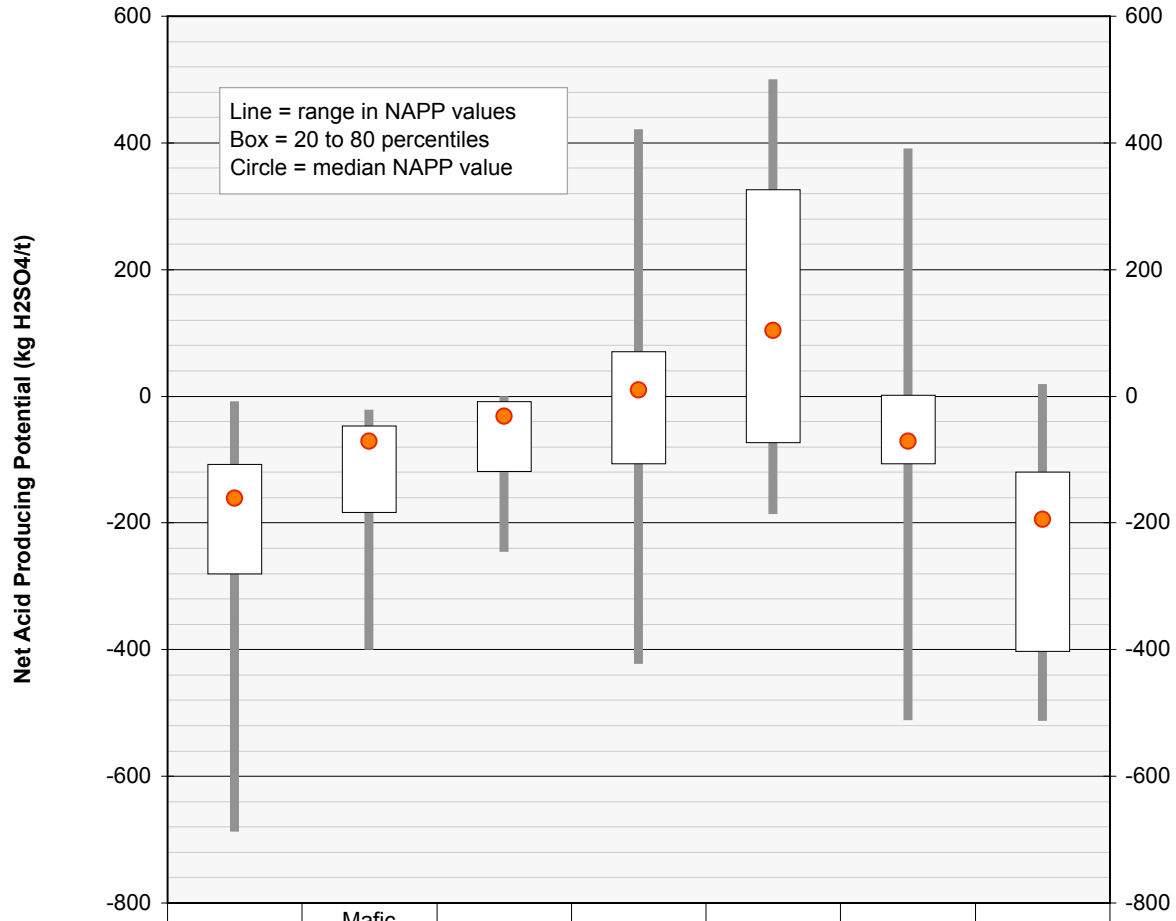
(compliation of results from all geochemical studies)



	Calc-silicate	Mafic feldspar porphyry	White mica schist	Hanging wall slate	Lode (waste)	Footwall slate	Footwall limestone
80 percentile	282	184	120	155	214	145	442
maximum	688	401	252	455	398	548	552
minimum	9	21	9	5	5	11	10
20 percentile	109	51	10	10	7	55	144
median	169	79	32	31	13	108	235

FIGURE 3: Statistical summary of ANC data for Dugald River waste rock

(compliation of results from all geochemical studies)



	Calc-silicate	Mafic feldspar porphyry	White mica schist	Hanging wall slate	Lode (waste)	Footwall slate	Footwall limestone
80 percentile	-108	-47	-9	71	326	2	-120
maximum	-9	-21	0	421	500	390	18
minimum	-688	-401	-246	-423	-187	-512	-513
20 percentile	-281	-183	-119	-107	-74	-106	-403
median	-161	-72	-31	10	104	-71	-195

FIGURE 4: Statistical summary of NAPP data for Dugald River waste rock

(compliation of results from all geochemical studies)

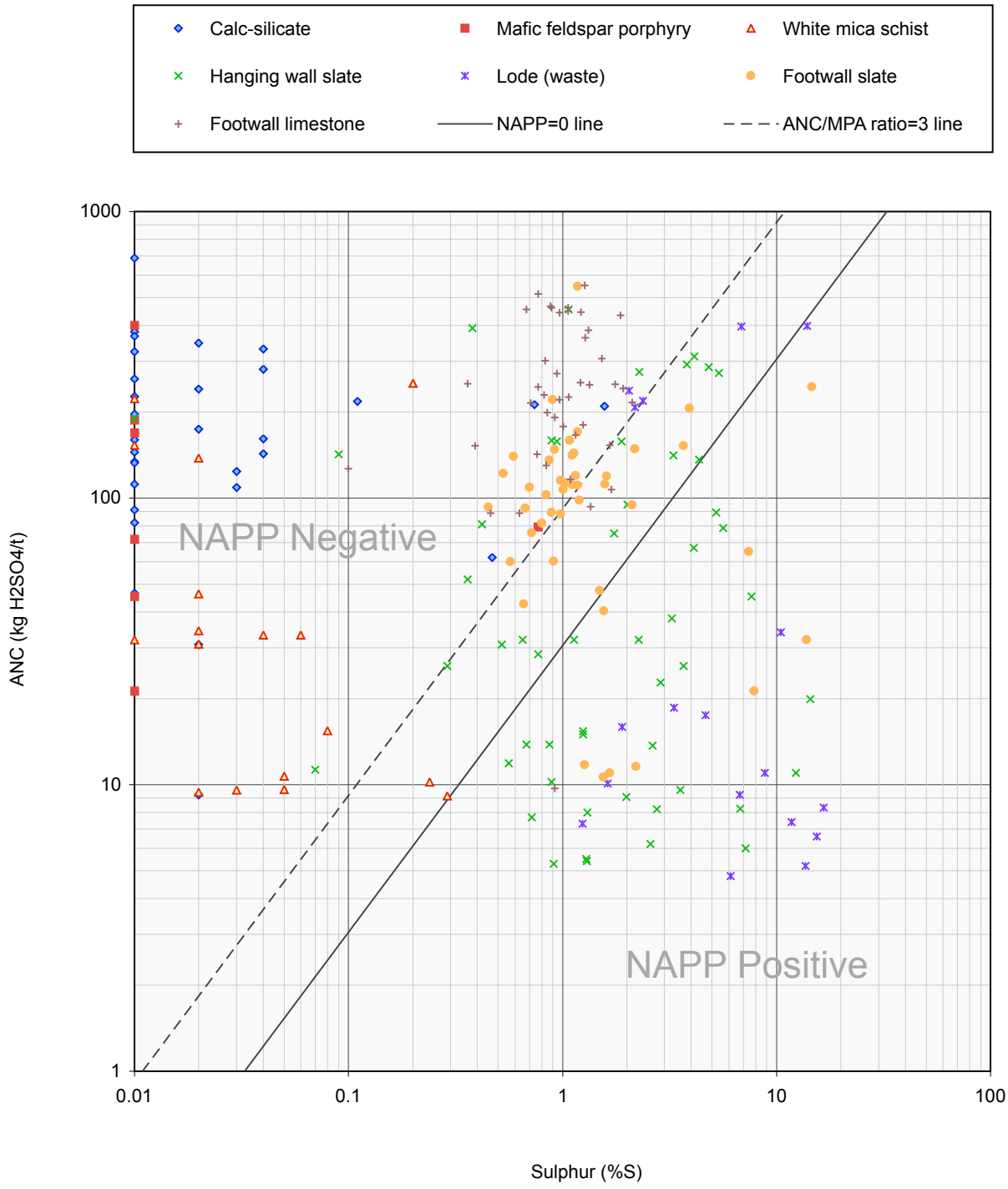


FIGURE 5: Acid-base account plot for Dugald River waste rock

(compliation of results from all geochemical studies)

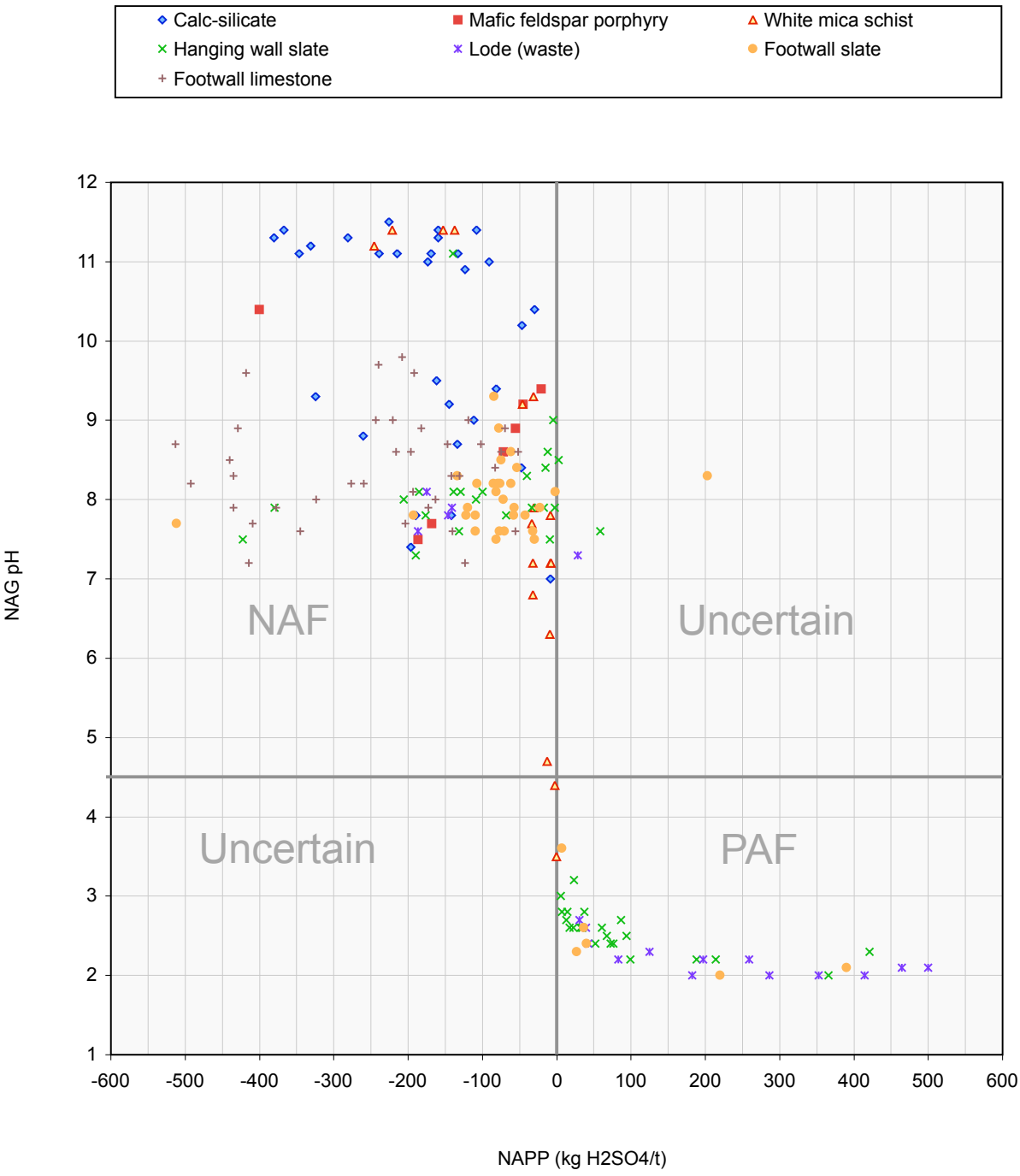
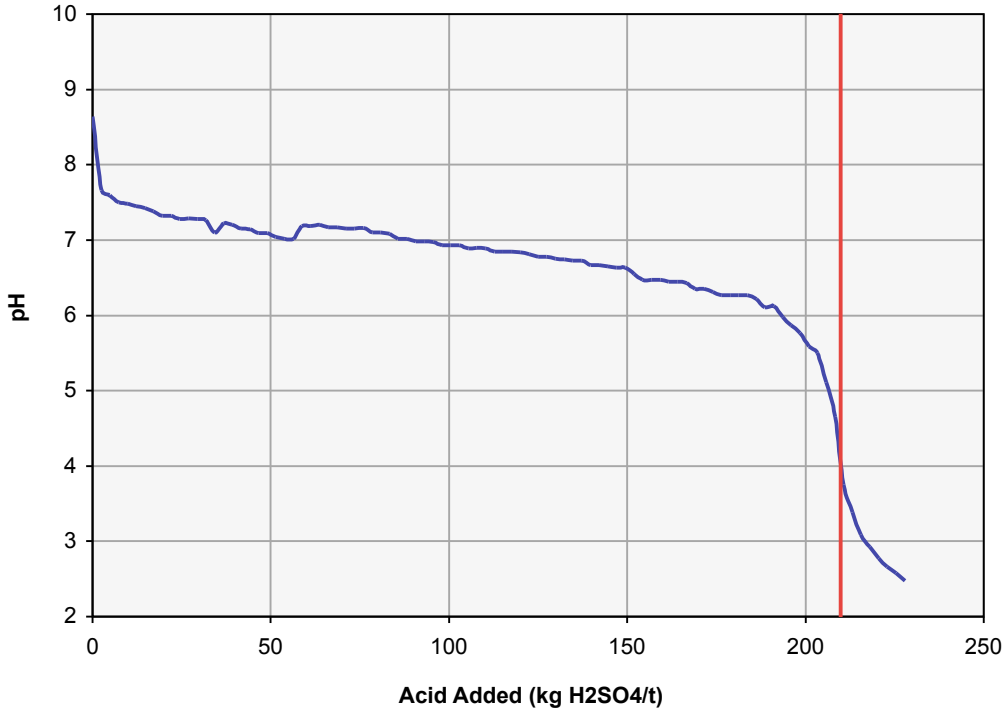


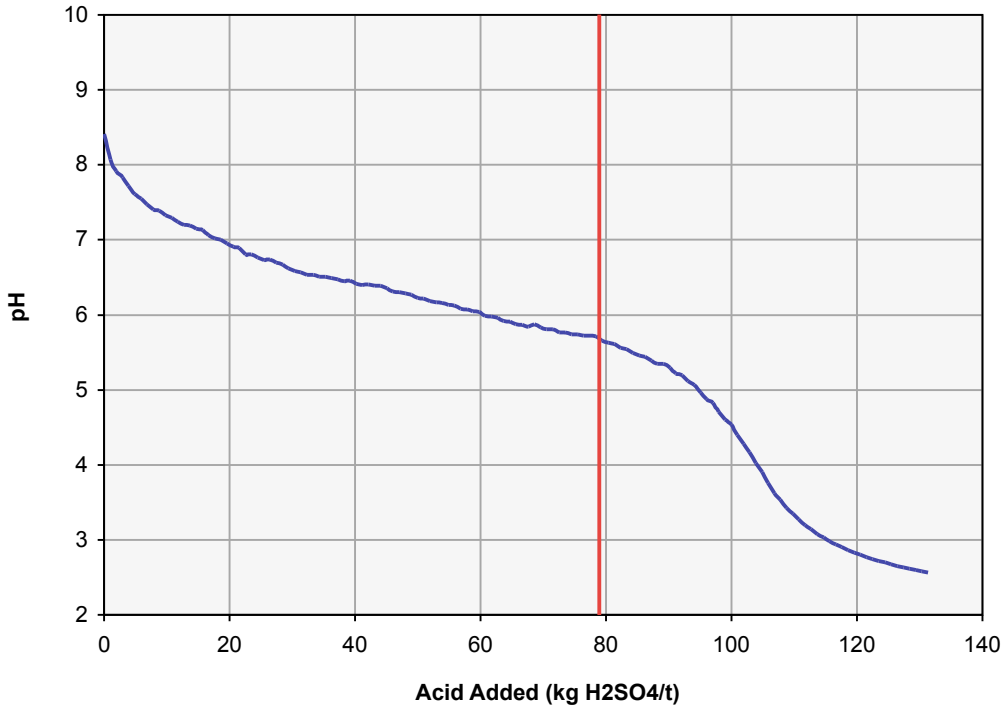
FIGURE 6: ARD classification plot for Dugald River waste rock

(compliation of results from all geochemical studies)



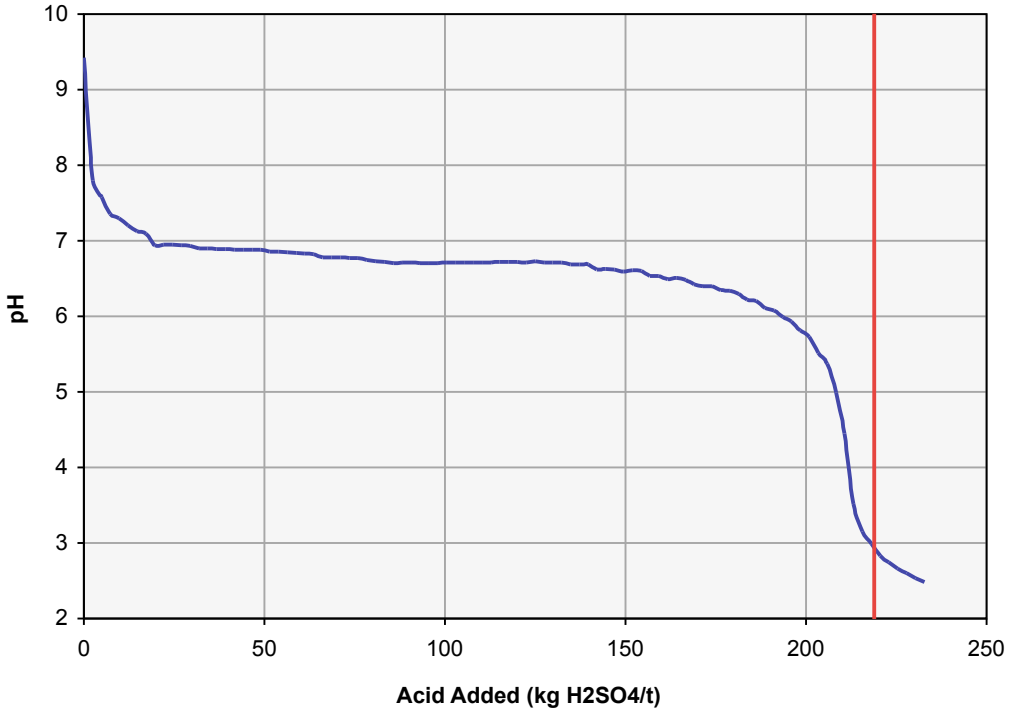
MMG / EGi Codes = 80448 / 40886	ANC = 210 kg H2SO4/t

FIGURE 7(a) - Acid buffer characteristic curve for Dugald River waste rock - Calc-silicate



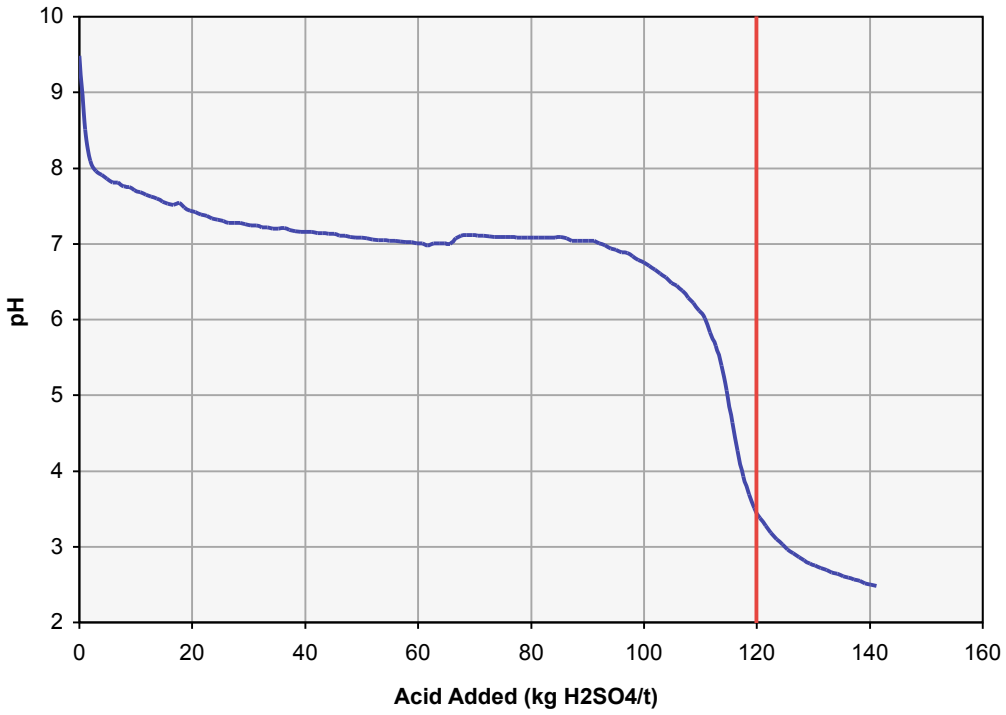
MMG / EGi Codes = 80424 / 40862	ANC = 79 kg H2SO4/t

FIGURE 7(b) - Acid buffer characteristic curve for Dugald River waste rock - Mafic feldspar porphyry



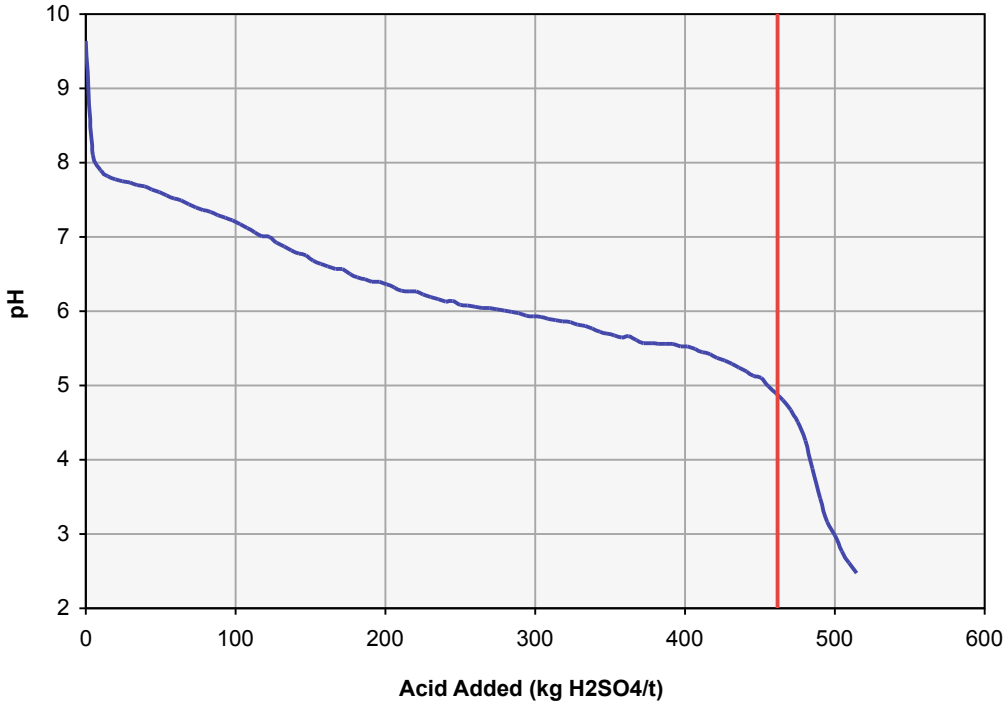
MMG / EGi Codes = 80478 / 40916	ANC = 219 kg H2SO4/t

FIGURE 7(c) - Acid buffer characteristic curve for Dugald River waste rock - Lode waste



MMG / EGi Codes = 80430 / 40868	ANC = 120 kg H2SO4/t

FIGURE 7(d) - Acid buffer characteristic curve for Dugald River waste rock - Foot wall slate



MMG / EGi Codes = 80436 / 40874	ANC = 462 kg H2SO4/t

FIGURE 7(e) - Acid buffer characteristic curve for Dugald River waste rock - Footwall limestone

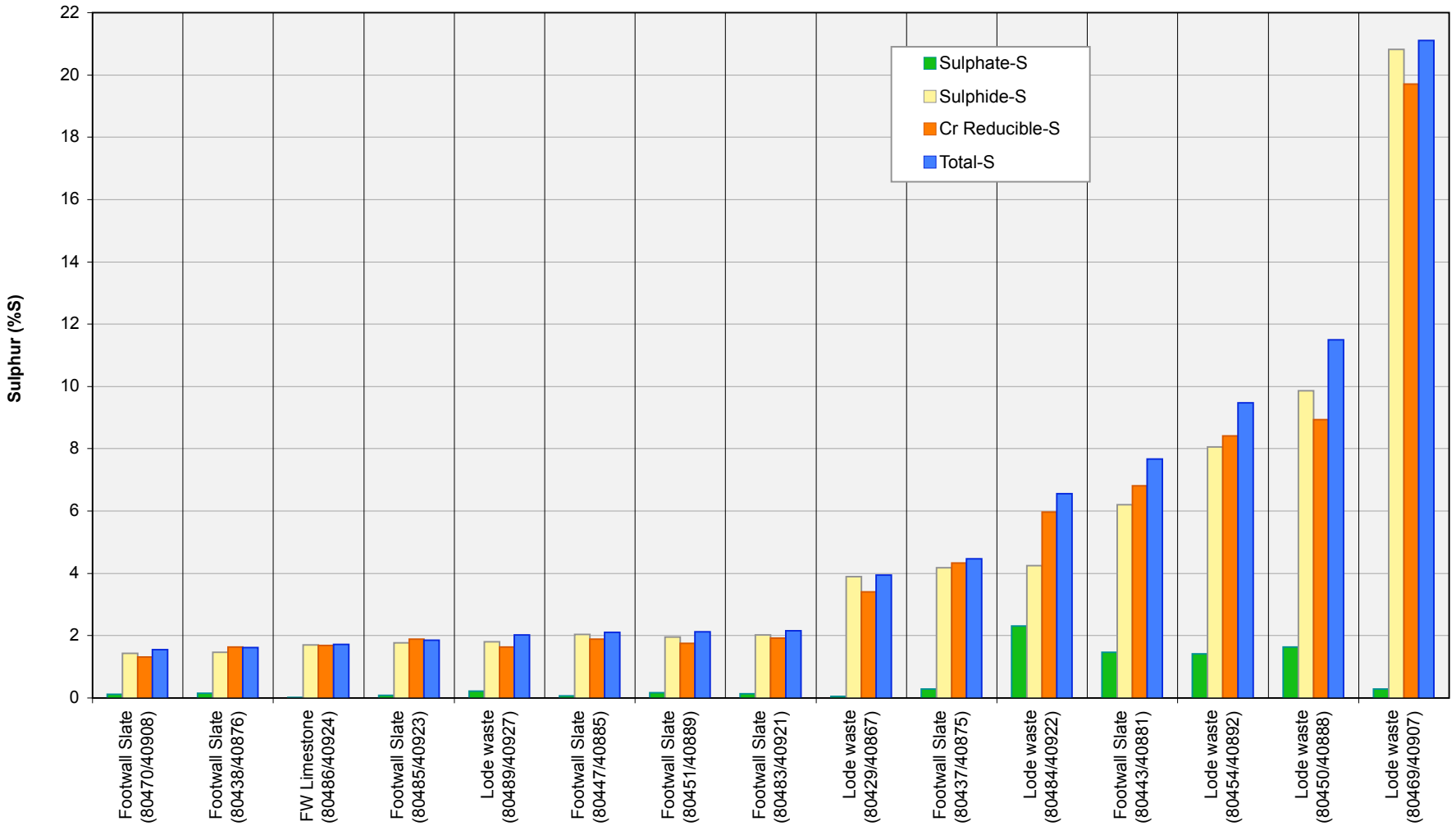
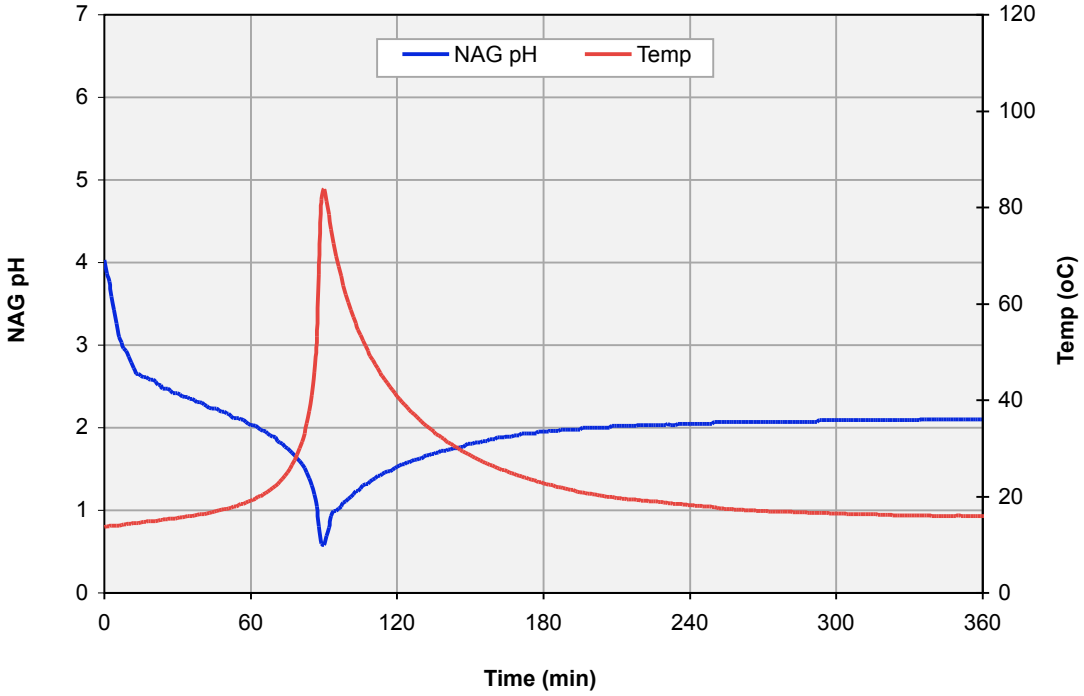
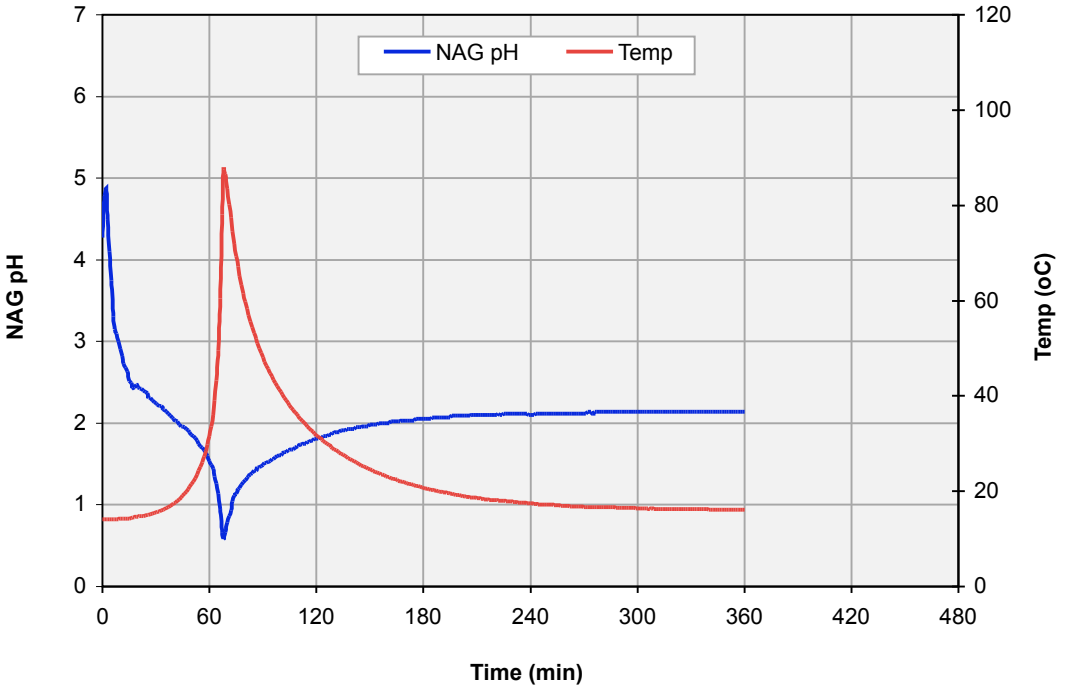


FIGURE 8: Sulphur speciation results for Dugald River waste rock



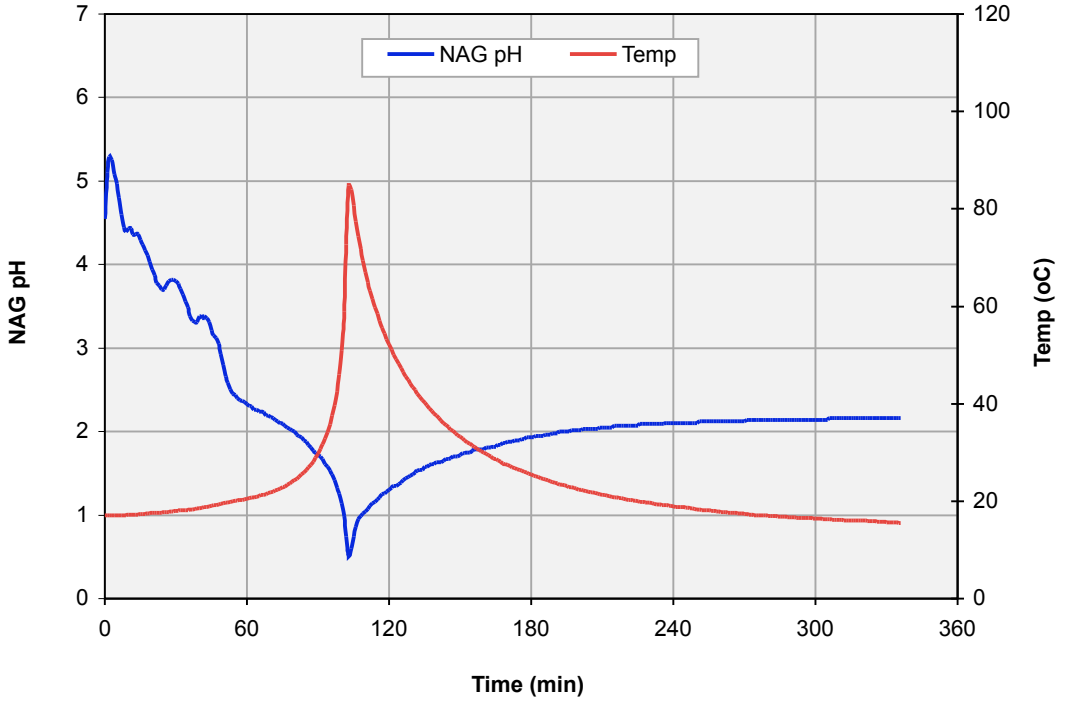
MMG Code = 80454 EGi Code = 40892
10.46%S, ANC = 34 kg H2SO4/t, NAPP = 286 kg H2SO4/t, NAGpH = 2.3

FIGURE 9(a): Kinetic NAG profiles for Dugald River waste rock - Lode waste



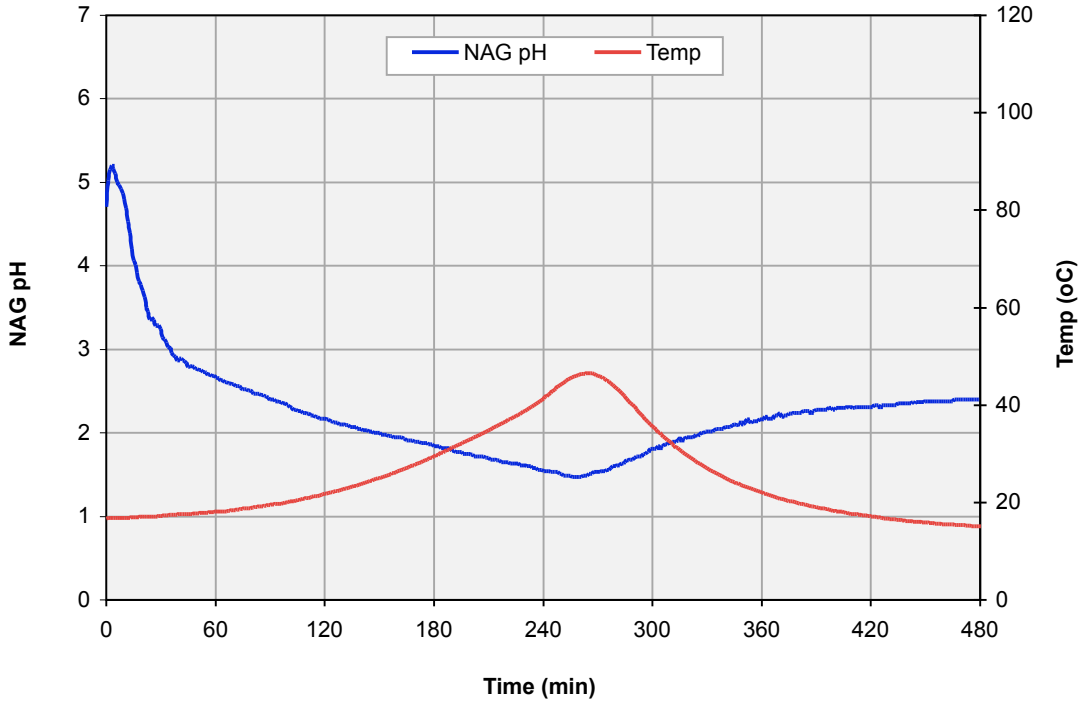
MMG Code = 80429 EGi Code = 40867
3.32%S, ANC = 19 kg H2SO4/t, NAPP = 83 kg H2SO4/t, NAGpH = 2.2

FIGURE 9(b): Kinetic NAG profiles for Dugald River waste rock - Lode waste



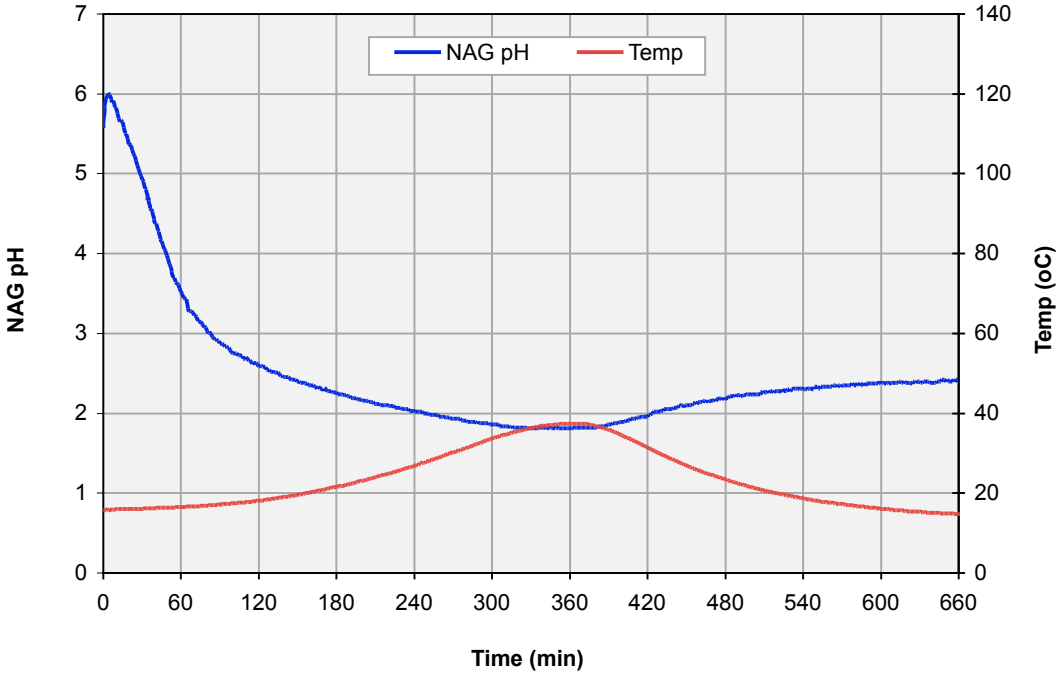
MMG Code = 80443 EGi Code = 40881
7.88%S, ANC = 21 kg H2SO4/t, NAPP = 220 kg H2SO4/t, NAGpH = 2.3

FIGURE 9(c): Kinetic NAG profiles for Dugald River waste rock - Foot wall slate



MMG Code = 80483 EGi Code = 40921
1.99%S, ANC = 9 kg H2SO4/t, NAPP = 52 kg H2SO4/t, NAGpH = 2.4

FIGURE 9(d): Kinetic NAG profiles for Dugald River waste rock - Hanging wall slate



MMG Code = 80438 EGi Code = 40876
1.66%S, ANC = 11 kg H2SO4/t, NAPP = 40 kg H2SO4/t, NAGpH = 2.4

FIGURE 9(e): Kinetic NAG profiles for Dugald River waste rock - Foot wall slate

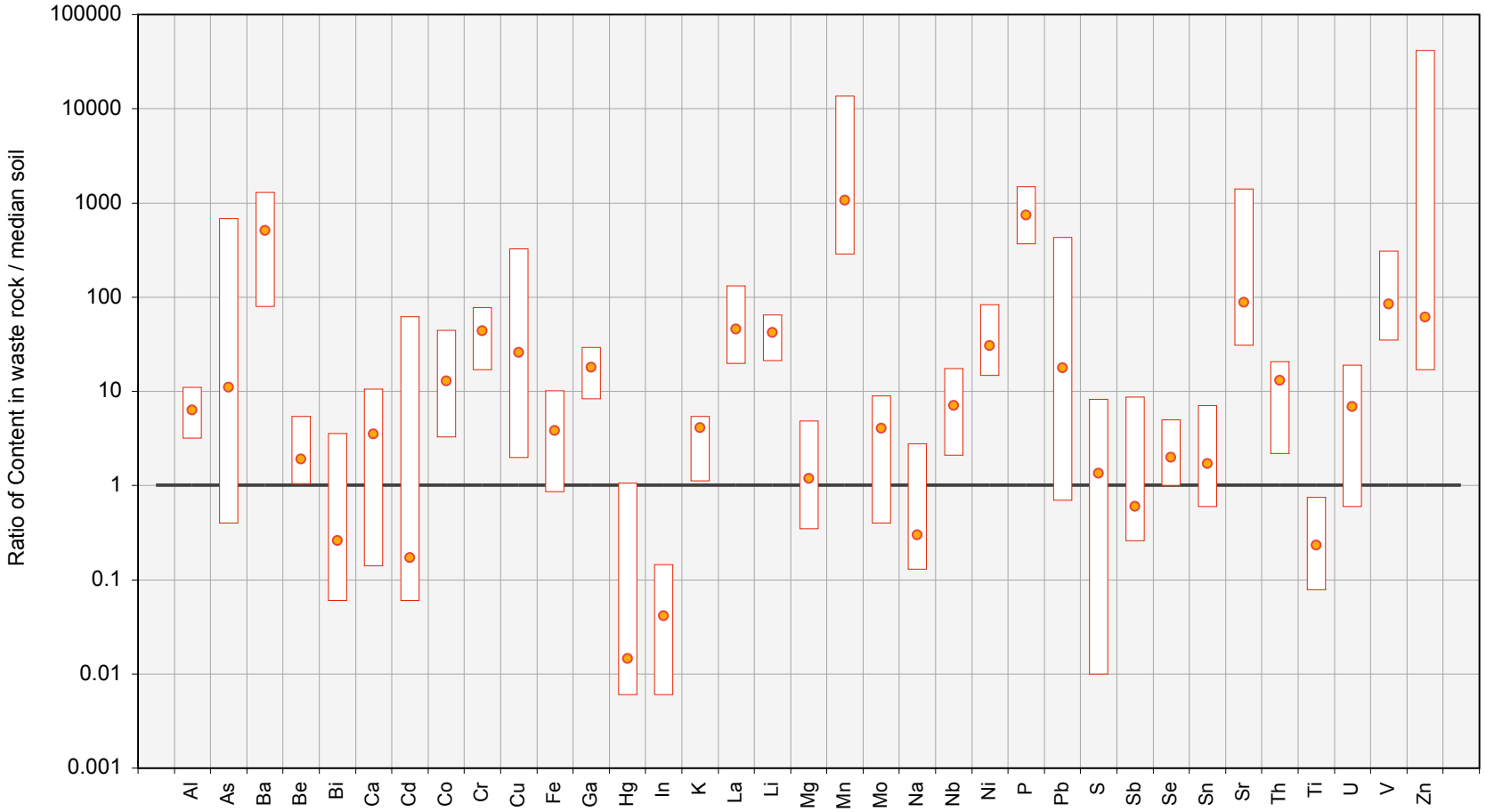


FIGURE 10: Box plot showing the ratios of element concentrations in Dugald River waste rock relative to median soil composition

(Bars = range in ratios Circles = median ratio)

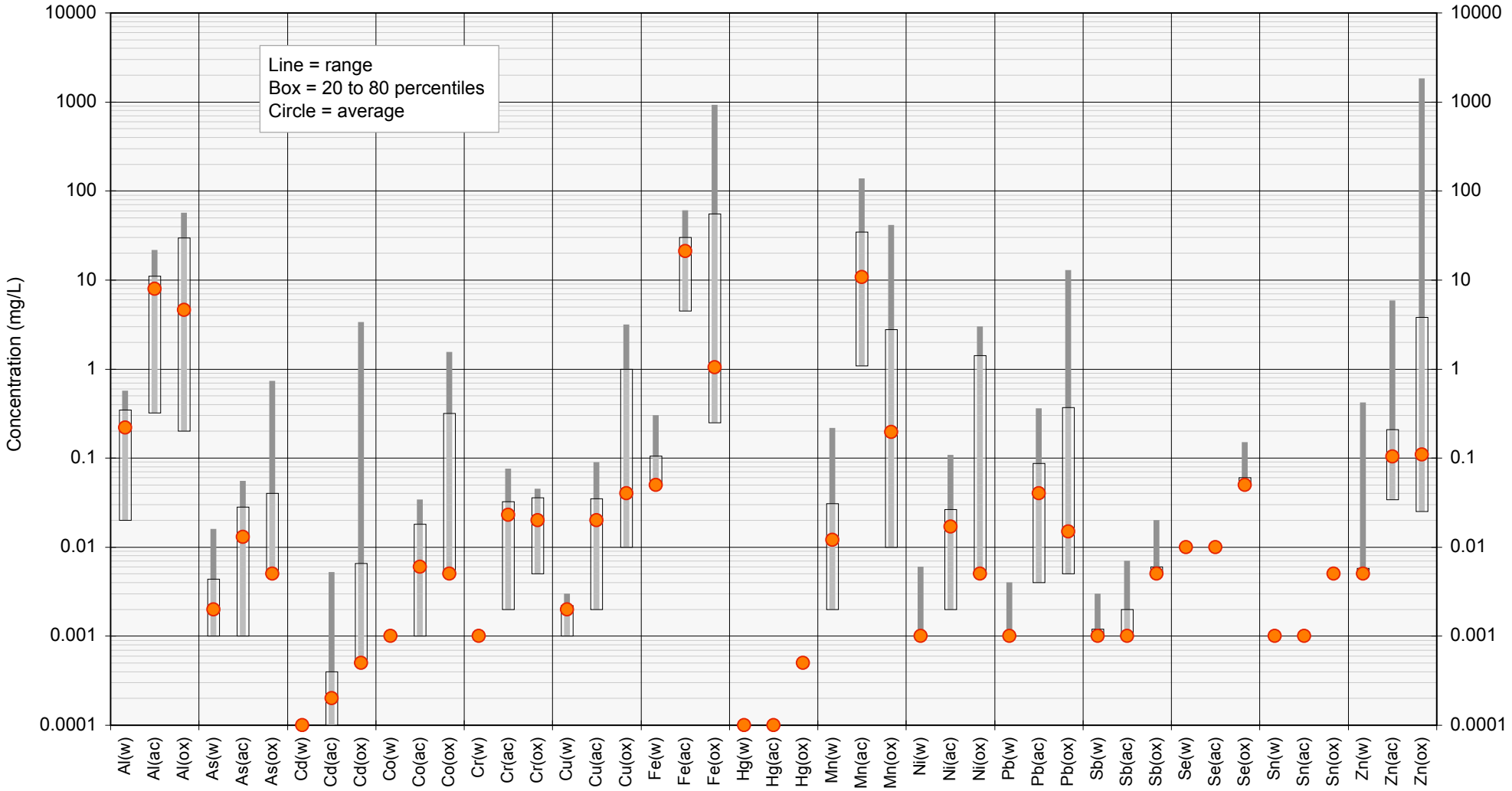


FIGURE 11: Statistical summary of extract assay data for water (w), acid (ac) and peroxide (ox) extraction tests fon Dugald River waste rock

(note: For comparison purposes the peroxide results were multiplied by a factor of 5 to simulate a solid:liquor ratio of 1:20 ratio as used in the water and acid extractions.

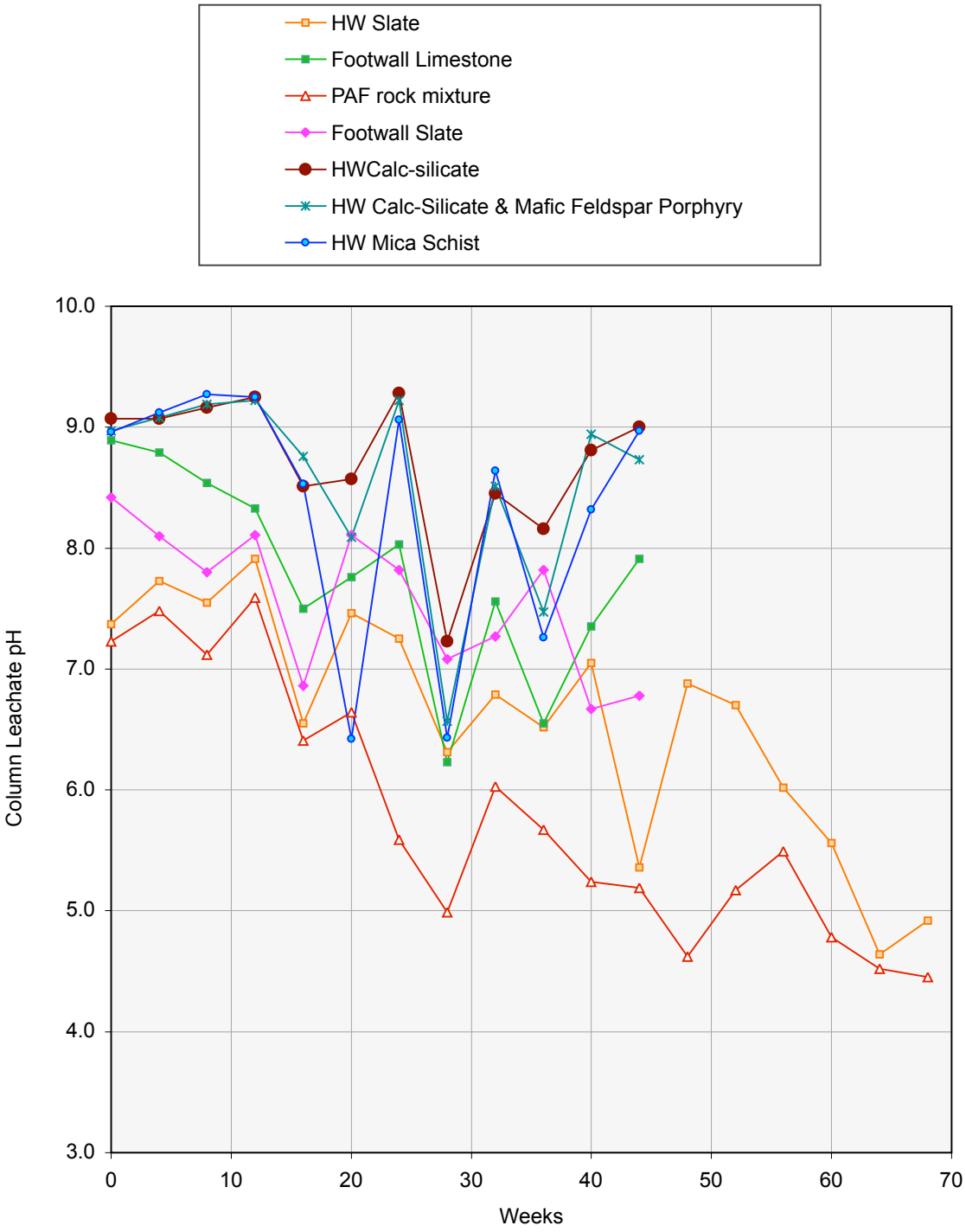


FIGURE 12: Plot of leachate pH for AARC column leach tests on Dugald River waste rock

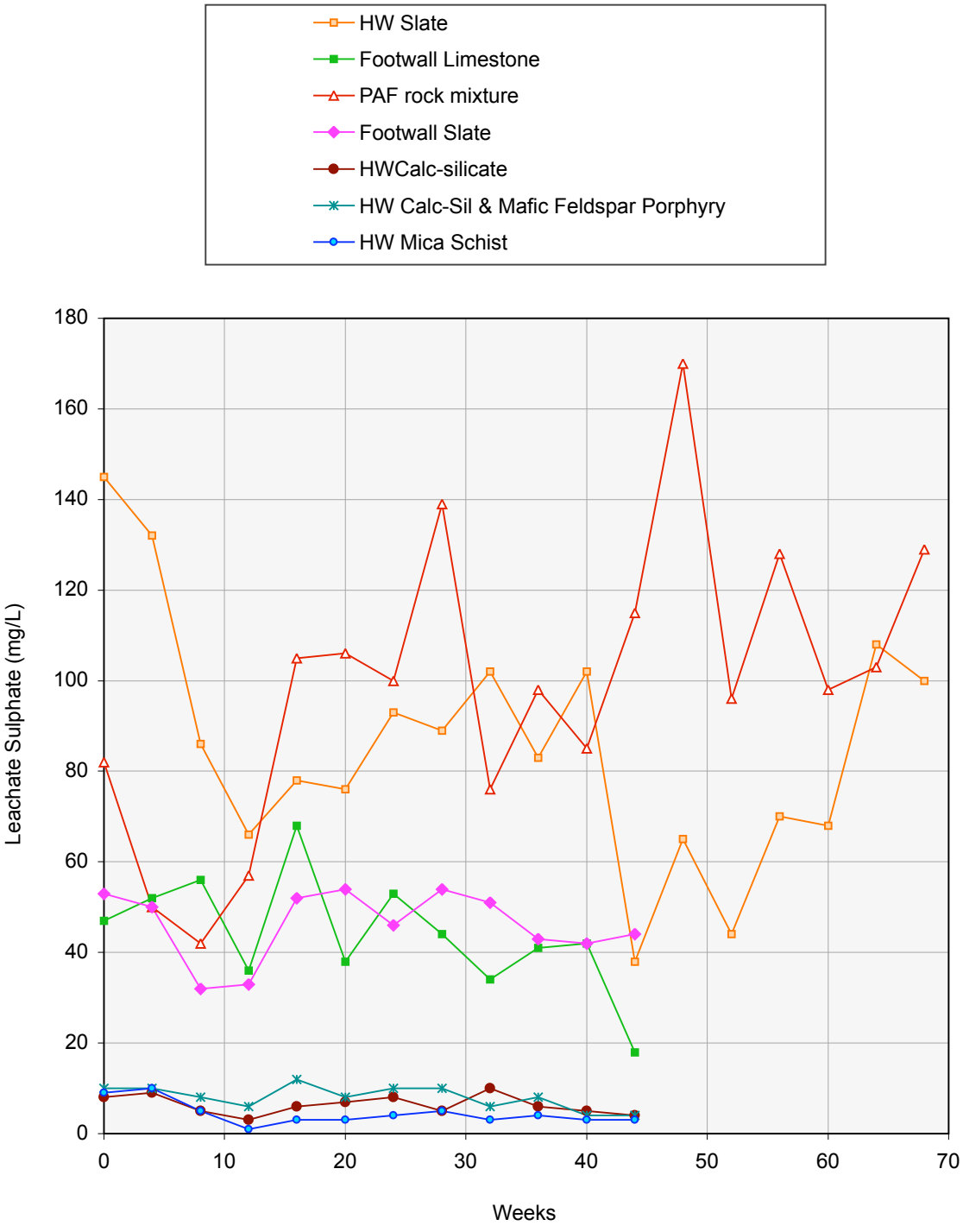


FIGURE 13: Plot of sulphate concentrations in leachates from AARC column leach tests on Dugald River waste rock

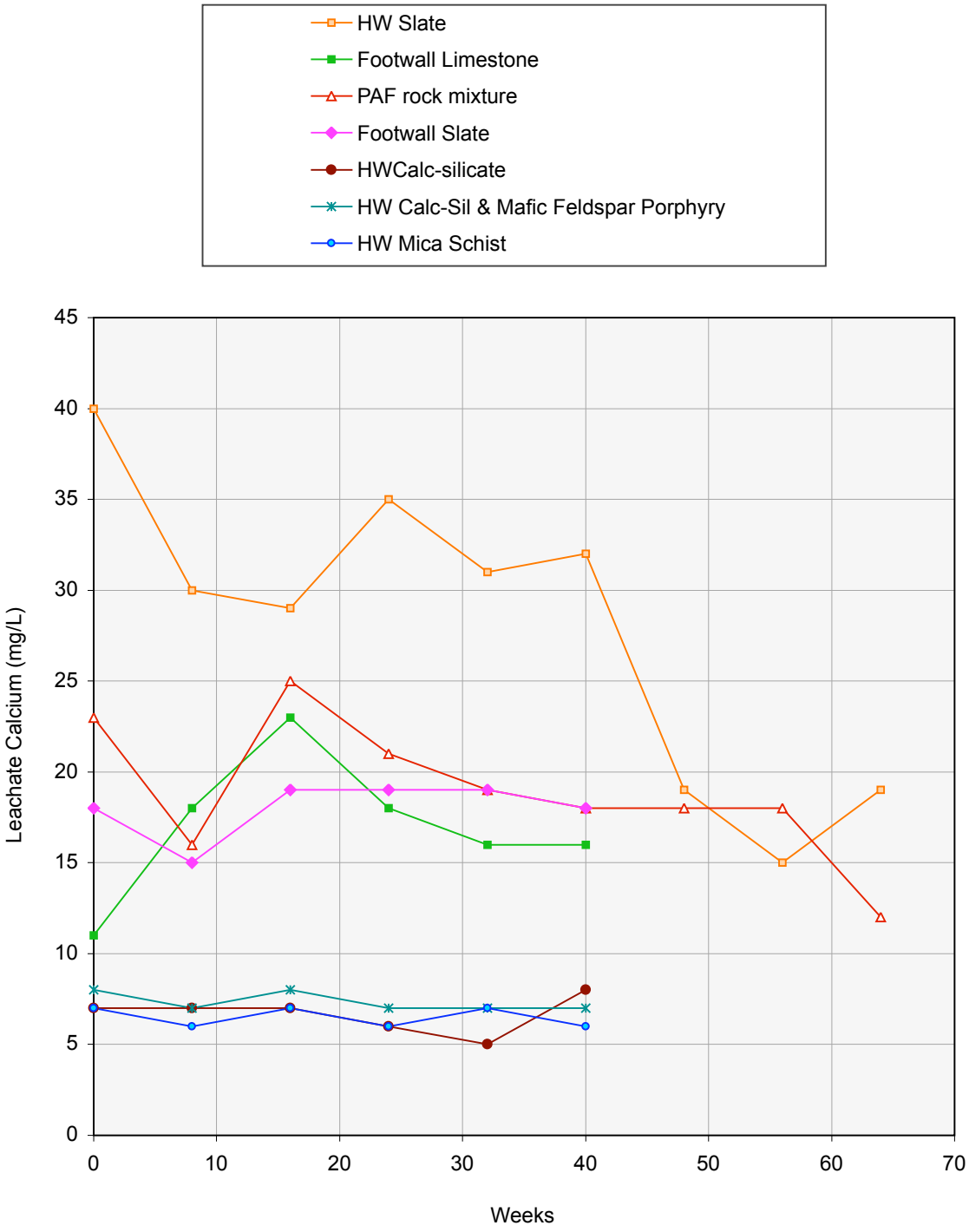


FIGURE 14: Plot of calcium concentrations in leachates from AARC column leach tests on Dugald River waste rock

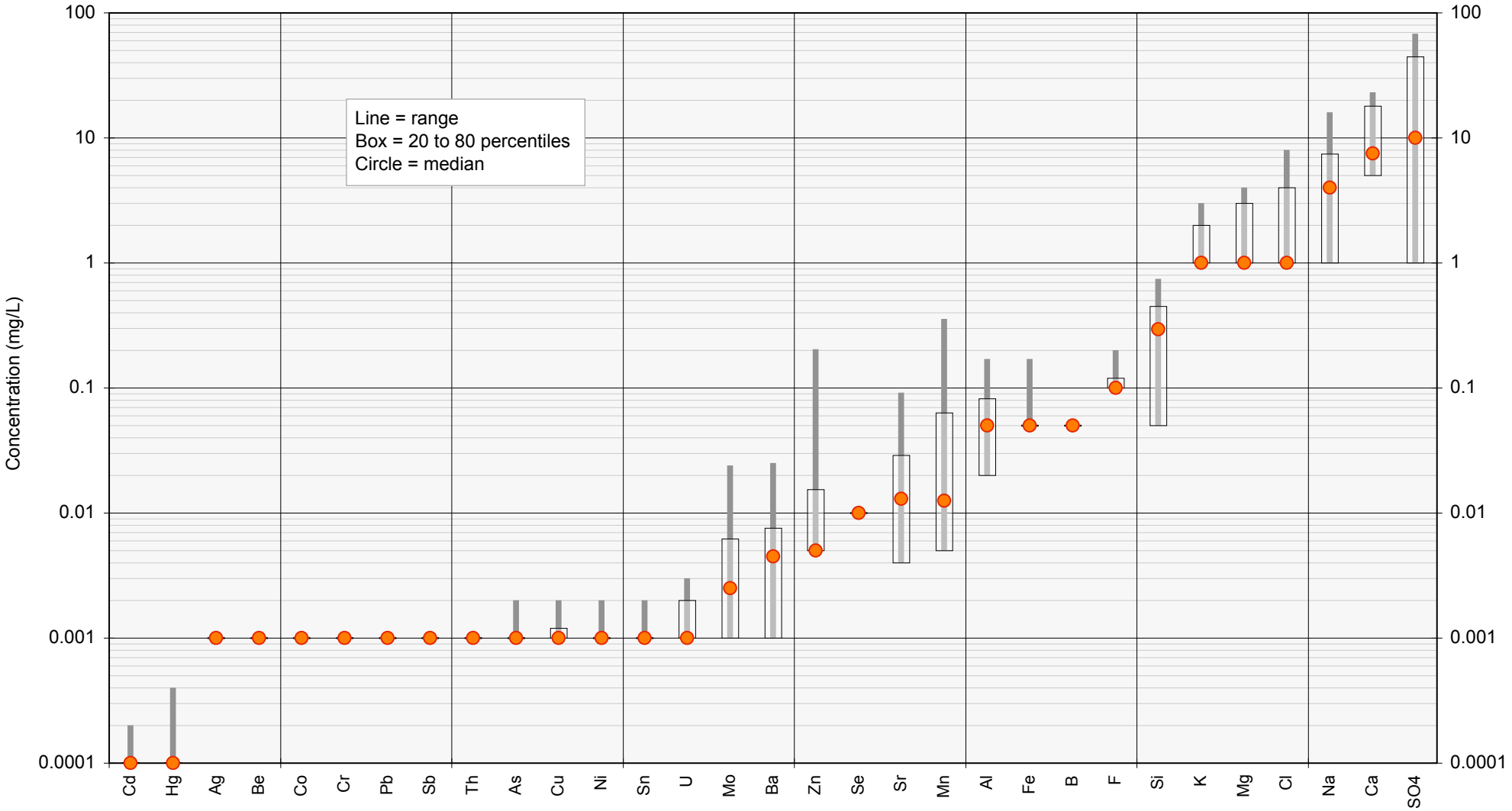


FIGURE 15: Statistical summary of AARC column leach assay data for samples comprising NAF Dugald River waste rock

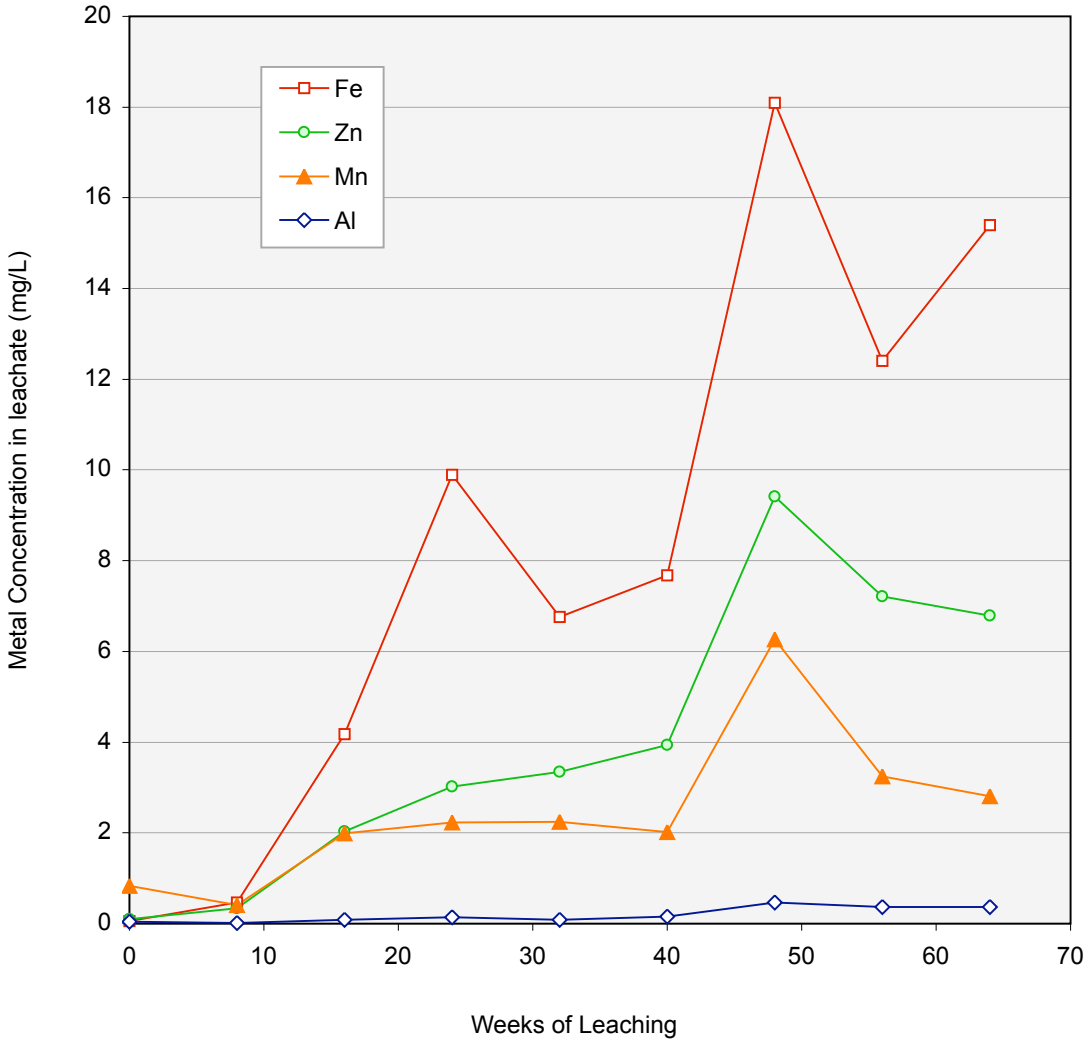


FIGURE 16: Plot of Fe, Zn, Mn and Al concentrations in leachate from Column 3 containing a PAF waste mixture

Appendix A

Acid Forming Characteristics of Drill Core Samples from Previous Geochemical Studies of Dugald River Waste Rock

AGC-Woodward Clyde (1991)

AustralAsian Resource Consultants (2008)

APPENDIX A : Acid forming characteristicsof drill core samples from previous geochemical studies of Dugald River waste rock

Study	Sample ID	Hole No.	From (m)	To (m)	Interval (m)	Lithology	EC	Existing pH	Total %S	MPA	ANC	ANC/MPA Ratio	NAPP	NAG	NAGpH	ARD Class
AGC-WWC 1991	-	229	700	701	1.0	Hanging wall slate	430	7.4	0.36	11	52	4.7	-41	-	-	NAF
AGC-WWC 1991	-	174	168	169	1.0	Hanging wall slate	1260	6.5	1.74	53	75	1.4	-22	-	-	NAF
AGC-WWC 1991	-	230	662	663	1.0	Hanging wall slate	370	7.9	1.25	38	15	0.4	23	-	-	**PAF**
AGC-WWC 1991	-	230	675	676	1.0	Hanging wall slate	890	7.35	2.88	88	23	0.3	65	-	-	**PAF**
AGC-WWC 1991	-	186	672	673	1.0	Hanging wall slate	1106	7.71	5.24	160	89	0.6	71	-	-	**PAF**
AGC-WWC 1991	-	231	491	492	1.0	Hanging wall slate	500	7.48	6.79	208	8	0.0	200	-	-	**PAF**
AGC-WWC 1991	-	174	171	172	1.0	Lode ore	640	7.3	15.3	468	225	0.5	244	-	-	**PAF**
AGC-WWC 1991	-	186	684	685	1.0	Lode ore	520	6.9	14.5	444	109	0.2	335	-	-	**PAF**
AGC-WWC 1991	-	229	720	721	1.0	Lode ore	607	8.1	12.2	373	22	0.1	352	-	-	**PAF**
AGC-WWC 1991	-	231	500	501	1.0	Lode ore	421	7.2	16.3	499	12	0.0	486	-	-	**PAF**
AGC-WWC 1991	-	230	684	685	1.0	Lode ore	910	6.4	20.1	615	22	0.0	593	-	-	**PAF**
AGC-WWC 1991	-	186	696	697	1.0	Footwall slate	310	8.1	1.08	33	159	4.8	-126	-	-	NAF
AGC-WWC 1991	-	230	703	704	1.0	Footwall slate	410	8	0.53	16	122	7.5	-106	-	-	NAF
AGC-WWC 1991	-	229	747	748	1.0	Footwall slate	472	8.14	3.91	120	206	1.7	-86	-	-	NAF
AGC-WWC 1991	-	174	180	181	1.0	Footwall slate	1230	7.1	1.58	48	112	2.3	-63	-	-	NAF
AGC-WWC 1991	-	231	508	509	1.0	Footwall slate	609	8	3.67	112	152	1.4	-40	-	-	NAF
AGC-WWC 1991	-	231	540	541	1.0	Footwall slate	300	9.1	0.7	21	109	5.1	-87	-	-	NAF
AGC-WWC 1991	-	217	1029	1030	1.0	Footwall slate	256	8.98	2.21	68	12	0.2	56	-	-	**PAF**
AGC-WWC 1991	-	202	792	793	1.0	Footwall slate	521	8.09	7.44	228	65	0.3	162	-	-	**PAF**
AGC-WWC 1991	-	186	824	825	1.0	Footwall limestone	305	8.3	0.97	30	221	7.4	-191	-	-	NAF
AGC-WWC 1991	-	174	185	186	1.0	Footwall limestone	820	7.65	2.12	65	215	3.3	-151	-	-	NAF
AGC-WWC 1991	-	217	1040	1041	1.0	Footwall limestone	210	9.1	0.84	26	130	5.0	-104	-	-	NAF
AGC-WWC 1991	-	230	760	761	1.0	Footwall limestone	330	8.3	0.92	28	10	0.3	18	-	-	**PAF**

APPENDIX A : *Continued*

Study	Sample ID	Hole No.	From (m)	To (m)	Interval (m)	Lithology	EC	Existing pH	Total %S	MPA	ANC	ANC/MPA Ratio	NAPP	NAG	NAGpH	ARD Class
AARC 2008	34180	DR319	121	121.5	0.5	Calc-silicate	319	9.0	0.01	0	688	2248	-688	0	11.5	NAF
AARC 2008	34189	DR322	132	132.5	0.5	Calc-silicate	173	9.5	0.01	0	381	1245	-381	0	11.3	NAF
AARC 2008	34181	DR319	121.5	122	0.5	Calc-silicate	135	9.6	0.01	0	367	-	-367	0	11.4	NAF
AARC 2008	34195	DR321	177.5	178	0.5	Calc-silicate	156	9.4	0.02	1	347	567	-346	0	11.1	NAF
AARC 2008	34188	DR322	129	129.5	0.5	Calc-silicate	206	9.3	0.04	1	332	271	-331	0	11.2	NAF
AARC 2008	34187	DR322	126	126.5	0.5	Calc-silicate	168	9.6	0.01	0	325	1062	-325	0	9.3	NAF
AARC 2008	34199	DR318	227	227.45	0.45	Calc-silicate	241	9.2	0.04	1	282	230	-281	0	11.3	NAF
AARC 2008	34046	DR342	107	107.5	0.5	Calc-silicate	122	9.5	0.02	1	240	392	-239	0	11.1	NAF
AARC 2008	34183	DR319	124.5	125	0.5	Calc-silicate	133	9.6	0.01	0	226	739	-226	0	11.5	NAF
AARC 2008	34174	DR320	112	112.5	0.5	Calc-silicate	154	9.5	0.11	3	218	65	-215	0	11.1	NAF
AARC 2008	34200	DR318	227.45	228	0.55	Calc-silicate	203	9.2	0.02	1	174	284	-173	0	11.0	NAF
AARC 2008	34182	DR319	124	124.5	0.5	Calc-silicate	153	9.5	0.01	0	169	552	-169	0	11.1	NAF
AARC 2008	34175	DR320	112.5	113	0.5	Calc-silicate	126	9.7	0.04	1	161	132	-160	0	11.4	NAF
AARC 2008	34026	DR342	106	106.5	0.5	Calc-silicate	123	9.4	0.01	0	160	523	-160	0	11.3	NAF
AARC 2008	34192	DR321	163	163.5	0.5	Calc-silicate	162	9.3	0.01	0	145	474	-145	0	9.2	NAF
AARC 2008	34198	DR318	225	225.5	0.5	Calc-silicate	200	9.4	0.01	0	133	435	-133	0	11.1	NAF
AARC 2008	34196	DR318	219	219.5	0.5	Calc-silicate	175	9.4	0.03	1	124	135	-123	0	10.9	NAF
AARC 2008	34193	DR321	166	166.5	0.5	Calc-silicate	134	9.5	0.01	0	112	366	-112	0	9.0	NAF
AARC 2008	34027	DR342	106.5	107	0.5	Calc-silicate	140	9.3	0.03	1	109	119	-108	0	11.4	NAF
AARC 2008	34197	DR318	222	222.5	0.5	Calc-silicate	141	9.5	0.01	0	91	-	-91	0	11.0	NAF
AARC 2008	34194	DR321	177	177.5	0.5	Calc-silicate	193	9.5	0.01	0	47	-	-47	0	10.2	NAF
AARC 2008	34009	DR346	140	140.5	0.5	Calc-silicate	121	9.3	0.02	1	31	50	-30	0	10.4	NAF
AARC 2008	34008	DR346	127.5	128	0.5	Calc-silicate	97	9.4	0.02	1	9	15	-9	0	7.0	NAF
AARC 2008	34029	DR342	151.5	152	0.5	Mafic feldspar porphyry	154	9.4	0.01	0	401	1310	-401	0	10.4	NAF
AARC 2008	34028	DR342	151	151.5	0.5	Mafic feldspar porphyry	132	9.8	0.01	0	45	-	-45	0	9.2	NAF
AARC 2008	34010	DR346	162.5	163	0.5	Mafic feldspar porphyry	107	9.5	0.01	0	21	-	-21	0	9.4	NAF
AARC 2008	34179	DR320	216.5	217	0.5	White mica schist	197	9.2	0.2	6	252	41	-246	0	11.2	NAF
AARC 2008	34177	DR320	212.5	213	0.5	White mica schist	163	9.5	0.01	0	222	725	-222	0	11.4	NAF
AARC 2008	34178	DR320	216	216.5	0.5	White mica schist	256	9.4	0.01	0	153	500	-153	0	11.4	NAF
AARC 2008	34176	DR320	212	212.5	0.5	White mica schist	189	9.3	0.02	1	138	225	-137	0	11.4	NAF
AARC 2008	34202	DR316	266	266.5	0.5	White mica schist	179	9.5	0.02	1	46	76	-46	0	9.2	NAF
AARC 2008	34205	DR316	272	272.5	0.5	White mica schist	151	9.7	0.02	1	34	56	-34	0	7.7	NAF
AARC 2008	34203	DR316	268	268.5	0.5	White mica schist	128	9.7	0.04	1	33	27	-32	0	7.2	NAF
AARC 2008	34204	DR316	270	270.5	0.5	White mica schist	137	9.7	0.01	0	32	105	-32	0	6.8	NAF
AARC 2008	34030	DR342	260	260.5	0.5	White mica schist	86	9.5	0.06	2	33	18	-31	0	9.3	NAF
AARC 2008	34201	DR316	264	264.5	0.5	White mica schist	132	9.6	0.02	1	31	50	-30	0	7.9	NAF
AARC 2008	34031	DR342	260.5	261	0.5	White mica schist	75	9.6	0.02	1	9	15	-9	0	7.8	NAF
AARC 2008	34047	DR342	273	273.5	0.5	White mica schist	68	9.7	0.03	1	10	10	-9	0	7.2	NAF
AARC 2008	34032	DR342	272.5	273	0.5	White mica schist	89	9.6	0.24	7	10	1.4	-3	1	4.4	UC (PAF)

APPENDIX A : *Continued*

Study	Sample ID	Hole No.	From (m)	To (m)	Interval (m)	Lithology	EC	Existing pH	Total %S	MPA	ANC	ANC/MPA Ratio	NAPP	NAG	NAGpH	ARD Class
AARC 2008	34035	DR342	363.5	364	0.5	Hanging wall slate	206	8.9	2.28	70	276	4.0	-206	0	8.0	NAF
AARC 2008	34033	DR342	362.5	363	0.5	Hanging wall slate	352	8.6	4.14	127	312	2.5	-185	0	8.1	NAF
AARC 2008	34034	DR342	363	363.5	0.5	Hanging wall slate	330	8.7	3.81	117	293	2.5	-176	0	7.8	NAF
AARC 2008	34191	DR322	162	162.5	0.5	Hanging wall slate	170	9.6	0.09	3	142	52	-139	0	11.1	NAF
AARC 2008	34037	DR342	364.5	365	0.5	Hanging wall slate	352	8.6	5.38	165	273	1.7	-108	0	8.0	NAF
AARC 2008	34039	DR342	365.5	366	0.5	Hanging wall slate	211	9.0	1.89	58	158	2.7	-100	0	8.1	NAF
AARC 2008	34165	DR315	102.5	103	0.5	Hanging wall slate	431	8.4	3.3	101	141	1.4	-40	0	8.3	NAF
AARC 2008	34038	DR342	365	365.5	0.5	Hanging wall slate	279	8.8	2.01	62	95	1.5	-33	0	7.9	NAF
AARC 2008	34052	DR341	111.5	112	0.5	Hanging wall slate	127	9.2	0.29	9	26	2.9	-17	0	7.9	NAF
AARC 2008	34051	DR341	111	111.5	0.5	Hanging wall slate	120	9.2	0.52	16	31	1.9	-15	0	8.4	NAF
AARC 2008	34014	DR346	409.5	410	0.5	Hanging wall slate	178	9.1	0.65	20	32	1.6	-12	0	8.6	NAF
AARC 2008	34190	DR322	157	157.5	0.5	Hanging wall slate	174	9.7	0.07	2	11	5	-9	0	7.5	NAF
AARC 2008	34049	DR341	99	99.5	0.5	Hanging wall slate	111	9.4	0.77	24	29	1.2	-5	0	9.0	NAF
AARC 2008	34036	DR342	364	364.5	0.5	Hanging wall slate	398	8.6	4.35	133	136	1.0	-3	0	7.9	NAF
AARC 2008	34015	DR346	410	410.5	0.5	Hanging wall slate	205	9.1	1.13	35	32	0.9	3	0	8.5	UC (NAF)
AARC 2008	34159	DR315	84.5	85	0.5	Hanging wall slate	591	8.6	4.11	126	67	0.5	59	0	7.6	UC (PAF)
AARC 2008	34066	DR340	126.5	127	0.5	Hanging wall slate	114	9.2	0.56	17	12	0.7	5	10	3.0	PAF
AARC 2008	34018	DR346	414.5	415	0.5	Hanging wall slate	172	9.2	0.68	21	14	0.7	7	8	2.8	PAF
AARC 2008	34017	DR346	414	414.5	0.5	Hanging wall slate	162	9.3	0.87	27	14	0.5	13	12	2.7	PAF
AARC 2008	34064	DR340	123	123.5	0.5	Hanging wall slate	139	9.4	0.72	22	8	0.3	14	16	2.8	PAF
AARC 2008	34050	DR341	99.5	100	0.5	Hanging wall slate	122	9.5	0.89	27	10	0.4	17	19	2.6	PAF
AARC 2008	34053	DR341	123	123.5	0.5	Hanging wall slate	89	8.8	0.91	28	5	0.2	23	25	2.6	PAF
AARC 2008	34162	DR315	101	101.5	0.5	Hanging wall slate	143	9.4	1.25	38	15	0.4	23	26	3.2	PAF
AARC 2008	34067	DR340	127	127.5	0.5	Hanging wall slate	185	8.2	1.31	40	8	0.2	32	35	2.6	PAF
AARC 2008	34054	DR341	123.5	124	0.5	Hanging wall slate	96	8.7	1.29	39	6	0.1	34	37	2.6	PAF
AARC 2008	34065	DR340	124.7	125.2	0.5	Hanging wall slate	106	9.0	1.3	40	5	0.1	34	33	2.6	PAF
AARC 2008	34158	DR315	84	84.5	0.5	Hanging wall slate	188	9.1	2.27	69	32	0.5	37	38	2.8	PAF
AARC 2008	34161	DR315	90.5	91	0.5	Hanging wall slate	399	8.6	3.24	99	38	0.4	61	55	2.6	PAF
AARC 2008	34160	DR315	90	90.5	0.5	Hanging wall slate	421	8.4	2.64	81	14	0.2	67	54	2.5	PAF
AARC 2008	34069	DR340	130.5	131	0.5	Hanging wall slate	660	8.0	2.57	79	6	0.1	72	68	2.4	PAF
AARC 2008	34011	DR346	402.5	403	0.5	Hanging wall slate	195	8.5	2.76	84	8	0.1	76	73	2.4	PAF
AARC 2008	34164	DR315	102	102.5	0.5	Hanging wall slate	316	8.3	3.69	113	26	0.2	87	80	2.7	PAF
AARC 2008	34016	DR346	410.5	411	0.5	Hanging wall slate	253	8.7	5.64	173	79	0.5	94	56	2.5	PAF
AARC 2008	34068	DR340	130	130.5	0.5	Hanging wall slate	515	8.1	3.55	109	10	0.1	99	90	2.2	PAF
AARC 2008	34040	DR342	376	377.5	1.5	Hanging wall slate	690	8.0	7.64	234	45	0.2	188	138	2.2	PAF
AARC 2008	34012	DR346	403	403.5	0.5	Hanging wall slate	239	7.6	7.18	220	6	0.0	214	144	2.2	PAF
AARC 2008	34013	DR346	403.5	404	0.5	Hanging wall slate	428	8.0	12.3	376	11	0.0	365	204	2.0	PAF
AARC 2008	34163	DR315	101.5	102	0.5	Hanging wall slate	581	8.2	14.4	441	20	0.0	421	198	2.3	PAF

APPENDIX A : *Continued*

Study	Sample ID	Hole No.	From (m)	To (m)	Interval (m)	Lithology	EC	Existing pH	Total %S	MPA	ANC	ANC/MPA Ratio	NAPP	NAG	NAGpH	ARD Class
AARC 2008	34184	DR319	399	400	1.0	Lode waste	276	9.0	6.87	210	397	2	-187	0	7.6	NAF
AARC 2008	34042	DR342	418.5	419.5	1.0	Lode waste	120	9.5	2.18	67	208	3.1	-141	0	7.9	NAF
AARC 2008	34019	DR346	434.5	435	0.5	Lode waste	260	7.9	1.24	38	7	0.2	31	31	2.7	PAF
AARC 2008	34020	DR346	435.5	436	0.5	Lode waste	139	9.1	1.63	50	10	0.2	40	32	2.6	PAF
AARC 2008	34166	DR315	270.5	271.5	1.0	Lode waste	412	8.1	4.66	143	18	0.1	125	115	2.3	PAF
AARC 2008	34070	DR340	141.5	142.5	1.0	Lode waste	172	8.6	6.75	207	9	0.0	197	133	2.2	PAF
AARC 2008	34173	DR332	414.5	415.4	0.9	Lode waste	270	9.0	8.82	270	11	0.0	259	183	2.2	PAF
AARC 2008	34071	DR340	142.5	143.5	1.0	Lode waste	238	6.7	13.7	419	5	0.0	414	186	2.0	PAF
AARC 2008	34059	DR341	146.5	147.5	1.0	Lode waste	255	8.3	15.4	471	7	0.0	465	215	2.1	PAF
AARC 2008	34058	DR341	137	138	1.0	Lode waste	186	8.5	16.6	508	8	0.0	500	200	2.1	PAF
AARC 2008	34072	DR340	159	159.5	0.5	Footwall slate	334	8.9	0.92	28	148	5.3	-120	0	7.9	NAF
AARC 2008	34075	DR340	160.5	161	0.5	Footwall slate	309	8.8	1.11	34	141	4.2	-107	0	8.2	NAF
AARC 2008	34074	DR340	160	160.5	0.5	Footwall slate	558	8.5	0.98	30	115	3.8	-85	0	8.2	NAF
AARC 2008	34077	DR340	161.5	162	0.5	Footwall slate	138	9.3	1.03	32	113	3.6	-81	0	8.1	NAF
AARC 2008	34061	DR341	157.5	158	0.5	Footwall slate	87	9.4	0.45	14	93	6.8	-79	0	8.2	NAF
AARC 2008	34076	DR340	161	161.5	0.5	Footwall slate	160	9.1	1.01	31	107	3.5	-76	0	8.2	NAF
AARC 2008	34168	DR315	273.2	273.7	0.5	Footwall slate	233	9.2	1.18	36	111	3.1	-75	0	8.5	NAF
AARC 2008	34073	DR340	159.5	160	0.5	Footwall slate	289	8.9	0.67	21	92	4.5	-72	0	8.0	NAF
AARC 2008	34062	DR341	162	162.5	0.5	Footwall slate	103	9.4	0.89	27	89	3.3	-62	0	8.2	NAF
AARC 2008	34167	DR315	272.7	273.2	0.5	Footwall slate	146	9.3	1.2	37	98	2.7	-61	0	8.6	NAF
AARC 2008	34063	DR341	162.5	163	0.5	Footwall slate	97	9.5	0.72	22	76	3.4	-53	0	8.4	NAF
AARC 2008	34060	DR341	157	157.5	0.5	Footwall slate	124	9.4	1.49	46	48	1.0	-2	0	8.1	NAF
AARC 2008	34048	DR342	424	425	1.0	Footwall slate	222	8.9	14.6	447	244	0.5	203	0	8.3	UC (PAF)
AARC 2008	34022	DR346	432.9	433.3	0.4	Footwall slate	134	8.8	1.27	39	12	0.3	27	25	2.3	PAF
AARC 2008	34021	DR346	432.5	432.9	0.4	Footwall slate	220	8.7	1.55	47	11	0.2	37	34	2.6	PAF
AARC 2008	34041	DR342	423	424	1.0	Footwall slate	208	8.6	13.8	422	32	0.1	390	133	2.1	PAF
AARC 2008	34186	DR319	446	446.5	0.5	Footwall limestone	262	9.3	1.27	39	552	14	-513	0	8.7	NAF
AARC 2008	34078	DR340	185	185.5	0.5	Footwall limestone	144	9.4	0.94	29	272	9.5	-243	0	9.0	NAF
AARC 2008	34055	DR341	177	177.5	0.5	Footwall limestone	110	9.4	0.36	11	251	23	-240	0	9.7	NAF
AARC 2008	34057	DR341	183	183.5	0.5	Footwall limestone	115	9.5	0.77	24	244	10	-220	0	9.0	NAF
AARC 2008	34079	DR340	185.5	186	0.5	Footwall limestone	138	9.4	1.21	37	253	6.8	-216	0	8.6	NAF
AARC 2008	34080	DR340	186	186.5	0.5	Footwall limestone	159	9.3	1.34	41	249	6.1	-208	0	9.8	NAF
AARC 2008	34172	DR315	292.5	293	0.5	Footwall limestone	226	9.2	1.76	54	250	4.6	-196	0	8.6	NAF
AARC 2008	34185	DR319	441	441.5	0.5	Footwall limestone	158	9.6	1.07	33	225	7	-192	0	9.6	NAF
AARC 2008	34056	DR341	177.5	178	0.5	Footwall limestone	125	9.4	1.92	59	241	4.1	-182	0	8.9	NAF
AARC 2008	34043	DR342	458	458.5	0.5	Footwall limestone	106	9.7	1.01	31	178	5.8	-147	0	8.7	NAF
AARC 2008	34025	DR346	496	496.5	0.5	Footwall limestone	143	9.4	1.25	38	180	5	-142	0	8.3	NAF
AARC 2008	34045	DR342	471	471.5	0.5	Footwall limestone	109	9.7	1.15	35	166	4.7	-131	0	8.3	NAF

APPENDIX A : *Continued*

Study	Sample ID	Hole No.	From (m)	To (m)	Interval (m)	Lithology	EC	Existing pH	Total %S	MPA	ANC	ANC/MPA Ratio	NAPP	NAG	NAGpH	ARD Class
AARC 2008	37335	DR342	460.1	460.4	0.3	Footwall limestone	168	9.6	0.76	23	142	6.1	-119	0	9.0	NAF
AARC 2008	34171	DR315	292	292.5	0.5	Footwall limestone	186	9.4	1.66	51	153	3.0	-102	0	8.7	NAF
AARC 2008	34170	DR315	281.5	282	0.5	Footwall limestone	234	9.3	1.09	33	116	3.5	-83	0	8.4	NAF
AARC 2008	34024	DR346	492	492.5	0.5	Footwall limestone	126	9.5	0.46	14	89	6	-75	0	8.6	NAF
AARC 2008	34023	DR346	490.5	491	0.5	Footwall limestone	144	9.4	0.63	19	89	5	-70	0	8.9	NAF
AARC 2008	34169	DR315	281	281.5	0.5	Footwall limestone	182	9.4	1.35	41	93	2.3	-52	0	8.6	NAF

Appendix B

Multi-Element Data and Geochemical Abundance Indices for Drill Core Samples from Previous Geochemical Studies of Dugald River Waste Rock

AGC-Woodward Clyde (1991)

AustralAsian Resource Consultants (2008)

APPENDIX B-1: Multi-element data for drill core samples from previous geochemical studies of Dugald River waste rock

Study	Sample ID	Hole No.	From (m)	To (m)	Lithology	ARD Class	As (mg/kg)	Ba (mg/kg)	Be (mg/kg)	Cd (mg/kg)	Co (mg/kg)	Cr (mg/kg)	Cu (mg/kg)	Hg (mg/kg)	Mn (mg/kg)	Ni (mg/kg)	Pb (mg/kg)	S (%)	Sb (mg/kg)	V (mg/kg)	Zn (mg/kg)
AGC-WWC 1991	-	229	700	701	Hanging wall slate	NAF	46	-	-	1	10	-	10	0.05	-	-	120	0.4%	5	-	470
AGC-WWC 1991	-	174	168	169	Hanging wall slate	NAF	80	-	-	1	5	-	250	0.1	-	-	250	1.7%	5	-	670
AGC-WWC 1991	-	230	662	663	Hanging wall slate	PAF	18	-	-	1	30	-	1650	0.05	-	-	25	1.3%	5	-	220
AGC-WWC 1991	-	230	675	676	Hanging wall slate	PAF	85	-	-	1	10	-	90	0.1	-	-	310	2.9%	5	-	1250
AGC-WWC 1991	-	186	672	673	Hanging wall slate	PAF	75	-	-	2	45	-	250	0.1	-	-	230	5.2%	5	-	640
AGC-WWC 1991	-	231	491	492	Hanging wall slate	PAF	19	-	-	1	25	-	250	0.05	-	-	45	6.8%	5	-	95
AGC-WWC 1991	-	174	171	172	Lode ore	PAF	65	-	-	240	30	-	470	4.4	-	-	1.52%	15.3%	25	-	11.9%
AGC-WWC 1991	-	186	684	685	Lode ore	PAF	450	-	-	330	15	-	195	5.3	-	-	6.84%	14.5%	140	-	13.8%
AGC-WWC 1991	-	229	720	721	Lode ore	PAF	65	-	-	125	5	-	145	1.45	-	-	1.78%	12.2%	5	-	8.8%
AGC-WWC 1991	-	231	500	501	Lode ore	PAF	520	-	-	210	30	-	70	2	-	-	5200	16.3%	5	-	8.4%
AGC-WWC 1991	-	230	684	685	Lode ore	PAF	210	-	-	290	20	-	85	2	-	-	3.24%	20.1%	5	-	14.6%
AGC-WWC 1991	-	186	696	697	Footwall slate	NAF	36	-	-	8	5	-	25	0.1	-	-	220	1.1%	5	-	3950
AGC-WWC 1991	-	230	703	704	Footwall slate	NAF	100	-	-	1	5	-	25	0.05	-	-	45	0.5%	5	-	490
AGC-WWC 1991	-	231	540	541	Footwall slate	NAF	24	-	-	1	5	-	25	0.05	-	-	30	0.7%	5	-	510
AGC-WWC 1991	-	229	747	748	Footwall slate	NAF	230	-	-	12	10	-	60	0.15	-	-	110	3.9%	5	-	1600
AGC-WWC 1991	-	174	180	181	Footwall slate	NAF	18	-	-	1	5	-	115	0.1	-	-	60	1.6%	5	-	730
AGC-WWC 1991	-	231	508	509	Footwall slate	NAF	155	-	-	44	15	-	30	0.55	-	-	175	3.7%	5	-	2.6%
AGC-WWC 1991	-	217	1029	1030	Footwall slate	PAF	60	-	-	6	5	-	65	0.15	-	-	420	2.2%	5	-	3800
AGC-WWC 1991	-	202	792	793	Footwall slate	PAF	210	-	-	14	25	-	45	1.5	-	-	1150	7.4%	5	-	2.8%
AGC-WWC 1991	-	186	824	825	Footwall limestone	NAF	38	-	-	1	5	-	40	0.05	-	-	110	1.0%	5	-	330
AGC-WWC 1991	-	174	185	186	Footwall limestone	NAF	105	-	-	1	20	-	95	0.05	-	-	45	2.1%	5	-	350
AGC-WWC 1991	-	217	1040	1041	Footwall limestone	NAF	85	-	-	1	10	-	50	0.05	-	-	80	0.8%	5	-	250
AGC-WWC 1991	-	230	760	761	Footwall limestone	PAF	12	-	-	1	10	-	40	0.05	-	-	85	0.9%	5	-	400

* Note: Samples in the AGC-Woodward Clyde (1991) study were also assayed for bismuth but the concentrations in all samples were at or below the analytical detection limit of 5 mg/kg.
As the detection limit was particularly high in comparison to typical soil values, the bismuth assay results were not considered in the current review.

APPENDIX B-1 : *Continued*

Study	Sample ID	Hole No.	From (m)	To (m)	Lithology	ARD Class	As (mg/kg)	Ba (mg/kg)	Be (mg/kg)	Cd (mg/kg)	Co (mg/kg)	Cr (mg/kg)	Cu (mg/kg)	Hg (mg/kg)	Mn (mg/kg)	Ni (mg/kg)	Pb (mg/kg)	S (%)	Sb (mg/kg)	V (mg/kg)	Zn (mg/kg)
AARC 2008	34009	DR346	140	140.5	Calc-silicate	NAF	5	60	2	1	15	37	5	0.1	596	28	5	0.02%	-	43	16
AARC 2008	34027	DR342	106.5	107	Calc-silicate	NAF	5	130	1	1	9	28	5	0.1	740	24	5	0.03%	-	42	5
AARC 2008	34174	DR320	112	112.5	Calc-silicate	NAF	5	40	1	1	2	8	9	0.1	694	12	18	0.1%	-	15	162
AARC 2008	34180	DR319	121	121.5	Calc-silicate	NAF	5	<10	1	1	2	10	7	0.1	1900	5	5	0.01%	-	6	5
AARC 2008	34182	DR319	124	124.5	Calc-silicate	NAF	9	180	1	1	2	7	5	0.1	594	4	5	0.01%	-	12	5
AARC 2008	34188	DR322	129	129.5	Calc-silicate	NAF	5	30	1	1	14	27	5	0.1	1560	19	5	0.04%	-	35	108
AARC 2008	34192	DR321	163	163.5	Calc-silicate	NAF	5	300	2	1	13	36	5	0.1	1710	22	5	0.01%	-	37	15
AARC 2008	34194	DR321	177	177.5	Calc-silicate	NAF	5	360	2	1	20	62	5	0.1	1230	37	5	0.01%	-	86	28
AARC 2008	34196	DR318	219	219.5	Calc-silicate	NAF	5	90	1	1	12	28	6	0.1	1220	25	5	0.03%	-	46	17
AARC 2008	34198	DR318	225	225.5	Calc-silicate	NAF	5	80	2	1	10	24	5	0.1	918	20	5	0.01%	-	41	6
AARC 2008	34200	DR318	227.45	228	Calc-silicate	NAF	5	40	2	1	16	42	6	0.1	1140	28	5	0.02%	-	55	8
AARC 2008	34029	DR342	151.5	152	Mafic feldspar porphyry	NAF	5	270	1	1	25	9	36	0.1	1200	28	5	0.01%	-	104	5
AARC 2008	34031	DR342	260.5	261	White mica schist	NAF	5	110	1	1	38	94	23	0.1	229	18	5	0.02%	-	82	5
AARC 2008	34047	DR342	273	273.5	White mica schist	NAF	5	110	1	1	6	53	16	0.1	215	18	5	0.03%	-	31	5
AARC 2008	34176	DR320	212	212.5	White mica schist	NAF	5	90	1	1	16	31	106	0.1	679	29	5	0.02%	-	46	18
AARC 2008	34178	DR320	216	216.5	White mica schist	NAF	5	120	1	1	15	31	23	0.1	1070	29	5	0.01%	-	59	13
AARC 2008	34202	DR316	266	266.5	White mica schist	NAF	5	100	3	1	17	28	64	0.1	553	30	5	0.02%	-	37	11
AARC 2008	34204	DR316	270	270.5	White mica schist	NAF	5	140	1	1	17	30	5	0.1	510	30	5	0.01%	-	43	19
AARC 2008	34033	DR342	362.5	363	Hanging wall slate	NAF	5	60	2	1	62	28	399	0.1	1270	24	7	4.1%	-	49	14
AARC 2008	34035	DR342	363.5	364	Hanging wall slate	NAF	5	60	2	1	19	38	689	0.1	1160	14	5	2.3%	-	57	116
AARC 2008	34037	DR342	364.5	365	Hanging wall slate	NAF	5	60	1	1	53	39	1040	0.1	1290	27	7	5.4%	-	71	175
AARC 2008	34039	DR342	365.5	366	Hanging wall slate	NAF	5	20	2	1	19	35	358	0.1	834	16	10	1.9%	-	54	84
AARC 2008	34049	DR341	99	99.5	Hanging wall slate	NAF	9	80	1	1	4	65	60	0.1	562	10	5	0.8%	-	43	14
AARC 2008	34051	DR341	111	111.5	Hanging wall slate	NAF	8	20	1	1	6	23	10	0.1	187	19	5	0.5%	-	5	11
AARC 2008	34190	DR322	157	157.5	Hanging wall slate	NAF	5	70	1	1	10	49	20	0.1	588	18	5	0.07%	-	62	28
AARC 2008	34011	DR346	402.5	403	Hanging wall slate	PAF	44	20	1	5	5	4	57	0.8	320	22	27	2.8%	-	5	4870
AARC 2008	34013	DR346	403.5	404	Hanging wall slate	PAF	188	20	2	2	42	8	225	0.4	741	78	68	12.3%	-	13	2780
AARC 2008	34017	DR346	414	414.5	Hanging wall slate	PAF	5	80	2	1	14	32	260	0.1	603	17	20	0.9%	-	55	43
AARC 2008	34053	DR341	123	123.5	Hanging wall slate	PAF	36	30	1	1	5	27	26	0.1	89	10	6	0.9%	-	8	42
AARC 2008	34065	DR340	124.7	125.2	Hanging wall slate	PAF	41	40	1	1	13	34	13	0.1	330	25	9	1.3%	-	75	46
AARC 2008	34067	DR340	127	127.5	Hanging wall slate	PAF	174	30	1	1	6	13	5	0.1	160	19	5	1.3%	-	11	10
AARC 2008	34069	DR340	130.5	131	Hanging wall slate	PAF	1190	60	1	1	20	4	31	0.1	107	41	18	2.6%	-	10	14
AARC 2008	34158	DR315	84	84.5	Hanging wall slate	PAF	69	20	1	9	29	33	632	0.4	518	45	22	2.3%	-	79	5360
AARC 2008	34160	DR315	90	90.5	Hanging wall slate	PAF	250	20	1	7	21	58	1770	0.5	316	53	6	2.6%	-	107	4350
AARC 2008	34162	DR315	101	101.5	Hanging wall slate	PAF	519	30	1	15	10	39	403	1.3	372	13	22	1.3%	-	104	1.1%
AARC 2008	34164	DR315	102	102.5	Hanging wall slate	PAF	108	20	1	32	10	32	514	2.3	498	27	23	3.7%	-	100	27100
AARC 2008	34015	DR346	410	410.5	Hanging wall slate	UC	6	60	1	1	41	41	652	0.1	328	61	23	1.1%	-	71	125

APPENDIX B-1 : *Continued*

Study	Sample ID	Hole No.	From (m)	To (m)	Lithology	ARD Class	As (mg/kg)	Ba (mg/kg)	Be (mg/kg)	Cd (mg/kg)	Co (mg/kg)	Cr (mg/kg)	Cu (mg/kg)	Hg (mg/kg)	Mn (mg/kg)	Ni (mg/kg)	Pb (mg/kg)	S (%)	Sb (mg/kg)	V (mg/kg)	Zn (mg/kg)
AARC 2008	34184	DR319	399	400	Lode (mineralised waste)	NAF	21	340	1	66	6	7	87	4.6	10300	18	128	6.9%	-	13	4.4%
AARC 2008	34059	DR341	146.5	147.5	Lode (mineralised waste)	PAF	246	80	1	38	25	44	209	2.2	219	32	197	15.4%	-	34	7.7%
AARC 2008	34071	DR340	142.5	143.5	Lode (mineralised waste)	PAF	304	20	1	52	29	3	95	1	1470	20	649	13.7%	-	8	4.4%
AARC 2008	34166	DR315	270.5	271.5	Lode (mineralised waste)	PAF	12	130	1	12	5	18	323	0.4	932	26	169	4.7%	-	69	6660
AARC 2008	34061	DR341	157.5	158	Footwall slate	NAF	29	50	1	1	2	66	8	0.1	3270	8	48	0.5%	-	31	203
AARC 2008	34063	DR341	162.5	163	Footwall slate	NAF	12	70	1	1	4	65	12	0.1	1970	11	21	0.7%	-	36	68
AARC 2008	34073	DR340	159.5	160	Footwall slate	NAF	36	50	1	1	3	7	7	0.1	2020	10	27	0.7%	-	7	333
AARC 2008	34075	DR340	160.5	161	Footwall slate	NAF	116	40	2	5	8	24	15	0.1	2540	22	38	1.1%	-	30	2830
AARC 2008	34077	DR340	161.5	162	Footwall slate	NAF	67	320	1	1	8	26	19	0.1	2390	19	185	1.0%	-	30	345
AARC 2008	34168	DR315	273.2	273.7	Footwall slate	NAF	23	200	1	1	6	31	50	0.1	1710	14	61	1.2%	-	43	218
AARC 2008	34170	DR315	281.5	282	Footwall slate	NAF	5	180	1	1	6	35	28	0.1	2480	19	18	1.1%	-	45	156
AARC 2008	34172	DR315	292.5	293	Footwall slate	NAF	22	60	1	1	10	7	25	0.1	944	16	73	1.8%	-	11	387
AARC 2008	34019	DR346	434.5	435	Footwall slate	PAF	26	120	3	1	6	8	158	0.1	394	14	48	1.2%	-	17	74
AARC 2008	34021	DR346	432.5	432.9	Footwall slate	PAF	5	70	1	1	4	2	36	0.1	147	13	33	1.6%	-	5	19
AARC 2008	34041	DR342	423	424	Footwall slate	PAF	1070	70	1	1	69	60	673	0.4	153	24	168	13.8%	-	39	197
AARC 2008	34023	DR346	490.5	491	Footwall limestone	NAF	9	150	2	1	4	39	127	0.1	1280	12	18	0.6%	-	63	65
AARC 2008	34025	DR346	496	496.5	Footwall limestone	NAF	183	100	1	1	6	28	335	0.1	2540	21	14	1.3%	-	43	47
AARC 2008	34043	DR342	458	458.5	Footwall limestone	NAF	14	90	2	1	10	34	110	0.1	3610	21	27	1.0%	-	37	42
AARC 2008	34045	DR342	471	471.5	Footwall limestone	NAF	5	70	1	1	8	28	191	0.1	2440	22	61	1.2%	-	27	29
AARC 2008	34055	DR341	177	177.5	Footwall limestone	NAF	7	30	1	1	3	13	7	0.1	915	5	43	0.4%	-	6	60
AARC 2008	34057	DR341	183	183.5	Footwall limestone	NAF	9	20	1	3	4	12	19	0.1	1130	8	67	0.8%	-	6	1250
AARC 2008	34079	DR340	185.5	186	Footwall limestone	NAF	16	70	1	1	5	6	14	0.1	787	11	44	1.2%	-	10	129
AARC 2008	34186	DR319	446	446.5	Footwall limestone	NAF	9	70	1	3	4	6	17	0.2	1330	10	77	1.3%	-	10	1800

* underlined values indicate concentration less than the analytical detection limit

APPENDIX B-2 Geochemical abundance indices for drill core samples from previous geochemical studies of Dugald River waste rock

Element		Calc-silicate											Mafic feldspar porphyry							Hanging wall slate																					
		DR346 (140-140.5m)	DR342 (106.5-107m)	DR320 (112-112.5m)	DR319 (121-121.5m)	DR319 (124-124.5m)	DR322 (129-129.5m)	DR321 (163-163.5m)	DR321 (177-177.5m)	DR318 (219-219.5m)	DR318 (225-225.5m)	DR318 (227.45-228m)	DR342 (151.5-152m)	DR342 (260.5-261m)	DR342 (273-273.5m)	DR320 (212-212.5m)	DR320 (216-216.5m)	DR316 (266-266.5m)	DR316 (270-270.5m)	DR342 (362.5-363m)	DR342 (363.5-364m)	DR342 (364.5-365m)	DR342 (365.5-366m)	DR341 (99-99.5m)	DR341 (111-111.5m)	DR322 (157-157.5m)	229 (700-701m)	174 (168-169m)	DR346 (410-410.5m)	230 (662-663m)	230 (675-676m)	186 (672-673m)	231 (491-492m)	DR346 (402.5-403m)	DR346 (403.5-404m)	DR346 (414-414.5m)	DR341 (123-123.5m)	DR340 (124.7-125.2m)	DR340 (127-127.5m)	DR340 (130.5-131m)	DR315 (84-84.5m)	DR315 (90-90.5m)	DR315 (101-101.5m)	DR315 (102-102.5m)
		NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	UC	PAF	PAF	PAF	PAF	PAF	PAF	PAF	PAF	PAF	PAF	PAF	PAF	PAF	PAF	PAF
As	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	0	1	3	3	1	2	4	0	2	2	4	6	2	4	5	3
Ba	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	0	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0
Be	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	0	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0
Cd	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3	1	0	0	0	0	0	4	3	4	5
Co	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	1	1	0	1	1	0	1	0	0	0	0	0	1	0	0	0
Cr	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	0	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0
Cu	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3	3	4	2	0	0	0	0	2	3	5	1	2	2	0	2	2	0	0	0	0	3	5	3	3
Hg	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	0	0	0	0	0	2	2	3	4
Mn	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	0	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0
Ni	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	0	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0
Pb	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0
S	(%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	4	5	4	2	2	0	1	4	3	3	4	5	6	4	6	3	3	3	3	4	4	4	3	5
Sb	(mg/kg)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	-	0	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-
V	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	0	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0
Zn	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	3	2	0	5	4	0	0	0	0	5	5	6	6

APPENDIX B-2: *Continued*

Element		Lode Waste				Footwall slate																		Footwall limestone												Median Soil Content	
		DR319 (399-400m)	DR341 (146.5-147.5m)	DR340 (142.5-143.5m)	DR315 (270.5-271.5m)	DR341 (157.5-158m)	DR341 (162.5-163m)	DR340 (159.5-160m)	DR340 (160.5-161m)	DR340 (161.5-162m)	DR315 (273.2-273.7m)	DR315 (281.5-282m)	DR315 (292.5-293m)	186 (696-697m)	230 (703-704m)	231 (540-541m)	229 (747-748m)	174 (180-181m)	231 (508-509m)	DR346 (434.5-435m)	DR346 (432.5-432.9m)	DR342 (423-424m)	217 (1029-1030m)	202 (792-793m)	DR346 (490.5-491m)	DR346 (496-496.5m)	DR342 (458-458.5m)	DR342 (471-471.5m)	DR341 (177-177.5m)	DR341 (183-183.5m)	DR340 (185.5-186m)	DR319 (446-446.5m)	186 (824-825m)	174 (185-186m)	217 (1040-1041m)	230 (760-761m)		
		NAF	PAF	PAF	PAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	PAF	PAF	PAF	PAF	PAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	NAF	PAF	
As	(mg/kg)	1	4	5	0	1	0	2	3	2	1	0	1	2	3	1	4	1	4	1	0	6	2	4	0	4	0	0	0	0	0	0	2	3	3	0	6 mg/kg
Ba	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	-	-	-	0	0	0	-	-	0	0	0	0	0	0	0	0	-	-	-	-	500 mg/kg
Be	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	-	-	-	0	0	0	-	-	0	0	0	0	0	0	0	0	-	-	-	-	6 mg/kg
Cd	(mg/kg)	6	6	6	4	0	0	0	3	0	0	0	0	3	0	0	4	0	6	0	0	0	3	4	0	0	0	0	0	2	0	2	0	0	0	0	0.4 mg/kg
Co	(mg/kg)	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	8 mg/kg
Cr	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	-	-	-	0	0	0	-	-	0	0	0	0	0	0	0	0	-	-	-	-	70 mg/kg
Cu	(mg/kg)	0	2	1	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	3	0	0	1	2	1	2	0	0	0	0	0	1	0	0	30 mg/kg
Hg	(mg/kg)	5	4	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	0	4	0	0	0	0	0	0	0	1	0	0	0	0	0.06 mg/kg
Mn	(mg/kg)	2	0	0	0	1	0	0	0	0	0	0	0	-	-	-	-	-	-	0	0	0	-	-	0	0	1	0	0	0	0	0	-	-	-	-	1000 mg/kg
Ni	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	-	-	-	0	0	0	-	-	0	0	0	0	0	0	0	0	-	-	-	-	50 mg/kg
Pb	(mg/kg)	1	1	3	1	0	0	0	0	1	0	0	0	2	0	0	1	0	1	0	0	1	3	4	0	0	0	0	0	0	0	0	1	0	0	0	35 mg/kg
S	(%)	6	6	6	5	2	2	2	3	3	3	3	4	3	2	2	5	3	5	3	3	6	4	6	2	3	3	3	1	2	3	3	3	4	3	3	0.07 %
Sb	(mg/kg)	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0	0	-	-	-	0	0	-	-	-	-	-	-	-	-	0	0	0	0	5 mg/kg
V	(mg/kg)	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	-	-	-	0	0	0	-	-	0	0	0	0	0	0	0	0	-	-	-	-	90 mg/kg
Zn	(mg/kg)	6	6	6	6	0	0	1	4	1	0	0	1	4	1	1	3	2	6	0	0	0	4	6	0	0	0	0	0	3	0	3	1	1	0	1	90 mg/kg

Appendix C

Results of Column Leach Tests Involving Dugald River Waste Rock

AustralAsian Resource Consultants (2008)

APPENDIX C-1: Results of column leach tests involving Dugald River waste rock - Acid forming characteristics of column leach samples

Parameter	Unit	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7
		HW Slate	Footwall Limestone	PAF Mixture	Footwall Slate	HW Calc-silicate	Calc-silicate & Porphyry	Mica Schist
Existing pH		8.6	9.3	8.8	9.0	9.4	9.4	9.6
EC	µS/cm	343	206	350	278	131	171	110
Total S	(%S)	2.39	0.56	9.47	0.96	0.03	0.02	0.05
MPA	kg H2SO4/t	73	17	290	29	1	1	2
ANC	kg H2SO4/t	71	222	35.6	112	180	197	80.3
NAPP	kg H2SO4/t	2	-205	254	-83	-179	-196	-79
NAG	kg H2SO4/t	0	0	161	0	0	0	0
NAGpH		8.5	10.7	1.9	8.4	11.5	11.8	11.7
ARD Class		UC	NAF	PAF	NAF	NAF	NAF	NAF

APPENDIX C-2: Results of column leach tests involving Dugald River waste rock - Leachate composition for HW Slate (Column 1)

Parameter	Collection Date and Duration of Leaching (days)																	
	19-Aug-08	16-Sep-08	15-Oct-08	11-Nov-08	9-Dec-08	12-Jan-09	3-Feb-09	5-Mar-09	31-Mar-09	28-Apr-09	26-May-09	23-Jun-09	22-Jul-09	18-Aug-09	15-Sep-09	13-Oct-09	10-Nov-09	1-Dec-09
	0	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68
pH	7.37	7.73	7.55	7.91	6.55	7.46	7.25	6.31	6.79	6.52	7.05	5.36	6.88	6.7	6.02	5.56	4.64	4.92
EC	401	379	229	218	203	275	244	170	297	227	259	98	191	119	196	171	209	375
Alk	17	21	25	22	24	19	22	15	4	6	9	4	6	1	<1	2	<1	<1
Acy	<1	<1	2	2	2	4	4	6	4	2	2	4	2	6	20	14	37	26
SO4	145	132	86	66	78	76	93	89	102	83	102	38	65	44	70	68	108	100
Si	0.42		0.7		0.5		0.73		0.41		0.47		0.23		0.12		0.35	
Cl	3		3		<1		3		<1		<1		<1		<1		<1	
Ca	40		30		29		35		31		32		19		15		19	
Mg	9		5		5		5		6		5		5		7		10	
Na	15		6		4		3		3		3		1		1		<1	
K	4		3		2		2		2		2		1		1		2	
Al	0.08		0.02		<0.01		0.02		0.1		<0.01		<0.01		0.05		0.19	
Sb	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
As	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
Be	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
Ba	0.005		0.004		0.006		0.006		0.006		0.005		0.004		0.003		0.004	
Cd	<0.0001		<0.0001		0.0003		0.0002		0.0009		0.0002		0.0007		0.0006		0.001	
Cr	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
Co	0.004		0.001		0.004		0.003		0.005		0.003		0.01		0.013		0.031	
Cu	0.013		<0.001		<0.001		0.001		<0.001		<0.001		0.005		0.013		0.021	
Pb	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		0.002	
Mn	0.284		0.102		0.122		0.066		0.124		0.074		0.209		0.248		0.513	
Mo	0.001		0.004		0.004		0.003		0.001		0.001		<0.001		<0.001		<0.001	
Ni	0.021		0.003		0.012		0.008		0.013		0.007		0.021		0.031		0.069	
Se	<0.010		<0.010		<0.010		<0.01		<0.01		<0.01		<0.01		<0.01		<0.01	
Ag	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
Sr	0.083		0.052		0.044		0.041		0.036		0.035		0.017		0.015		0.015	
Th	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
Sn	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
U	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		0.002	
Zn	0.028		0.013		0.095		0.057		0.083		0.053		0.174		0.255		0.503	
B	<0.05		<0.05		<0.05		<0.05		<0.05		<0.05		<0.05		<0.05		<0.05	
Fe	<0.05		<0.05		0.62		0.46		1.04		0.15		1.85		5.5		10.4	
Hg	0.0007		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001	
SiO2	0.9		1.5		1.1		1.6		0.9		1		0.5		0.2		0.8	
F	<0.1		0.1		<0.1		<0.1		<0.1		<0.1		<0.1		<0.1		<0.1	

APPENDIX C-3: Results of column leach tests involving Dugald River waste rock - Leachate composition for FW Limestone (Column 2)

Parameter	Collection Date and Duration of Leaching (days)																	
	19-Aug-08	16-Sep-08	15-Oct-08	11-Nov-08	9-Dec-08	12-Jan-09	3-Feb-09	5-Mar-09	31-Mar-09	28-Apr-09	26-May-09	23-Jun-09	22-Jul-09	18-Aug-09	15-Sep-09	13-Oct-09	10-Nov-09	1-Dec-09
	0	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68
pH	8.89	8.79	8.54	8.33	7.5	7.76	8.03	6.23	7.56	6.55	7.35	7.91						
EC	177	173	170	140	180	149	162	122	149	144	137	72						
Alk	21	128	22	24	23	31	21	23	20	17	13	11						
Acy	<1	<1	<1	<1	<1	6	6	<1	2	2	2	4						
SO4	47	52	56	36	68	38	53	44	34	41	42	18						
Si	0.22		0.36		0.21		0.23		0.14		0.13							
Cl	2		6		<1		2		8		<1							
Ca	11		18		23		18		16		16							
Mg	1		3		4		4		2		3							
Na	16		10		9		5		2		2							
K	2		3		3		2		2		2							
Al	0.11		0.03		0.03		0.02		0.02		0.02							
Sb	0.001		0.001		0.001		<0.001		<0.001		<0.001							
As	0.001		0.001		<0.001		<0.001		0.001		<0.001							
Be	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Ba	0.025		0.012		0.014		0.01		0.013		0.007							
Cd	<0.0001		<0.0001		0.0002		<0.0001		0.0001		<0.0001							
Cr	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Co	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Cu	0.002		<0.001		0.001		0.001		<0.001		<0.001							
Pb	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Mn	0.042		0.02		0.037		0.015		0.021		0.013							
Mo	<0.001		0.003		0.002		0.002		0.001		0.001							
Ni	0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Se	<0.010		<0.010		<0.010		<0.01		<0.01		<0.01							
Ag	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Sr	0.072		0.091		0.089		0.062		0.045		0.044							
Th	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Sn	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
U	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Zn	<0.005		0.012		0.019		0.007		0.09		<0.005							
B	<0.05		<0.05		<0.05		<0.05		<0.05		<0.05							
Fe	<0.05		<0.05		<0.05		0.07		<0.05		<0.05							
Hg	0.0003		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001							
SiO2	0.5		0.8		0.4		0.5		0.3		0.3							
F	0.2		0.2		0.2		0.1		<0.1		0.1							

APPENDIX C-4: Results of column leach tests involving Dugald River waste rock - Leachate composition for PAF Rock Mixture (Column 3)

Parameter	Collection Date and Duration of Leaching (days)																	
	19-Aug-08	16-Sep-08	15-Oct-08	11-Nov-08	9-Dec-08	12-Jan-09	3-Feb-09	5-Mar-09	31-Mar-09	28-Apr-09	26-May-09	23-Jun-09	22-Jul-09	18-Aug-09	15-Sep-09	13-Oct-09	10-Nov-09	1-Dec-09
	0	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68
pH	7.23	7.48	7.12	7.59	6.41	6.64	5.59	4.99	6.03	5.67	5.24	5.19	4.62	5.17	5.49	4.78	4.52	4.45
EC	241	160	124	173	216	269	247	255	237	230	238	272	453	231	266	233	233	297
Alk	20	20	20	22	4	4	4	4	28	3	1	3	<1	<1	<1	2	<1	<1
Acy	<1	<1	2	2	15	20	26	33	18	22	18	15	64	24	47	35	51	63
SO4	82	50	42	57	105	106	100	139	76	98	85	115	170	96	128	98	103	129
Si	0.1		0.08		0.07		0.09		0.08		0.1		0.11		0.12		0.07	
Cl	<1		<1		<1		3		<1		<1		1		2		<1	
Ca	23		16		25		21		19		18		18		18		12	
Mg	3		2		8		8		8		8		19		12		8	
Na	10		3		4		3		1		1		1		1		2	
K	4		2		2		2		<1		<1		<1		<1		<1	
Al	0.04		0.02		0.09		0.14		0.08		0.16		0.47		0.36		0.37	
Sb	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
As	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
Be	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
Ba	0.018		0.011		0.023		0.01		0.01		0.008		0.006		0.006		0.004	
Cd	0.0002		0.0003		0.0021		0.0031		0.0037		0.0045		0.009		0.0089		0.0084	
Cr	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
Co	0.003		0.003		0.014		0.016		0.014		0.012		0.036		0.02		0.02	
Cu	0.001		<0.001		0.004		0.003		0.002		0.006		0.019		0.026		0.031	
Pb	<0.001		0.003		0.014		0.019		0.008		0.016		0.018		0.028		0.031	
Mn	0.829		0.406		1.99		2.23		2.24		2.02		6.27		3.24		2.81	
Mo	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
Ni	0.01		0.01		0.052		0.056		0.051		0.05		0.14		0.075		0.074	
Se	<0.010		<0.010		<0.010		<0.01		<0.01		<0.01		<0.01		<0.01		<0.01	
Ag	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
Sr	0.07		0.032		0.041		0.032		0.022		0.024		0.026		0.023		0.015	
Th	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
Sn	0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
U	<0.001		<0.001		0.003		0.005		0.002		0.004		0.008		0.007		0.008	
Zn	0.102		0.339		2.03		3.02		3.35		3.94		9.41		7.21		6.79	
B	<0.05		<0.05		<0.05		<0.05		<0.05		<0.05		<0.05		<0.05		<0.05	
Fe	<0.05		0.46		4.18		9.89		6.76		7.68		18.1		12.4		15.4	
Hg	0.0004		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001	
SiO2	0.2		0.2		0.1		0.2		0.2		0.2		0.2		0.2		0.1	
F	0.2		0.2		0.3		0.2		<0.1		0.1		0.4		0.2		0.2	

APPENDIX C-5: Results of column leach tests involving Dugald River waste rock - Leachate composition for FW Slate (Column 4)

Parameter	Collection Date and Duration of Leaching (days)																	
	19-Aug-08	16-Sep-08	15-Oct-08	11-Nov-08	9-Dec-08	12-Jan-09	3-Feb-09	5-Mar-09	31-Mar-09	28-Apr-09	26-May-09	23-Jun-09	22-Jul-09	18-Aug-09	15-Sep-09	13-Oct-09	10-Nov-09	1-Dec-09
	0	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68
pH	8.42	8.1	7.8	8.11	6.86	8.11	7.82	7.08	7.27	7.82	6.67	6.78						
EC	176	161	113	126	137	172	137	133	178	132	136	136						
Alk	12	15	23	82	14	21	22	16	16	9	13	10						
Acy	<1	<1	2	<1	2	2	4	12	12	2	2	2						
SO4	53	50	32	33	52	54	46	54	51	43	42	44						
Si	0.16		0.08		<0.05		0.07		0.11		0.07							
Cl	<1		4		<1		1		<1		<1							
Ca	18		15		19		19		19		18							
Mg	3		2		4		3		4		3							
Na	5		2		2		2		1		1							
K	3		2		2		2		1		1							
Al	0.06		0.03		0.03		0.02		0.04		0.02							
Sb	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
As	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Be	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Ba	0.012		0.004		0.006		0.004		0.006		0.004							
Cd	<0.0001		<0.0001		<0.0001		<0.0001		0.0002		<0.0001							
Cr	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Co	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Cu	<0.001		<0.001		0.002		<0.001		<0.001		<0.001							
Pb	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Mn	0.216		0.184		0.308		0.232		0.354		0.149							
Mo	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Ni	0.002		<0.001		0.002		0.001		<0.001		<0.001							
Se	<0.010		<0.010		<0.010		<0.01		<0.01		<0.01							
Ag	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Sr	0.025		0.015		0.018		0.014		0.013		0.012							
Th	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Sn	0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
U	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Zn	<0.005		<0.005		0.017		0.007		0.043		0.007							
B	<0.05		<0.05		<0.05		<0.05		<0.05		<0.05							
Fe	<0.05		<0.05		0.17		<0.05		<0.05		0.05							
Hg	0.0004		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001							
SiO2	0.4		0.2		<0.1		0.1		0.2		0.1							
F	0.2		0.1		0.1		0.1		<0.1		<0.1							

APPENDIX C-6: Results of column leach tests involving Dugald River waste rock - Leachate composition for HW Calc-Silicate (Column 5)

Parameter	Collection Date and Duration of Leaching (days)																	
	19-Aug-08	16-Sep-08	15-Oct-08	11-Nov-08	9-Dec-08	12-Jan-09	3-Feb-09	5-Mar-09	31-Mar-09	28-Apr-09	26-May-09	23-Jun-09	22-Jul-09	18-Aug-09	15-Sep-09	13-Oct-09	10-Nov-09	1-Dec-09
	0	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68
pH	9.07	9.07	9.16	9.25	8.51	8.57	9.28	7.23	8.45	8.16	8.81	9.00						
EC	83	87	75	61	61	88	64	55	63	57	57	50						
Alk	36	214	38	116	25	66	24	27	27	22	31	22						
Acy	<1	<1	<1	<1	<1	4	<1	<1	<1	<1	<1	2						
SO4	8	9	5	3	6	7	8	5	10	6	5	4						
Si	0.74		0.68		0.39		0.43		0.44		0.33							
Cl	2		4		<1		2		3		<1							
Ca	7		7		7		6		5		8							
Mg	<1		<1		<1		<1		2		<1							
Na	9		6		4		5		13		3							
K	1		1		<1		1		1		<1							
Al	0.17		0.08		0.07		0.05		0.12		0.05							
Sb	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
As	<0.001		<0.001		0.002		<0.001		<0.001		<0.001							
Be	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Ba	0.004		0.004		0.004		0.005		0.007		0.004							
Cd	<0.0001		<0.0001		<0.0001		<0.0001		0.0002		<0.0001							
Cr	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Co	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Cu	<0.001		<0.001		0.002		<0.001		<0.001		<0.001							
Pb	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Mn	0.012		0.005		0.018		0.007		0.008		0.007							
Mo	0.024		0.017		0.009		0.012		0.006		0.007							
Ni	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Se	<0.010		<0.010		<0.010		<0.01		<0.01		<0.01							
Ag	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Sr	0.013		0.01		0.01		0.01		0.007		0.007							
Th	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Sn	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
U	0.002		0.003		0.002		0.003		0.002		0.001							
Zn	<0.005		<0.005		<0.005		<0.005		0.062		<0.005							
B	<0.05		<0.05		<0.05		<0.05		<0.05		<0.05							
Fe	<0.05		<0.05		<0.05		<0.05		<0.05		<0.05							
Hg	0.0003		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001							
SiO2	1.6		1.5		0.8		0.9		1		0.7							
F	0.2		0.1		<0.1		<0.1		<0.1		<0.1							

APPENDIX C-7: Results of column leach tests involving Dugald River waste rock - Leachate composition for HW Calc-Silicate & Mafic Feldspar Porphyry (Column 6)

Parameter	Collection Date and Duration of Leaching (days)																	
	19-Aug-08	16-Sep-08	15-Oct-08	11-Nov-08	9-Dec-08	12-Jan-09	3-Feb-09	5-Mar-09	31-Mar-09	28-Apr-09	26-May-09	23-Jun-09	22-Jul-09	18-Aug-09	15-Sep-09	13-Oct-09	10-Nov-09	1-Dec-09
	0	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68
pH	8.97	9.08	9.19	9.22	8.76	8.09	9.22	6.57	8.51	7.47	8.94	8.73						
EC	100	106	76	73	69	90	70	65	67	61	53	43						
Alk	32	120	24	85	22	62	21	26	24	19	18	13						
Acy	<1	<1	<1	<1	<1	2	<1	<1	<1	<1	<1	2						
SO4	10	10	8	6	12	8	10	10	6	8	4	4						
Si	0.57		0.52		0.26		0.37		0.34		0.24							
Cl	5		8		1		4		<1		<1							
Ca	8		7		8		7		7		7							
Mg	<1		<1		<1		<1		<1		<1							
Na	9		7		7		5		4		3							
K	1		1		1		1		1		<1							
Al	0.09		0.05		0.05		0.04		0.07		0.04							
Sb	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
As	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Be	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Ba	0.006		0.004		0.007		0.006		0.006		0.004							
Cd	<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001							
Cr	<0.001		<0.001		0.001		<0.001		<0.001		<0.001							
Co	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Cu	<0.001		<0.001		0.002		0.002		0.001		<0.001							
Pb	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Mn	0.012		0.01		0.023		0.01		0.011		0.008							
Mo	0.006		0.006		0.005		0.005		0.002		0.002							
Ni	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Se	<0.010		<0.010		<0.010		<0.01		<0.01		<0.01							
Ag	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Sr	0.019		0.015		0.018		0.015		0.01		0.008							
Th	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Sn	0.002		<0.001		<0.001		<0.001		<0.001		<0.001							
U	0.001		0.003		0.002		0.003		0.001		0.001							
Zn	<0.005		<0.005		0.006		<0.005		0.203		<0.005							
B	<0.05		<0.05		<0.05		<0.05		<0.05		<0.05							
Fe	<0.05		<0.05		<0.05		<0.05		<0.05		<0.05							
Hg	0.0003		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001							
SiO2	1.2		1.1		0.5		0.8		0.7		0.5							
F	0.2		<0.1		<0.1		<0.1		<0.1		<0.1							

APPENDIX C-8: Results of column leach tests involving Dugald River waste rock - Leachate composition for HW Mica Schist (Column 7)

Parameter	Collection Date and Duration of Leaching (days)																	
	19-Aug-08	16-Sep-08	15-Oct-08	11-Nov-08	9-Dec-08	12-Jan-09	3-Feb-09	5-Mar-09	31-Mar-09	28-Apr-09	26-May-09	23-Jun-09	22-Jul-09	18-Aug-09	15-Sep-09	13-Oct-09	10-Nov-09	1-Dec-09
	0	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68
pH	8.96	9.12	9.27	9.25	8.53	6.42	9.06	6.43	8.64	7.26	8.32	8.97						
EC	78	80	53	45	43	65	49	59	56	58	60	45						
Alk	24	47	36	35	23	44	17	27	23	16	19	15						
Acy	<1	<1	<1	<1	<1	2	<1	<1	<1	<1	<1	2						
SO4	9	10	5	1	3	3	4	5	3	4	3	3						
Si	0.56		0.49		0.15		0.33		0.41		0.19							
Cl	1		4		<1		2		<1		<1							
Ca	7		6		7		6		7		6							
Mg	<1		<1		<1		<1		<1		<1							
Na	6		4		3		3		2		2							
K	<1		<1		<1		<1		<1		<1							
Al	0.13		0.08		0.07		0.07		0.12		0.06							
Sb	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
As	0.002		0.001		0.002		0.002		0.002		<0.001							
Be	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Ba	0.002		0.001		0.001		0.001		0.002		0.001							
Cd	<0.0001		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001							
Cr	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Co	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Cu	0.001		<0.001		0.002		0.001		<0.001		<0.001							
Pb	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Mn	0.011		0.009		0.017		0.009		0.009		0.007							
Mo	0.008		0.005		0.004		0.004		0.002		0.002							
Ni	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Se	<0.010		<0.010		<0.010		<0.01		<0.01		<0.01							
Ag	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Sr	0.011		0.007		0.007		0.006		0.004		0.004							
Th	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
Sn	0.001		<0.001		<0.001		<0.001		<0.001		<0.001							
U	0.002		0.001		0.001		<0.001		<0.001		<0.001							
Zn	<0.005		<0.005		0.015		<0.005		0.013		<0.005							
B	<0.05		<0.05		<0.05		<0.05		<0.05		<0.05							
Fe	<0.05		<0.05		<0.05		<0.05		<0.05		<0.05							
Hg	0.0003		<0.0001		<0.0001		<0.0001		<0.0001		<0.0001							
SiO2	1.2		1		0.3		0.7		0.9		0.4							
F	0.1		<0.1		<0.1		<0.1		<0.1		<0.1							

Appendix H

Tailings Storage Facility Final Report



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REPORT

MMG DUGALD RIVER

Dugald River Project
Feasibility Study

Tailings Storage Facility
Final Report – 2010 EIS Revision

North West Queensland

August 2010

108003R07

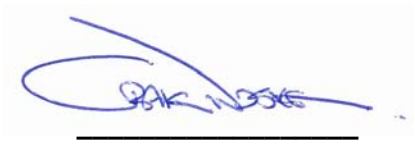
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IMPORTANT NOTICE

Please refer to our Conditions of Investigation and Report

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CONDITIONS OF INVESTIGATION AND REPORT

Conditions of Report

1. This report has been prepared by us for the purposes stated herein. We do not accept responsibility for the consequences of extrapolation, extension or transference of the findings and recommendations of this report to different sites, cases or conditions.

2. This report is based in part on information which was provided to us by the client and/or others and which is not under our control. We do not warrant or guarantee the accuracy of this information.

3. We believe the conclusions and recommendations contained herein were reasonable and appropriate at the time of issue of the report. However, the user is cautioned that fundamental input assumptions upon which this report is based may change with time. It is the user's responsibility to ensure that input assumptions remain valid.

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Geotechnical Investigation

7. Geotechnical site investigation necessarily involves the investigation of the subsurface conditions at a site at a few isolated locations, and the interpretation and extrapolation of those conditions to elsewhere on the site not so investigated. This procedure has been adopted at the site that is the subject of this report and due care and skill has been applied in carrying out and reporting on the work. Thus the findings, conclusions and comments contained in this report represent professional estimates and opinions and are not to be read as facts unless the context makes it clear to the contrary. In general, statements of fact are confined to statements as to what was done and/or what was observed. Other statements have been based on professional judgement.

8. The scope of the work has been planned in the absence of any fore-knowledge of the site other than that stated in the report. Unless otherwise stated we consider that the number of locations investigated and the depths to which they have been investigated are reasonable bearing in mind the scale and nature of the project, and the defined purpose for which the investigation was undertaken.

9. We do not accept any responsibility for any variance between the interpreted and extrapolated conditions and those that are revealed by any means subsequently. Specific warning is also given that many factors, either natural or artificial, may render ground conditions different from those which pertained at the time of the investigation. Should there be revealed during the construction or at any other time any apparent difference from subsurface conditions described or assessed in this report, it is strongly recommended that such differences be brought to our attention so that its significance may be assessed and appropriate advice given.

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EXECUTIVE SUMMARY

1. GENERAL

Mineral and Metals Group ((MMG) is studying the development of its Dugald River Project, located in Queensland, about 70km northwest of Cloncurry. Dugald River is a zinc-lead deposit with the presence of copper mineralisation. ATCW have been commissioned to conduct the tailings storage facility (TSF) component of the study, with the objective being the investigation of storage options, analyses, design, costing and documentation of a working life of mine tailings storage scheme to feasibility study level.

2. STUDY PARAMETERS

The TSF design has been based on a mining inventory of 46.8 million tonnes of ore, processed at up to 2 million tonnes per annum over a 26 year mine life. The total tailings quantity for the TSF is 22.8 Mt, assuming an overall proportion to underground paste backfill of 36.8%.

Tailings characterisation testwork has shown the material to be a low plasticity silt, with a P_{80} of 50µm and a particle specific gravity of 2.96. Geochemistry testwork has indicated the tailings will be potentially acid generating.

The tailings will be thickened to a target solids content of 51% at discharge, and a conservative final insitu dry density of 1.5 t/m^3 has been adopted. The required TSF capacity is thus 15.2 million m^3.

The study has been based on the Queensland Government's Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland. These guidelines state that the TSF must have available a sufficient volume on 1st November of any year to store the Design Storage Allowance (DSA), which in this case is 3,250 megalitres (ML), due to rainfall totalling 1089mm, plus the process water inputs.

3. OPTIONS STUDY

Six TSF sites were considered, including locations within, to the west and to the east of the Knapdale Range which runs north-south through the centre of the project area. Only one of the three original sites from the 2000 pre-feasibility study was included, due to lease boundary constraints. Criteria for assessment of the sites included physical characteristics, capital and operating costs, sterility, and the potential for expansion of the TSF beyond the Feasibility Study resource, which may include the copper mineralisation identified in the Project area.

Two sites were recommended to proceed to conceptual design – these being Site A2 (the Knapdale valley scheme) and Site H2 (perimeter discharge cells adjacent to the Plant Site). The Knapdale Valley site was ultimately preferred with respect to all review criteria, particularly in the key issues of Total Cost, Potential Sterilisation and Expandability for future mining plans.

4. KNAPDALE VALLEY TSF LAYOUT

The site is a long, narrow bifurcated valley running north-south on the western side of the Knapdale Ranges. The valley is approximately 4km north-west of the processing plant. The TSF concept will involve down-valley discharge of tailings, with all decant and runoff water being stored centrally within the tailings impoundment (ie. no secondary water storage pond).

Containment will almost entirely be provided by the valley topography, with the main tailings retaining features being the Main Embankment on the west side, the Eastern Decant Access Embankment, and the Northern Discharge Bunds. The latter two perimeter works items have been included for Feasibility

Study purposes to limit the TSF extents to within the current MMG lease tenure. Transportation lease corridors will be required to gain access to the tailings discharge and decant return routes.

Tailings will be pumped up into the Knapdale Ranges from the process plant, via the Mine Camp access road route. Discharge will occur from both ends of the valley over the life of mine to create a self-shedding profile for rehabilitation and closure. Decant return to the plant will occur via a floating pontoon.

The 43m high embankment on the western side will be designed as a water retaining embankment, due to the potential for water ponding against it during the life of mine. The valley has a large catchment of 335 hectares, which is a benefit of the site, in that it can be used to collect and temporarily store runoff during the wet season for use in the process plant. The embankment will be raised downstream in three stages to minimise upfront capital costs.

The Eastern Decant Access Embankment will be required at start-up, and will provide initial construction access to the valley. At the time of the second and final raises, the Northern Discharge Bunds will be constructed and raised to confine the tailings to within the mining lease boundary.

A preliminary geotechnical investigation of the Knapdale Valley area has been conducted, and the site is considered well suited to the proposed TSF scheme. The Knapdale Ranges consist of competent, hard quartzite rock of low permeability. No significant groundwater resource is present within the Knapdale Range, and there is no practical means of hydrogeological connectivity with the Cabbage Tree Creek catchment area to the west.

5. MAIN EMBANKMENT

For the reasons of construction costs and availability of materials, two Main Embankment configuration options have been considered for the TSF Main Embankment. These are as follows:

(i) Clay Core Option – conventional zoned earth and rockfill embankment.
(ii) Geomembrane Option – rockfill embankment fitted with a waterproofing geomembrane sealing system (GSS) on the upstream face.

Designs were completed and analyses performed for each option. Feasibility study-level costings were then developed, based on an assessment of materials requirements and sources, quantities, and budget rates submitted by specialist construction contractors. On the basis of capital costs, construction efficiency, materials availability and future expandability, the GSS option was selected as the preferred configuration for the Main Embankment.

Due to its superior mechanical and durability properties, as well as its demonstrable precedence in similar applications, a 2.5mm thick, PVC geocomposite supplied and installed by Carpi Tech – a Swiss/Italian specialist dam waterproofing contractor, was selected for the GSS. The geocomposite will be an exposed installation, anchored to the upstream face in continuous vertical lines to a base layer of porous extruded concrete curbs. The bulk of the Main Embankment will be rockfill, quarried from within the TSF impoundment.

6. WATER MANAGEMENT

Water balance modelling for the TSF site has indicated that the maximum wet season excess water volume accumulating in the TSF will be 3,000 ML, which will pond for extended durations to depths of up to 10m at the Main Embankment. This result occurred once only in the 121 year rainfall database. The pond volume exceeded 2,000 ML on a total of four occasions, resulting from the four highest ranked 2 month rainfall years in the climatic database. The frequency and duration of a more realistically expected volume of 600 ML was assessed, revealing an average of eight occurrences for a total duration of between 10% and 20% of the 26 year mine life.

The tailings are expected to have relatively rapid consolidation characteristics, even when sub-aqueous deposition over the life of mine is assumed. Given the conservative adopted design density for sizing the TSF and staging the Main Embankment construction, the possibility of sustained flooding of the beach is not expected to have any long term effect on the tailings storage concept or the overall tailings insitu density.

7. FLOOD AND SEEPAGE CONTAINMENT

The TSF will be equipped with emergency spillways for each stage, even though the 1 in 10,000 year spillway design flood will be safely stored within the TSF. This is because the flood capacity of each embankment stage has been sized for the DSA, which is considerably greater than the volume generated by the spillway design flood.

The Knapdale Valley TSF concept does not include impoundment lining, preferring to rely on the natural characteristics of the site, and the proposed TSF operational methodology as a means of impoundment seepage containment. This has been based upon the following expected seepage containment regime during the operation of the TSF:

- The Knapdale Range does not have an identified groundwater resource. Groundwater is considered to exist locally in the defects within the rock mass.

- The adjacent Cabbage Tree Creek groundwater resource is of poor quality and not considered significant. It is separated from the TSF by 600m of Knapdale Ranges quartzite, rising to levels generally at least 40m above the final tailings surface.

- Tailings will be beached from both ends of the valley, forming a low permeability barrier over the valley floor, limiting seepage flux into the underlying rock mass. As a result, decant water will only come into contact with the impoundment at the edges of the tailings surface.

- During TSF operation, it is expected that the moderately permeable, near-surface (upper 5m) rock mass will slowly saturate. This will predominantly occur at the decant pond edges as the tailings level rises.

- The zone of saturation will, over time, expand along preferential seepage paths into the underlying (5m to 15m depth) less permeable foundation zone. However, flow will become unsaturated beyond this depth, due to the decrease in rock mass fracturing and jointing.

- The only means of seepage within this locally saturated zone exiting the TSF valley will be through the drainage outlet on the western side. At this location the water-retaining Main Embankment will be constructed, including a 15m deep grout curtain at the upstream toe, which will fully penetrate the upper 15m of the foundation profile.

- The zone of saturation will be confined to the valley floor beneath the tailings level. Seepage will not be able to flow out of the valley elsewhere along the western valley profile, due to the height of the western valley ridge line.

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1 INTRODUCTION

This report presents the revised and updated results of a tailings management study and the design of a Tailings Storage Facility (TSF) for the Dugald River Feasibility Study.

Dugald River is a zinc-lead deposit with presence of copper mineralisation. The project is owned by Mineral and Metals Group (MMG), who are updating the feasibility study to assess the requirements for development of a lead-zinc mine at the site. The original study was completed by OZ Minerals in late 2008, prior to their acquisition by MMG. The original tailings storage feasibility study was conducted by ATCW Williams (ATCW, formerly Australian Tailings Consultants), and documented in **[Ref. 1]**.

This tailings study update has been conducted by ATCW, in accordance with a proposal (Ref. 108003.02-001 Rev1) dated 28th May 2010, and MMG Principal Agreement Number 01654. This report supersedes the previous **Ref.1** report.

The objectives of the tailings management study have been the investigation of storage options, analyses, design, costing and documentation of a working life of mine tailings storage scheme to feasibility study level.

2 BACKGROUND

2.1 Previous Studies

The Dugald River Project is a zinc and lead reserve in north-west Queensland, approximately 70 km north-west of Cloncurry. The deposit has been known of for many years, originally for its copper ore outcrops. Lead-zinc metallurgical testing began in 1952, and since that time, ownership has changed hands many times.

A pre-feasibility study for the Dugald River site was completed by the previous owner, Pasminco in 2000. ATCW carried out the tailings management options study, which examined potential sites for the tailings storage, and considered a number of different tailings management methodologies.

Since the completion of the pre-feasibility study, much of the lease holdings held by Pasminco have been sold. As a result, the current MMG Dugald River leases are surrounded by mining and exploration leases belonging to Universal Resources Limited.

2.2 2010 Update

The original **Ref.1** study identified the preferred location for the Dugald River TSF, with two of the key design criteria being:

- the mandatory Design Storage Allowance (DSA), and
- the daily water balance, which assessed the validity of the storage concept and provided an indication of likely return water availability to the process plant.

The DSA, as defined in **Section 4.2**, involves the excess storage required as a result of the 1 in 100 year, 2 month critical wet period. Since the completion of the **Ref.1** study, an extremely wet period was experienced at the project site during January – February 2009.

As MMG are currently finalising the Environmental Impact Statement (EIS) for the project, it was considered important to redress the hydrological aspects of the original study, to include meteorological data from 2009. In addition, a geotechnical investigation of the preferred TSF site was completed subsequent to the issuing of the of the **Ref.1** report. This update hence allows a discussion of the investigation results to be included where appropriate herein.

3 STUDY PARAMETERS

3.1 Tailings Tonnage

Dugald River will be an underground mining operation, and will utilise paste backfill of stopes on an ongoing basis. Mining and tailings production parameters are summarised in **Tables 3.1** and **3.2**.

TABLE 3.1
MINING DATA

Total Resource:	46.8 Mt
Life of Mine:	26.5 Years (ramp-up Year 1, ramp-down Years 23-26)
Processing Rate (Maximum / Average):	2.0 Mtpa / 1.77Mtpa
Zinc Concentrate (Maximum / Average):	430,000 tpa / 368,000 tpa
Lead Concentrate (Maximum / Average):	51,000 tpa / 37,000 tpa
Tailings as Paste Backfill (Maximum / Average):	821,000 tpa / 505,000 tpa

TABLE 3.2
TAILINGS PRODUCTION PARAMETERS

Annual Tailings to TSF (Maximum / Average):	1.3 Mtpa / 0.87 Mtpa
Tailings Quantity to TSF:	22.8 Mt

The overall annual average proportion of tailings directed to underground backfill will be 36.8%. The paste plant will not be operating full time, and hence the maximum discharge rate into the TSF has been based on the overall maximum tailings production rate of 1.6 Mtpa.

3.2 Thickening

Based on an assessment of tailings thickening and delivery issues at each of the TSF site options, it was concluded by ATCW in **[Ref. 2]** that paste thickening at Dugald River is not warranted. This is primarily based on the cost implications relative to the benefits of paste thickening.

High-rate thickening still provides for significant water savings, and the tailings can be delivered to the TSF using conventional centrifugal pumps. Based on bench-scale testwork conducted by Outotec **[Ref. 3]**, the target thickener underflow solids content will be in the range 50% to 55%.

For Feasibility Study purposes, an average value of 53% solids ex. thickener has been adopted. Accounting for gland water in the delivery system, the tailings discharge solids content used in the study is 51%.

4 DESIGN CRITERIA

4.1 Climate Data

A database of 121 years of daily rainfall and evaporation has been compiled for hydrological modelling of the Dugald River TSF site. This data includes the recent 2009 wet season, and was provided by WRM water + environment **[Ref. 4]**.

The data was obtained from the SILO Data Drill, which is a facility for extracting Australian Bureau of Meteorology data from an archive of interpolated rainfall and climate surfaces maintained by the Queensland Department of Environment and Resource Management. The interpolated data are all synthetic, with no original meteorological station data left in the calculated grid fields. However, the Data Drill does have the advantage of being available for any set of coordinates in Australia.

4.1.1 Rainfall

The SILO Data Drill daily rainfall data supersedes the data compiled by ATCW from sites in Cloncurry (excluding 2009), which was used in **Ref. 1**. A comparison of the two data sets is given below:

- Average annual rainfall — SILO = 514 mm; Cloncurry = 483 mm

The rainfall databases were interrogated using the Log-Pearson Type III probability distribution, producing the following 1 in 100 year average recurrence interval (ARI) estimates:

- 1:100 year, 2 month rainfall — SILO = 1083 mm; Cloncurry = 911 mm
- 1:100 year annual rainfall — SILO = 1330 mm; Cloncurry = 1237 mm

It is evident from the above comparison that the SILO data is generally comparable, but slightly wetter than the Cloncurry rainfall. The reason for this is partly considered to be regional, although the inclusion of the 2009 wet season is also a factor.

The annual rainfall database compiled for the site, together with the 26 year moving average is shown in **Chart 4.1**. A year in this context is a "water year", i.e. 1st July - 30th June. Any given year is defined in terms of the calendar year when it commenced, thus the rainfall year 1st July 1910 - 30th June 1911 is referred to as 1910.

The average monthly rainfall is presented together with average monthly evaporation in **Chart 4.2**.

4.1.2 Evaporation

Evaporation data has also been synthetically developed from the SILO Data Drill, and supersedes the data compiled by ATCW from sites in Cloncurry (excluding 2009), which was used in **Ref. 1**. The average monthly evaporation is presented together with the average monthly rainfall data in **Chart 4.2**.

CHART 4.1
ANNUAL RAINFALL DATABASE

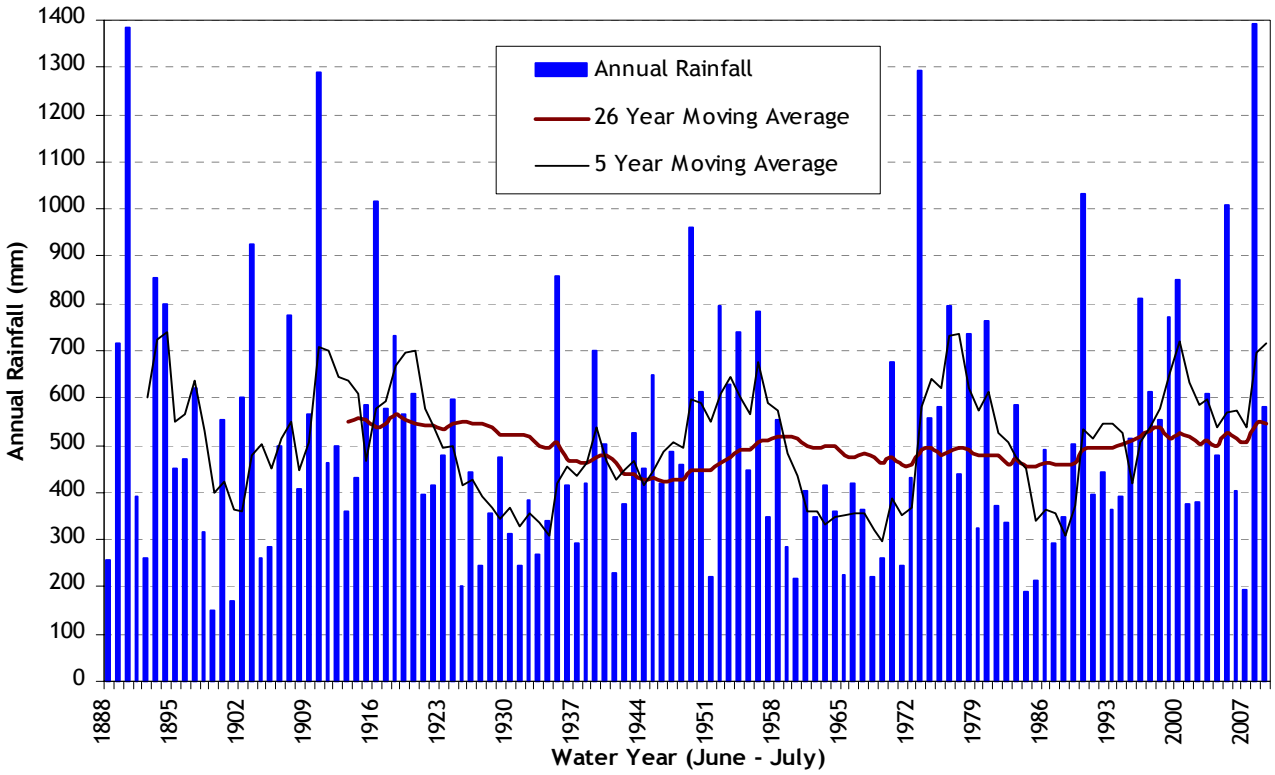
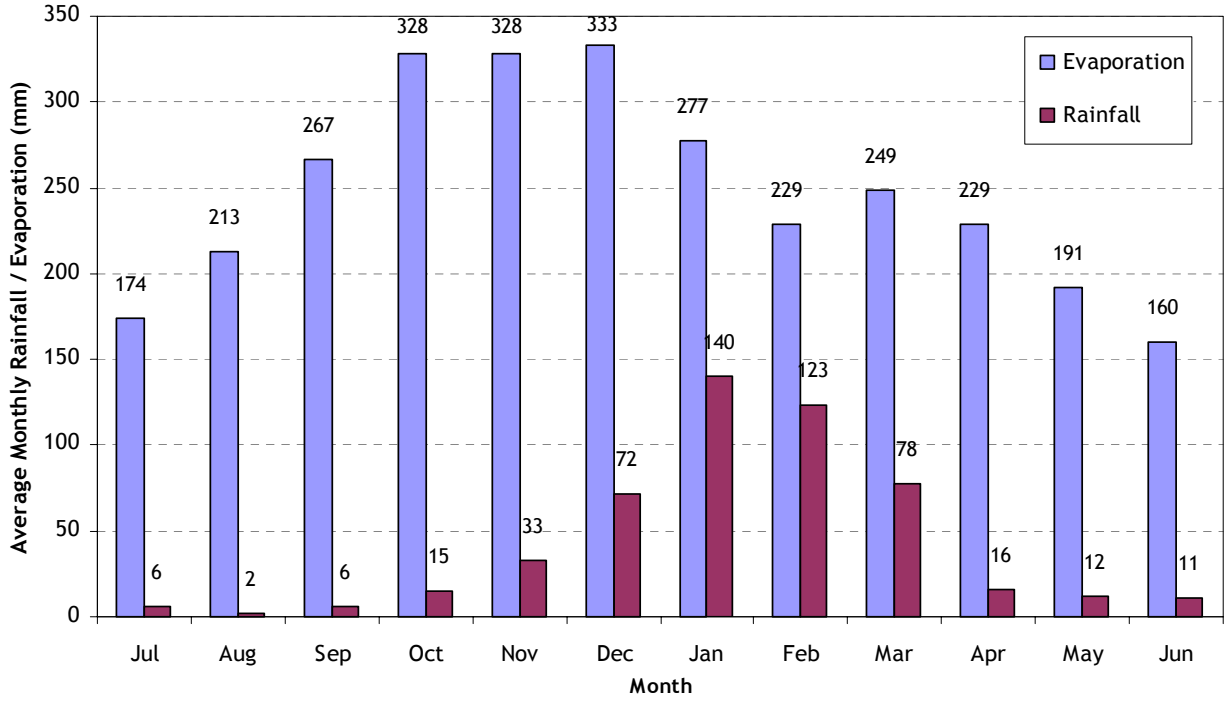


CHART 4.2
AVERAGE MONTHLY RAINFALL AND PAN EVAPORATION



4.2 Flood Management

The design of the Dugald River TSF has been based upon the Queensland Government Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland **[Ref. 5]**. The two key parts of the guidelines with respect to tailings are the sections relating to Site Water Management and Tailings Management.

The first key issue with respect to Site Water Management is what to do with water from storm events that result in runoff from the tailings impoundment that is considered to be contaminated. Such water is generally available for recycling through the plant. An issue arises when the volume of water arrives at a rate quicker than can be utilised in the plant, as this excess water must be stored. The guidelines define the storage requirement for this situation as the Design Storage Allowance (DSA).

The definition of the DSA is the excess storage required at the 1st of November each year that will be filled by the process inputs and runoff from the critical wet period, less average evaporation.

For Dugald River the critical wet period is two months and the ARI for a high hazard dam (i.e. assuming that the decant liquor is "toxic") is a 1 in 100 year return period. The appropriate rainfall for calculation of the DSA (from **Section 4.1.1**) is thus 1083 mm.

4.3 Seismicity

For the purposes of the seismic analysis of the Dugald River TSF Main Embankment, a deterministic, prescribed approach to design has been adopted, which is the method recognised as the most widely used to date. A probabilistic seismic hazard assessment of the region was conducted by the Seismology Research Centre (SRC) in Australia, with all identified faults added to the seismotectonic model. The SRC review **[Ref. 6]** presents an annual exceedence probability (AEP) versus ground motion relationship determined for the seismotechnic province in which Dugald River is located.

The ANCOLD dam design guidelines **[Ref. 7]** define this approach to design, with two levels of earthquake motion as follows:

Operating Basis Earthquake:

- the OBE is for the purposes of evaluating the serviceability of the dam, rather than its safety. It is an earthquake which could reasonably be expected to occur during the life of the dam, and should only result in minor, easily repairable damage. The dam and appurtenant structures should remain functional after the occurrence of earthquake shaking not exceeding the OBE.
- The ANCOLD guidelines description of the OBE reports deterministically derived earthquakes with a typical annual exceedence probability (AEP) range of 1 in 200 to 1 in 1,000 years. For Dugald River, the OBE acceleration coefficient is based upon a 10 percent chance of exceedence in 50 years, which is roughly equivalent to an AEP of 1 in 500 years.

Maximum Design Earthquake:

- the MDE will produce the maximum level of ground motion for which the dam should be designed or analysed. It is a minimum requirement that the impounding capacity of the dam be maintained when subjected to that seismic load.

- The ANCOLD guidelines summarise MDE deterministic, prescribed design methods used by various international dam authorities. From this summary, accepted practice for High Hazard dams is typically to adopt a probabilistic AEP of 1 in 10,000 years.

From the SRC review **[Ref. 6]**, the horizontal peak ground acceleration (PGA) for both the OBE and MDE events are as presented in **Table 4.1**, where 'g' refers to the acceleration due to gravity.

TABLE 4.1
SUMMARY OF SEISMIC DESIGN CRITERIA

Design Event	OBE	MDE
Average Recurrence Interval	1 in 500 yrs	1 in 10,000 yrs
Peak Ground Acceleration	0.042 g	0.24 g

4.4 Embankment Stability

Main Embankment stability has been assessed using the following minimum factors of safety (FS):

- Static loading - FS ≥ 1.5
- Static loading, flood storage level - FS ≥ 1.3
- Pseudo-static loading - FS ≥ 1.0 (refer to **Section 10.1**)

5 OPTIONS STUDY

5.1 Pre-Feasibility Study

A pre-feasibility study for tailings management at the Dugald River site was completed by ATCW for Pasminco in 2000. The study identified three potential sites for the tailings storage, and considered a number of different tailings management methodologies. Viable options included both ex-concentrator tailings ("unthickened") and enhanced thickened tailings, and the study explored the use of up-valley, down-valley, and central thickened discharge approaches.

Due to the changes in lease holdings since OZ Minerals (now MMG) acquired the site, two of the three site options originally identified now fall partially outside the mining and exploration leases, and have hence been discounted from the current study.

5.2 Current Study

The basis for selection of the two short-listed TSF options was detailed in a Site Options Assessment conducted by ATCW **[Ref. 2]**. Six sites were considered, including locations within, to the west and to the east of the Knapdale Range which runs north-south through the centre of the project area. Three of the sites were also assessed on less than the life of mine capacity, on the basis that they be utilised in pairs. Criteria for assessment of the site options included:

- the physical characteristics of the TSF with regard to embankments, storage efficiency, tailings delivery and water management requirements.

- Basic capital and operating costs.
- The existence of potential copper resources underlying the site.
- The potential for expansion of the TSF beyond the Feasibility Study resource.

Based upon a qualitative ranking of all site options, two sites were recommended to proceed to the Conceptual Design phase of the Feasibility Study. Site A2 (the Knapdale valley scheme without the dividing embankment) was ranked the highest due to its storage efficiency and potential for expansion, with water balance modelling required to investigate the water management issues involved in storing runoff on the tailings.

Site H2 (the perimeter discharge scheme located immediately south of the Process Plant Site) was also considered deserved of further study, given its proximity to the process plant site and lack of significant water management issues.

5.3 Preferred TSF Site

Following the completion of the Site Options Assessment **[Ref. 2]**, the two short-listed TSF sites were further developed to the conceptual design stage, to facilitate selection of the preferred option. This work is documented in the Conceptual Design Report **[Ref. 8]**. The two sites are:

Site A2 – Knapdale Valley TSF

This is the only remaining site from the 2000 pre-feasibility study, and consists of a long, narrow bifurcated valley running north-south on the western side of the Knapdale Ranges. The valley is approximately 4km north-west of the processing plant.

The TSF would consist of a single large embankment to close the valley outlet on the west side, a down-valley discharge of tailings, and all decant and runoff water being stored within the tailings impoundment (ie. no secondary water storage pond).

Site H2 Cell TSF

Site H2 is located on the relatively flat area 0.5km south of the process plant site, bounded by Silver Mine Creek to the north, the hill known locally as “Copper Hill” to the west, and the mine lease boundary to the east. The proposed TSF is a perimeter discharge scheme with a series of upstream raises and a central decant structure.

Assessment

The following criteria were reviewed to determine the preferred TSF site option for the Dugald River Project Feasibility Study:

(i) Capital Costs
(ii) Operating Requirements and Costs
(iii) Site Water Management Implications
(iv) Risk of Failure
(v) Rehabilitation Requirements
(vi) Site Disturbance Footprint Implications
(vii) Sterilisation of Potential Resources
(viii) Expandability

When both TSF site options were assessed with respect to the review criteria, the Site A2 Knapdale valley scheme was favoured over the Site H2 perimeter discharge cells.

Apart from slightly increased start-up capital costs and some disturbance to the Cabbage Tree Creek catchment, the Site A2 valley was preferred with respect to all review criteria, particularly in the key economic criteria of Total Cost, Potential Sterilisation and Expandability for future mining plans.

6 SITE CONDITIONS

6.1 Site Description

Photographs of the Knapdale Valley TSF site are presented below, whilst the topography is shown in **Figures 8.1** and **8.2**. The valley is some 3,000m long, and is generally less than 500m wide within the tailings storage area.

The sides of the valley are generally quite 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 207m to RL 235m at the southern end.

The valley catchment boundary is shown in **Figure 8.2**. The eastern side of the catchment extends across the Knapdale plateau some 700m, whilst the western side ridge line rises more abruptly before dropping down to the western toe of the ranges.

The single drainage outlet is a relatively narrow valley approximately mid-way along the western side. This valley runs some 600m before reaching the western extent of the ranges and discharging into the Cabbage Tree Creek catchment.

Vegetation within the valley is relatively sparse, as can be seen in the photos. Trees are generally small, and are confined to the valley floor and lower slopes. Due to the lack of topsoil, the remainder of the site is covered only with Spinifex grasses and minor brush.



Photo 1 – Looking east into Knapdale Valley from Main Embankment south abutment



Photo 2 – Looking north from the southern head of the Knapdale Valley



Photo 3 – Looking north at the Main Embankment site from the southern abutment

6.2 Geology

The Dugald River project site is located within the Mary Kathleen Zone of the Eastern Foldbelt of the Mt Isa Inlier, on Proterozoic sandstone, siltstone and quartzite. Based on the BMR Quamby Sheet 6957, 1980 Regional Geology Sheet, the 14km long, 3km wide Knapdale Ranges consist of Knapdale Quartzite of the Mount Albert Group, which overlie the Corella Formation calc-silicates. Separating the quartzite from the Corella Formation is a low angle, mylonitic thrust fault.

The quartzite is a massive formation of medium grained, pink-grey metamorphosed sandstone, striking predominantly north – south with a dip of foliation angle in the range 60 to 80 degrees to the west. There are no known or inferred faults running through the valley. A plan of the local geology of the Dugald River site, including all mapped structures, is presented as **Figure 6.1**.

6.3 Hydrogeology

An assessment of the hydrogeology of the Dugald River site and the groundwater aspects of the proposed mine development has been conducted by Rob Lait and Associates **[Ref. 9]**. It is evident from this assessment that the majority of information regarding the Dugald River hydrogeological regime pertains to the Corella Formation in the area east of the Knapdale Ranges. This is because the prime Dugald River aquifer is considered to occur within fractured calc-silicate rocks in the Corella Formation at the geological boundary between it and the Dugald River Slate above the mineralized zone.

Groundwater occurs in fractures, joints, solution channels and along bedding planes (secondary porosity) to a depth of approximately 70m. The average depth to groundwater in this area is 10m to 15m. Production bores generally indicate the aquifer sequence to be of low permeability, and structurally controlled.

Very little is known regarding the hydrogeology of 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. Due to the lack of weathering, surface fractures and its generally massive structure, the quartzite is also presumed to be of low permeability. Groundwater is expected to be present, but at depths of 20m or more below the base of the TSF valley. Due to the nature of the quartzite formation, the groundwater is expected to exist only locally in the fissures within the rock mass.

It is reported in **[Ref. 9]** that from visual inspection it appears that the potential for infiltration of tailings leachate to the Knapdale Quartzite will be low. Therefore the potential for groundwater contamination will also be low. As with the Knapdale Range, there is likewise little available groundwater information in the Cabbage Tree Creek catchment area to the west. However the lack of production bores or wells in the area suggest it is a poor groundwater resource.

As reported in **[Ref. 9]**, two groundwater monitoring bores were installed downstream of the TSF Main Embankment where the drainage feature exits the Knapdale Ranges (MB5 and MB 6, as shown in **Figure 8.2**). These were in order to further evaluate the hydrogeology and groundwater quality of the Knapdale Quartzite and the Cabbage Tree Creek catchment area. The two boreholes indicate groundwater at a depth of approximately 10m, with a potentiometric gradient of the order of 0.01 to the west.

Discharge testing in the boreholes yielded negligible supply in the more westerly bore (MB6), and less than 1 litre/sec in MB5. Rising head permeability testing gave overall average results of 10^{-8} m/sec in MB6, and 10^{-6} m/sec in MB5. However, from discussions with Rob Lait and Associates, it is understood that MB5 was deliberately located in the narrow zone of structural weakness running north-south at the westerly edge of the Knapdale Quartzite (refer to the geology plan in **Figure 6.1**, and the indicative subsurface Section 1 of **Figure 16.2**). They refer to this zone as a highly localised, confined "shoe-string" aquifer with generally low yield and poor capacity for recharge.

6.4 Geotechnical Investigation

6.4.1 Field Work

Access to the Knapdale Valley was difficult during the Feasibility Study period. As result, a preliminary geotechnical investigation of the site was only able to be conducted in December

2008, after completion of the original study report **[Ref. 1]**. The purpose of the geotechnical investigation was to:

(i) investigate the nature and condition of the Main Embankment foundation stratigraphy,
(ii) estimate rock mass permeability within the Main Embankment footprint area,
(iii) investigate the depth to groundwater downstream of the Main Embankment and install a groundwater monitoring bore.

Work originally proposed, but unable to be completed due to the onset of wet weather included the investigation of rock quality within potential rockfill quarry areas, and obtaining samples of potential construction materials for subsequent laboratory testing.

A total of four boreholes to depths ranging from 20m to 30m along the alignment of the proposed Main Embankment. Rock core was recovered from the boreholes, and insitu permeability tests conducted at regular intervals. A monitoring bore was installed in the base of the gully, at the downstream toe of the embankment footprint.

Six test pits were excavated to refusal in the near-surface soils and weathered rock at the upstream and downstream toes of the embankment footprint.

A detailed report documenting the preliminary geotechnical investigation and the results obtained was issued in February 2009 **[Ref. 10]**.

6.4.2 General Foundation Conditions

The preliminary investigation of the proposed TSF Main Embankment alignment revealed a subsurface stratigraphy generally consisting of moderate to high strength, highly weathered to moderately weathered quartzite (metamorphosed fine grained sandstone).

The rock is typically highly fractured within the upper 5m to 10m. The rock weathering profile is generally shallower on the abutment slopes and becomes deeper towards the gully floor. For the purposes of this feasibility study, the highly weathered quartzite rock is considered a satisfactory foundation material for the proposed embankment in terms of strength and deformability.

At the entrance to the gully in the vicinity of the embankment upstream toe, up to 1.5m of colluvial-alluvial clayey, sandy gravel overlies the quartzite. Test pit excavations in this area penetrated up to 2.6m in depth, indicating the likely maximum foundation stripping depths that will be necessary to reveal competent rock. It is expected that stripping depths will reduce to a likely minimum of 1m on the abutments and towards the downstream toe.

6.4.3 Embankment Construction Materials

Based on the core obtained from the embankment boreholes, the quartzite within the TSF area can be expected to yield suitable select rockfill for embankment construction. However, the suitability of the proposed embankment rockfill quarry areas were not investigated due to limited time and site access conditions. This will need to be addressed during the detailed design phase.

The test pit investigation revealed up to 1.5m of clayey, sandy gravel colluvium-alluvium in the valley floor. However, the actual extents of this material, together with its suitability as earthfill material for a low permeability embankment zone, will require further investigation for detailed design purposes.

6.4.4 Permeability and Groundwater

In general, the rock mass permeability of the quartzite rocks are considered low to moderate beneath the gully floor and the left (south) abutment, and low at the right abutment. Permeabilities were found to range from 10^{-5} to 10^{-7} m/sec in the upper foundation region (0 to 5m depth) to less than 10^{-7} m/sec in the more competent underlying rock. It is evident from the investigation that the rock mass permeability is independent of the weathering profile, with the degree of jointing and fracturing being the dominant factor.

The groundwater conditions at the embankment site have been difficult to establish, however it is considered likely that it exists locally in the joints and defects within the rock mass, typically within a depth of 10m below the surface of the gully floor. The monitoring bore installed downstream of the proposed embankment footprint has not been dipped since it was installed, hence the existence of a local groundwater table in that particular area has not been established.

7 TAILINGS CHARACTERISATION

7.1 Physical Properties

Prototype, bulk floatation tailings samples were prepared at Amdel Mineral Laboratories, and shipped in May 2008 to the NATA (National Association of Testing Authorities) accredited ATCW laboratory in Melbourne for the characterisation of their physical properties.

ATCW testwork has included basic characterisation tests (particle density, plasticity) and specialised tailings testing (initial and shrinkage limit density, rheology, Rowe Cell consolidation).

An ATCW tailings laboratory testwork report is presented in **Appendix A**. The following is a summary of the tailings physical properties resulting from the testwork:

7.1.1 Tailings Classification

Specific Gravity (SG) :	2.96	
Particle Size Distribution :	P_{80} ~ 50 µm	
Atterberg Limits :	Liquid Limit Plasticity Index	= 21 = 6
Unified Soil Classification :	Low plasticity Silt	
Segregation Threshold :	46% solids	

7.1.2 Tailings Density

The tailings densities resulting from the laboratory testwork are presented in **Table 7.1**. These parameters can be defined as follows:

Sedimented Density : This is the density that the tailings reach as they settle soon after discharge, and is related to the discharge solids content. During the sedimentation phase bleed water is released. For the study tailings discharge solids content of 51% and an average tailings beach layer thickness of 50mm, a sedimented density of 1.19 t/m^3 has been adopted.

Shrinkage Limit Density : This is the limiting density that tailings will achieve at the surface when subject to solar desiccation. Desiccation occurs when the rate of evaporation exceeds the rate at which consolidation water is expelled from the tailings surface. The process of desiccation is actually consolidation, however, the forces causing it are due to a process known as suction and are considerably greater than those caused by self-weight.

TABLE 7.1
TAILINGS DENSITY PARAMETERS

Discharge Solids Content (%)	Sedimented Density		Shrinkage Limit Density (t/m^3)
	Solids Content (%)	Density (t/m^3)	
50	66	1.18	1.63
55	67	1.20	

7.2 Design Density

7.2.1 Overview

In general the density of tailings increases with time. The increase in density is a result of three processes: sedimentation, desiccation and consolidation. The densities achievable through sedimentation and desiccation can be estimated from laboratory testing, and are described above.

Consolidation is a time dependent process whereby water is “squeezed” from the pore spaces in the tailings due to their self weight. Consolidation is accepted to commence when sedimentation is complete. Tailings density increases with depth, however, the rate of density increase is affected by the permeability of the tailings and rate of discharge. As deposition continues, the addition of tailings will eventually lead to further consolidation and resultant increase in density.

For design purposes, the Overall Insitu Density is used to estimate the required capacity of the TSF. In a well-designed TSF the Overall Insitu Density will approach the Shrinkage Limit Density. In the case of the Dugald River TSF, the theoretical beach area needed to dry the tailings back to the shrinkage limit density can be calculated and is 7 ha. In practice it will of course be more in winter and less in summer.

A beach area of 7 ha will be achieved after only a few months of operation. Thus it would normally be reasonable to assume for design purposes that a density at or close to the shrinkage limit density will be achieved virtually throughout. However, as discussed in **Section 8.2**, the Dugald River TSF concept will involve decant and runoff storage over the tailings, with extended periods of elevated pond levels predicted. The density must therefore be de-rated to reflect sub-aqueous deposition into the decant pond.

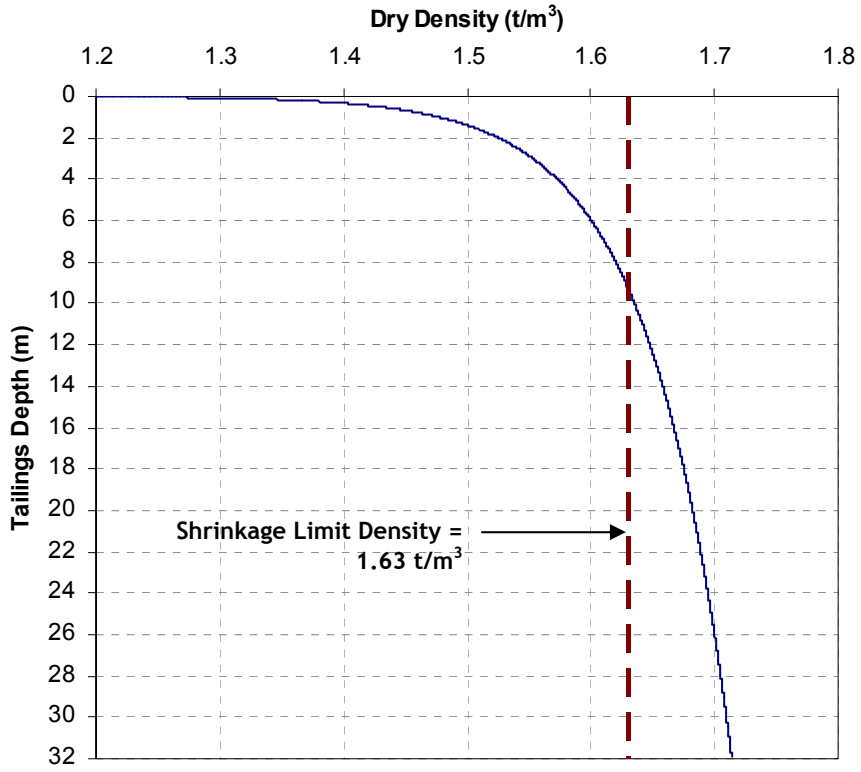
7.2.2 Consolidation

Consolidation testing of the Dugald River tailings was conducted as part of the laboratory testwork described in **Appendix A**. The analysis of consolidation behaviour is complex, as it is a time dependent phenomenon that is governed by tailings permeability. Thus if the rate of rise in the TSF is too rapid there will be insufficient time for the tailings at depth to respond and low densities can persist.
The process was studied using software developed by ATCW **[Ref. 11]** specifically to model large strain consolidation of tailings deposits. The background of the model and a description of the program inputs are provided in **Appendix B**.

7.2.3 Modelling Results

Chart 7.1 presents the computed dry density profile for the tailings adjacent to the Main Embankment at the end of mine life. The shrinkage limit density is also shown in **Chart 7.1**.

CHART 7.1
NORMALLY CONSOLIDATED TAILINGS DENSITY PROFILE



It is evident that the tailings will be at least normally consolidated during the majority of the deposition period, and that there will be minimal post deposition settlement. This is due to the expected overall low rate of rise of the deposited tailings (refer to **Section 8.4**), and the relatively high values of coefficient of consolidation (c_v) obtained for the tailings laboratory testing.

The typical depth of tailings required to exceed the shrinkage limit density is approximately 9m. Under normal operating conditions the dry beach area will develop a crust relatively quickly, and desiccation, accompanied by surface cracking, will commence.

It is important to note that the consolidation profile shown in **Chart 7.1** neglects the desiccation effects of evaporative drying on the exposed beach. If the Shrinkage Limit Density is superimposed on the density profile, it can be expected that most of the shallow tailings will achieve a significantly higher density than the normally consolidated profile, as a direct consequence of evaporative drying.

7.2.4 Adopted Design Density

The TSF design has been based on an Overall Insitu Density value of 1.5 t/m^3.

Whilst this appears conservative based on the results of the consolidation modelling, it is considered a sound, defensive design policy given that the TSF will be configured to temporarily store catchment runoff and bleed water on the tailings. The implications of this design concept and its potential effect on the overall density is examined in the Water Balance (**Section 15**) of this Report.

7.3 Tailings Geochemistry

A suite of geochemical testwork on the tailings solids and liquor has been conducted at the laboratories of Environmental Geochemistry International (EGi) in Sydney. Testwork has included:

- pH, alkalinity, EC and multi-element analysis of tailings liquor.
- Acid Neutralising Capacity (ANC) of tailings solids.
- Net Acid Generation (NAG) capacity of tailings solids.
- Acid Buffering Characteristic Curve.
- Multi-element analysis of solids.
- Sulphur and carbon speciation in solids.
- Determination of Net Acid Producing Potential (NAPP).
- Column Leach Test of 52 weeks duration, including monthly multi-element analysis of leachate.

A report from EGi documenting testwork details and a discussion of results is included in this Report as **Appendix C**.

The results of static testing indicated that the tailings are potentially acid forming, with a high sulphide content comprising mainly pyrite, with some sphalerite and galena not recovered during processing. The acid forming characteristics are as follows:

- Net Acid Generation capacity (NAG) = 140 kg H_2SO_4/tonne
- Acid Neutralising Capacity (ANC) = 54 kg H_2SO_4/tonne
- Net Acid Producing Potential (NAPP) = 86 kg H_2SO_4/tonne

This NAPP represents a high acid potential and suggest that the tailings will have the capacity to generate significant acidity if exposed to atmospheric conditions.

Although the tailings have a moderately high ANC, the column test results indicate that, due to the high sulphide reactivity, the initial rate of acid generation exceeds the reactivity of the carbonates contributing to the ANC. Within the first four weeks of column testing the tailings acidified to pH 3.9, and reached a minimum pH of 3.5 after 16 weeks.

Thereafter, the pH of leachate increased again, eventually stabilising at around pH 7 toward the end of the 52 week test period.

The return to pH neutrality can be attributed to a slowing in the rate of sulphide oxidation, and would likely remain for a number of years. However, given the strongly positive NAPP and NAG values it is expected that the tailings would eventually re-acidify with long-term exposure to atmospheric conditions.

During the column test there was also significant release of a number of environmentally important metals, including zinc (13 to 75 mg/L), manganese (7 to 95 mg/L), lead (0.25 to 1.4 mg/L) and cadmium (0.12 to 0.55 mg/L). These concentrations are typically one or two orders-of-magnitude higher than the corresponding metal concentrations reported for the tailings liquor, and are a consequence of the initial acidification of the tailings.

Based on the above interim results it has been assumed that the tailings decant liquor will be "toxic". This assumption is made strictly for the purpose of interpretation of the Queensland Government Guidelines on tailings management and is not meant to be used for any other purpose.

8 TSF PLANNING AND DESIGN

8.1 Required TSF Capacity

Based upon a total tailings tonnage of 22.8 million tonnes (refer to **Section 3.1**) at an overall insitu dry density of 1.5 t/m^3 at the end of filling (refer to **Section 7.2**), the required life of mine TSF capacity for Feasibility Study purposes is 15.2 million m^3.

It is apparent when comparing this capacity with the conceptual design amount in **[Ref. 8]** that the quantity of tailings requiring storage in the TSF has risen by almost 60 percent. It is primarily for this reason that a number of changes have been made to the original Knapdale Valley TSF concept.

8.2 Tailings Storage Concept

An overall site plan of the Knapdale Valley TSF is shown in **Figure 8.1**, whilst the general arrangement of the TSF at the end of mine life is shown in **Figure 8.2**. The tailings storage concept is relatively simple, and makes use of the inherent characteristics of the valley. Tailings will be pumped up into the Knapdale Ranges from the process plant, making use of the Mine Camp access road route.

Discharge will occur on a rotational basis from both the southern and northern ends of the valley, such that the tailings beach low point is maintained in the centre of the valley, where the decant pond will form. Decant return will be via a floating pontoon tethered on the eastern side of the valley. A decant return pipeline and access road will be required to link the eastern side of the TSF to the Mine Camp access road, as shown in **Figure 8.1**.

For Feasibility Study purposes the TSF extents have been limited to within the current MMG lease tenure. Containment will almost entirely be provided by the valley topography, with the main tailings retaining features being the Main Embankment on the west side, the Eastern Decant Access Embankment, and the Northern Discharge Bunds.

A number of transportation lease corridors will be required in order to gain access to the tailings discharge and decant return routes. These proposed corridors are shown in **Figures 8.1** and **8.2**.

The 43m high Main Embankment will be the primary structure, and is required to close the valley outlet on the western side. It will need to be designed as a water retaining embankment, due to the presence of water ponding against it during the life of mine. The embankment will be raised downstream in three stages to minimise upfront capital costs.
The Eastern Decant Access Embankment will be required at start-up, and will provide initial construction access to the valley. At the time of the final two TSF stages, the Northern Discharge Bunds will be constructed and then raised to confine the TSF within the current MMG lease tenure, as shown in **Figure 8.2**.

The TSF valley will have a catchment of 335 hectares, with no diversion drains. Construction of diversion drains to reduce the catchment area of the TSF is not considered viable given the site topography. This large catchment is however a benefit of the site, in that it can be used to collect and temporarily store runoff during the wet season for use in the process plant.

At the end of mine life, the final beach profile will have its low-point at the Main Embankment, as shown in **Figure 8.2**. Thus, a self-shedding profile will be created for rehabilitation and closure.

8.3 Design Storage Allowance

The Design Storage Allowance (DSA) is defined in **Section 4.2**. For the 335 hectare catchment, assuming no runoff losses, two month's average wet season pond evaporation, plus two month's tailings bleed water, the Knapdale Valley TSF DSA is estimated to be 3,250 megalitres (ML).

8.4 Embankment Staging

The tailings rate of rise at the two discharge ends and at the Main Embankment are plotted in terms of Volume and Time in **Charts 8.1** and **8.2**. Also depicted is the embankment staging schedule.

The required Main Embankment crest level is a function of the tailings beach level with time. However, as discussed in **Section 4.2**, the Design Storage Allowance DSA of 3,250 ML must also be catered for. It is evident in **Charts 8.1** and **8.2** that the DSA will add on average between 8m and 11m to the embankment crest. The crest level needed at start-up to contain the DSA will be RL 226.5m, requiring an embankment height of at least 19.5m.

The embankment staging schedule will be as follows:

Stage I - Crest level 234m. The objective being to minimise the upfront capital cost, whilst providing a realistic stage life of 5 years.

Stage II - Crest level 242m. The life of this stage will be timed to coincide with the construction of the Northern Discharge Bunds, which will be required at Year 14.

Stage III - Final crest level of 248.75m.

In devising the embankment staging, consideration has also been given to providing a general balance in embankment fill volumes.

CHART 8.1
TSF VOLUME – TAILINGS LEVEL RELATIONSHIP

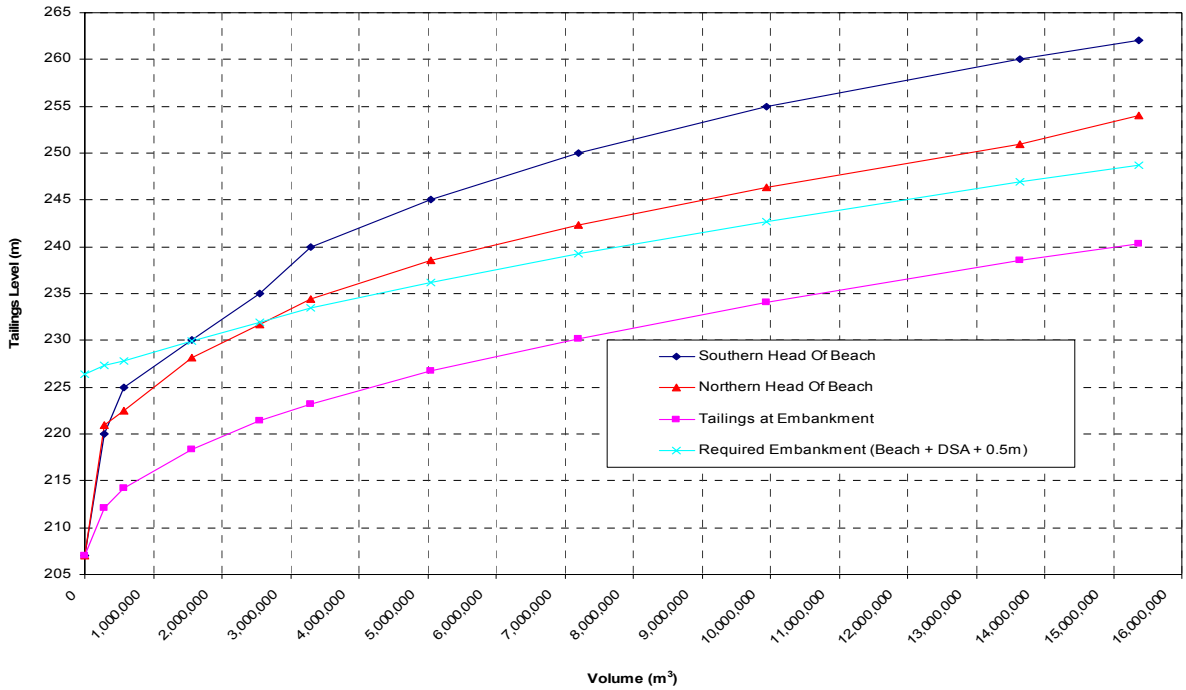
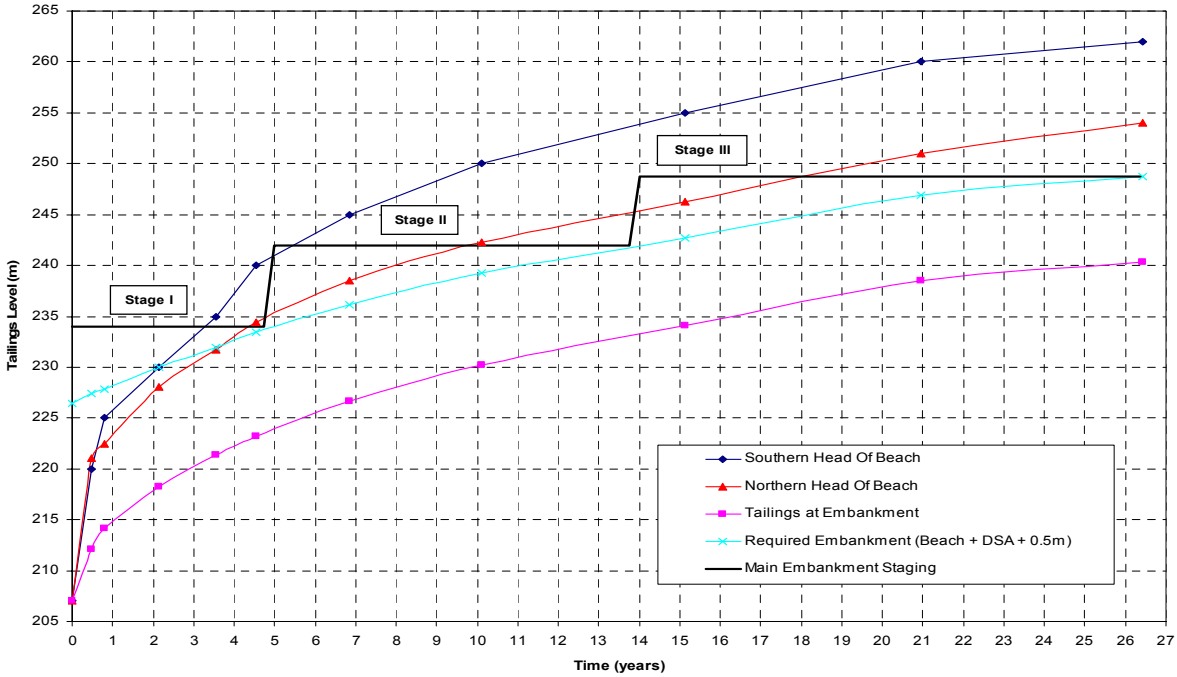


CHART 8.2
TSF STAGING – TIME – TAILINGS LEVEL RELATIONSHIP



It is evident from **Charts 8.1** and **8.2** that the base of the valley will fill quickly, and the head of beach will rise rapidly (average 2.25m per year) during years 1 to 5.

However, due to the topography of the valley, the rate will reduce markedly, to an average of 1m per year from Years 5 to 14 (Stage II).

From Years 14 to 26 (Stage III), the tailings level is predicted to rise just 7m. Rates of rise of this order are considered beneficial with respect to achieving optimum density in the deposited tailings.

8.5 Beach Slope

This is the slope formed by the tailings after deposition, and impacts upon embankment requirements and thus cost. The slope depends upon the tailings discharge solids content, segregation threshold and rheology. The segregation limit is well below the expected discharge solids content, which indicates that there will be little or no segregation or sorting on the beach.

Tailings beach slopes are related to the sheared yield stress and viscosity, as well as the total flow in the tailings stream. Increases in sheared yield stress and viscosity result in an increase in the beach slope of the tailings surface. Also, reducing the flow in a tailings stream increases the beach slope, thus the number of tailings discharge points is an important consideration.

The beach slope design has been based on the adopted tailings discharge solids content of 51%. At this solids content, and based on particle size distribution, mineralogy and rheology, the test results for the bulk floatation tailings indicate beach slopes in the following ranges:

- 1 discharge point : 0.8 – 1.1%
- 2 discharge points : 1.0 – 1.5%

Experience shows that, in practice, the percent solids from the thickeners will vary from day to day. The variation depends on many factors such as fluctuations in feed rate, flocculant behaviour, ore type, and operational decisions. The outcome is a slightly concave beach profile as the lower density tailings will beach at the toe of the slope at the flattest angle and the highest density tailings will beach at the head of the beach at the steepest angle.

As a consequence, the “rule of thirds” has been applied to the overall average slope to account for the concave effect. This results in the following adopted profile, on the basis of two discharge points operating at any one time:

- Top 1/3 of beach : 1.5 %
- Middle 1/3 of beach : 1.0 %
- Bottom 1/3 of beach : 0.67 %

This beach profile is shown for the TSF at the end of mine life in **Figure 8.2**.

8.6 Beach Slope Stability

8.6.1 Liquefaction Potential

Because of the excess of evaporation over rainfall at this site, it is expected that the tailings beach will not be in a fully saturated condition, and hence not susceptible to liquefaction processes.

However, given the large catchment and potential for long periods of flood water inundation, it is conservatively assumed that during operations the tailings may become saturated for short periods.

Based upon the tailings particle size distribution and Atterberg Limits reported in **Section 7.1**, the tailings are a fine grained silt of low plasticity. These index properties can be used to estimate liquefaction susceptibility. The criteria recently published by Boulanger **[Ref. 12]** show that a fine grained silt tailings with Plasticity Index less than 5 will be potentially liquefiable when saturated. Given the bulk floatation tailings have a PI of 6, they can be considered potentially susceptible to liquefaction.

8.6.2 Post-Liquefaction Beach Stability

Experience indicates that for tailings deposits with a saturated tailings beach, a degree of deformation may occur during seismic events (cyclic mobility), depending on the angle of the beach, the strength of the tailings, and the intensity and duration of shaking. Continuing deformations (liquefaction flow sliding) after the end of shaking are not indicated.

However, as a precaution, a post-liquefaction stability analysis **[Ref. 13]** has been carried out for the final Stage III tailings beach using infinite-slope theory. It is important to note that, even if a beach mobilisation were to occur at this final beach level, overtopping of the Main Embankment would not result, despite the final head of beach level being 14m above the embankment crest. The total tailings volume of 15.2 million m^3 would redistribute horizontally to a level of RL 245m, which is 3m lower than the Stage III embankment crest.

For the post-liquefaction stability analysis it has been assumed that the tailings have been deposited and dried to the overall insitu dry density (1.5 t/m^3), from which the following is derived:

bulk density, γ = 1.99 t/m^3, given the density of water, γ_w = 1 t/m^3

The post-liquefaction steady-state (residual) shear strength is not constant, but is dependent on the vertical effective stress assuming a normally consolidated deposit. On the basis of previous ATCW test results obtained for testing of other samples of zinc (and copper) tailings, the post-liquefaction shear strength of tailings can be expressed as:

S_{us} = k x σ_{vo}' , where
S_{us} = (steady-state) undrained, post liquefaction shear strength,
k = constant
σ_{vo}' = vertical effective stress

The results for laboratory shear vane testing indicate that values of k = 0.07 are appropriate. Results from triaxial testing suggest higher values of k, but for this analysis, we have conservatively taken the lower value.

The equations derived from the stability of long, shallow slopes ("infinite slope theory") may be used to analyse this situation. The concave beach slope profile described in **Section 8.5** has been adopted. Two cases may be considered:

1. Upper Slope

For the upper, steepest portion of the beach:

Slope angle β = 1.5% (sin β = 0.015)

It is conservatively assumed that the slope is saturated, but does not have a phreatic surface. For this condition, the stability equation for the Factor of Safety (FS) reduces to:

$$FS = \frac{k}{\sin\beta} = \frac{0.07}{0.015} = 4.67$$ i.e. the slope will remain stable.

2. Lower Slope

For the lower, flatter portion of the tailings beach:

Slope angle β = 0.67% ($Sin\ \beta$ = 0.0067)

In this case it is assumed that the slope is saturated, and has a phreatic surface at the top of the tailings (ie. has hydrostatic pore pressures). This situation would occur below the decant pond. For this condition, the equation for stability is:

$$FS = \frac{k}{\sin\beta}\left(1-\frac{\gamma_w}{\gamma}\right) = \frac{0.07}{0.02} \times \left(1-\frac{1}{3.22}\right) = 2.41$$ i.e. the slope will remain stable.

8.6.3 Conclusion

Whilst the tailings physical characteristics suggest they are potentially liquefiable, the post liquefaction stability analyses have shown that the adopted tailings beach slopes will remain stable, even when hydrostatic pore pressure conditions are assumed after seismic-induced liquefaction.

Following capping and closure the design conditions anticipate the tailings beach to be unsaturated below the capping layer, and cyclic mobility will not occur.

9 MAIN EMBANKMENT OPTIONS

9.1 Overview

For the reasons of construction costs and availability of materials, two embankment configuration options have been considered for the TSF Main Embankment. These are as follows:

(i) Clay Core Option – conventional zoned earth and rockfill embankment.

(ii) Geomembrane Option – rockfill embankment fitted with a waterproofing geomembrane sealing system (GSS) on the upstream face.

In order to determine the preferred embankment configuration, designs were completed and stability analyses performed. Feasibility study level (+/- 15%) costings were then developed, based on an assessment of materials requirements and sources, quantities, and budget rates for civil works items submitted by specialist construction contractors. These are discussed in the following **Sections 10** and **11**.

9.2 Clay Core Option

A typical section and materials summary for the zoned earth and rockfill embankment option are shown in **Figure 9.1**. The Zone 1 clay core has been inclined in order to reduce the material quantity and to facilitate downstream raising.

The presence and suitability of earthfill materials on the floor of the valley have always been considered the main issues with this arrangement. Since the conceptual design was prepared, basic data on the depth and nature of surface soils in the valley have been collected by the project environmental consultants. This information has shown the quantity of potentially suitable clayey alluvial soils to be less than originally envisaged, with the majority of investigation locations revealing shallow (less than 300mm) gravel deposits.

Whilst the geotechnical investigation within the embankment footprint (refer to **Section 6.4**) revealed colluvial soils and highly weathered rock to depths of up to 2.6m, at best only the upper 0.5m of this horizon would be expected to yield suitable construction materials.

Clay core materials would hence need to be hauled from the eastern side of the Knapdale Range, where a confirmed source exists at the alternative TSF site immediately south of the Process Plant (discussed in the **Ref. 8** Conceptual Design Report).

Embankment foundation preparation requirements are assumed to be relatively straight-forward, with nominal 0.5m surface stripping required. A key trench terminating on moderately weathered rock (between 1m and 2.5m deep) would be excavated within the Zone 1 core footprint to minimise near-surface foundation seepage.

The geotechnical investigation (refer to **Section 6.4**) revealed low to moderate foundation rock permeability beneath the gully floor and the left (south) abutment. It is hence considered that a program of foundation curtain grouting will be required prior to embankment construction. The actual extents of this program will need to be confirmed, however it is likely that the curtain will need to extend to a depth of 10m to 15m, in areas of moderate permeability (say, greater than 10^{-6} metres/second). In order to control grouting in the upper few metres of the foundation, a mass concrete grout cap is also considered to be required.

Embankment side slopes for this option would be 2.25:1 (horiz:vert) upstream and 2:1 (overall) downstream. The Zone 1 core would lie close to the upstream face, inclined at 2:1 to minimise the intermediate stage crest widths.

The embankment would incorporate two-stage granular filters (Zone 2A and 2B) downstream of the Zone 1 core. These are necessary in order to prevent erosion of clay materials into the Zone 3 rockfill under the seepage forces generated during the elevated pond levels expected during the life of mine.

The Zone 2A Fine Filter would consist of a clean, well-graded sand-gravel mix, with a maximum particle size of 5mm. The Zone 2B Intermediate Filter would require a blended sand-gravel-cobble material with a maximum particle size of 100mm. These materials would either be produced on site from processed colluvium and/or crushed rock, or imported from commercial operations.

The Zone 3 rockfill materials would form the outer shells of the embankment, and would consist of blasted, quarried quartzite. Zone 3A transition rockfill would incorporate more weathered

rockfill compacted in 400mm lifts, whilst the outer Zone 3B would consist of slightly weathered to fresh rockfill compacted in 800mm layers.

The clay core embankment option would require a diversion pipe installed in the base of the gully during Stage I construction. This is due to the inability to construct a coffer dam upstream of the works, the comparatively long construction period, and the increased susceptibility to this embankment configuration to damage due to overtopping.

9.3 GSS Option

A typical section and materials summary for the GSS rockfill embankment option are shown in **Figure 9.2**. The general embankment design comprises an exposed PVC geocomposite anchored to a base layer of extruded porous concrete curbs, and to a reinforced concrete toe plinth along the foundation perimeter. Further discussion regarding the details and selection process for this system are given in **Section 12**.

The curbs would rest upon a 3m wide support and drainage layer constructed of Zone 2 granular fill. The remainder, and bulk of the embankment raise, would consist of Zone 3A and 3B quarried rockfill. The rockfill provides strength and stability to the structure and supports the upstream GSS. The rockfill zones would differ on the basis of maximum allowable particle size, placed layer thickness and the compaction requirements.

Similarly to the clay core option, foundation curtain grouting is considered necessary, although a grout cap will not be required as the concrete plinth will be able to serve this purpose.

The embankment side slopes would be 1.5:1 (horiz:vert) upstream, and 1.75:1 (overall) downstream, made up of 1.5:1 slopes and 5m wide benches, as shown in **Figure 9.2**. Due to the shorter construction period and increased resilience to damage from overtopping, the Stage 1 embankment would not require a diversion pipe during construction.

10 EMBANKMENT STABILITY

10.1 Overview

General Methodology

Stability analyses were performed on each of the Main Embankment options under consideration. The governing design principle is that the embankment must be designed in a manner such that the integrity of the structure with respect to stability under static and seismic loading conditions is preserved.

The Main Embankment static and pseudo-static stability have been assessed using the maximum height cross sections shown in **Figures 9.1** and **9.2**, which are considered to be the critical cases in terms of stability. Analyses were performed using SLOPE/W Version 6 software **[Ref. 14]** and employing a GLE (General Limit Equilibrium) approach, which satisfies both force and moment equilibrium.

Stages I and III were analysed, and both upstream and downstream slope failures were considered. Upstream analyses were conducted at the end of construction of the particular Stage and at a point half way through filling. The extreme flood condition (DSA) was also analysed for Stage I.

The critical time for the downstream slope is at the end of the particular Stage, when the upstream pond level is highest.

Pseudo-Static Stability Methodology

Pseudo-static analyses were conducted using the OBE (serviceability) and MDE (safety) loading cases specified in **Section 4.3**.

OBE analyses were performed using conventional peak strength analyses and the US Army Corps of Engineers (USCE) screening method **[Ref. 15]**. The USCE method is an internationally recognised screening tool for seismic instability, applicable to well compacted embankments not susceptible to liquefaction, as is the case with the Knapdale Valley TSF Main Embankment.

The USCE method recommends use of a seismic coefficient equal to one-half of peak ground acceleration (PGA) using drained conditions for free draining granular materials, with a 20 percent strength reduction to allow for strain weakening during the earthquake loading.

The design objective was for zero predicted deformations under the OBE (serviceability) criteria. This determination was based upon USCE Screening resultant Factors of Safety being greater than 1.0 (an FS of 1.0 indicates deformations of less than 1m along the nominal failure "plane").

MDE pseudo-static analyses were conducted using conventional, peak strength properties, in order to assess the safety of the embankment when subjected to the maximum design earthquake load.

Embankment design procedures generally proceed as required from initial, simplified methods to more complex, rigorous methods. Hence the purpose of the pseudo-static analyses was to determine if more detailed embankment deformation analyses are required.

10.2 Material Properties

The material properties used in the stability analyses are summarised in **Table 10.1**.

TABLE 10.1
MATERIALS PARAMETERS FOR MAIN EMBANKMENT STABILITY ANALYSES

Type	Static & Pseudo-static Analysis			USCE Screening (factor x 0.8)			γ_{sat} (kN/m^3)	γ_d (kN/m^3)
	c' (kPa)	ϕ'	Model	c' (kPa)	ϕ'	Model		
Tailings	Su_{min} = 10	-	S_u/σ'_{vo} = 0.20	Su_{min} = 8	-	S_u/σ'_{vo} = 0.16	20	-
Zone 1 (Core)	Su_{min} = 50	-	S_u/σ'_{vo} = 0.35	Su_{min} = 40	-	S_u/σ'_{vo} = 0.27	19	20
Zone 2 (Filter)	0	35	Mohr-Coloumb	0	29	Mohr-Coloumb	19	20
Zone 3 (Rockfill)	Shear Stress-Normal Stress Function, $\tau - \sigma$						22.5	

Due to the absence of geotechnical information, the shear strength and density properties were obtained from published literature, established correlations such as **[Ref. 16]**, and previous experience. The following information summarises the selection of these parameters:

Tailings:

It has been established that the tailings will consist of low plasticity silt fines. As such, undrained shear strength parameters have been derived for use in the stability analyses, as it is believed that any slope failure passing through tailings will mobilise its undrained shear strength.

The effective (drained) stress parameters were derived empirically, based upon experience with copper and zinc tailings of similar characteristics. A critical state approach was employed to determine a SHANSEP type strength model, which estimates the undrained strength of the tailings as a function of effective overburden stress.

Zone 1 Core:

Due to the impervious nature of clayey material, it would be expected that any static or dynamic failure of Zone 1 will occur largely under undrained conditions. Thus undrained shear strength parameters were considered for Zone 1 in the stability analyses.

A strength as a function of overburden model was derived, based upon previous studies conducted on similar materials. The ratio of undrained shear strength to the effective overburden stress has been derived assuming that the core material will be compacted within the embankment at optimum moisture content to 95% relative standard density.

Zone 2 Granular Filter:

Significant differences between drained and undrained strength response are not expected for the granular filter materials, hence drained strength parameters have been used for the Zone 2, 2A and 2B materials in all stability analyses. The saturated density and drained friction angle of 35° for the gravels have been conservatively adopted from **[Ref. 16]**, which correlates test results for medium to dense, angular gravels and sands.

Zone 3 Rockfill:

Because of the large maximum particle size, and essentially well graded nature of the Zone 3A and 3B Rockfill materials, significant differences between drained and undrained strength response are not expected.

With regard to the shear strength of the rockfill, Leps **[Ref. 17]** has shown that shear strength, as expressed by its friction angle, varies markedly as a function of the effective normal stress. **Figure D1** of **Appendix D** shows the relationship derived for Zone 3A and 3B Rockfill for both static and pseudo-static loading conditions.

Zone 3B has been conservatively assessed as being equal to the Leps average function, with the Zone 3A transition material function lying between the average and the lower-bound. The quartzite rockfill which will be used in embankment construction is potentially of higher quality than these estimates, however this can only be confirmed after completion of the geotechnical investigation.

The density values for the compacted rockfill have been adopted based on past experience with compacted, well-graded metamorphic rockfill.

10.3 Results – Clay Core Option

A summary of the stability analysis results for the clay core option are presented in **Tables 10.2** (Stage I) and **10.3** (Stage II). The Figure Numbers in the table refer to graphical output of the critical failure surfaces, which are presented in **Appendix D**.

TABLE 10.2
STABILITY ANALYSIS RESULTS – CLAY CORE OPTION (STAGE I)

Case	FS	Allowable FS	Figure Number
UPSTREAM SLOPE			
Static Loading - End of Construction - 20m of flood water (DSA) - 10m of tailings, 5m of wet season flood water	 1.49 1.32 1.39	 1.5 1.3 1.3	 - D2 -
Seismic (USCE screening, OBE) - 9m tailings, 1m of water (normal conditions)	 1.03	 1.0	 D3
Seismic (MDE) - 9m tailings, 1m of water (normal conditions)	 0.83	 1.0	 D4
DOWNSTREAM SLOPE			
Static Loading - 20m of flood water (DSA) - End of Stage, 5m of wet season flood water	 2.16 2.16	 1.3 1.3	 - -
Seismic (USCE screening, OBE) - End of Stage, 1m of water (normal conditions)	 1.66	 1.0	 -
Seismic (MDE) - End of Stage, 1m of water (normal conditions)	 1.31	 1.0	 -

TABLE 10.3
STABILITY ANALYSIS RESULTS – CLAY CORE OPTION (STAGE III)

Case	FS	Allowable FS	Figure Number
UPSTREAM SLOPE			
Static Loading - End of Construction, 5m of wet season flood water	 1.68	 1.3	 -
Seismic (USCE screening, OBE) - End of Construction, 5m of wet season flood water	 1.27	 1.0	 D5
Seismic (MDE) - End of Construction, 5m of wet season flood water	 1.01	 1.0	 -
DOWNSTREAM SLOPE			
Static Loading - End of Stage, 5m of wet season flood water	 2.06	 1.3	 -
Seismic (USCE screening, OBE) - End of Stage, 1m of water (normal conditions)	 1.58	 1.0	 -
Seismic (MDE) - End of Stage, 1m of water (normal conditions)	 1.25	 1.0	 D6

Using the design criteria summarised in **Section 4** and the USCE seismic screening approach, the Clay Core embankment option was found to comply in terms of all static and OBE loading cases.

It is evident that the Stage 1 upstream slope is the most prone to potential instability, particularly after flooding during the initial deposition period. The presence of tailings on the upstream face of the embankment is beneficial. The bulk weight and strength of the tailings acts as a toe surcharge and results in an increased factor of safety (FS) against failure.

The inclination of the core reduces the vertical thickness of rockfill cover. The strength of the clay for use in seismic stability analyses is termed the "undrained" strength, and is dependent upon the weight of rockfill above the point in question. Hence, when the tailings are at a low level and a water cover exists, the shear strength of the clay is comparatively low and the FS is reduced.

The USCE Screening minimum FS for the upstream slope was found to be 1.03, which is satisfactory for serviceability requirements given that an FS of 1.0 indicates "tolerable" deformations of less than 1m along the nominal failure "plane".

The MDE loading condition represents a pseudo-static assessment of the safety of the embankment. The results show that there will potentially be deformations during MDE shaking in the upstream slope. Under the requirements of the established design criteria, in order to investigate the characteristics and magnitude of these deformations, more accurate and detailed dynamic analyses would be required for the Clay Core option during detailed design.

10.4 Results – GSS Option

A summary of the stability analysis results for the GSS embankment option are presented in **Tables 10.4** (Stage I) and **10.5** (Stage II). The Figure Numbers in the table refer to graphical output of the critical failure surfaces, which are presented in **Appendix D**.

TABLE 10.4
STABILITY ANALYSIS RESULTS – GSS OPTION (STAGE I)

Case	FS	Allowable FS	Figure Number
UPSTREAM SLOPE			
Static Loading - 5m of tailings, 5m of wet season flood water - 20m of flood water (DSA)	 1.83 2.57	 1.5 1.3	 D7 -
Seismic (USCE screening, OBE) - 5m of tailings, 5m of wet season flood water	 1.41	 1.0	 -
Seismic (MDE) - 5m of tailings, 5m wet season flood water	 1.14	 1.0	 D8
DOWNSTREAM SLOPE			
Static Loading - 20m of flood water (DSA) - End of Stage, 5m of wet season flood water	 1.93 1.92	 1.3 1.3	 - -
Seismic (USCE screening, OBE) - End of Stage, 5m of wet season flood water	 1.48	 1.0	 -
Seismic (MDE) - End of Stage, 5m of wet season flood water	 1.19	 1.0	 D9

Using the design criteria summarised in **Section 4** and the USCE seismic screening approach, the GSS embankment option was found to comply in terms of all static and seismic loading cases.

The OBE (serviceability loading) minimum factor of safety (FS) for the upstream slope was found to be 1.41 during Stage 1, whilst for the downstream slope a minimum FS of 1.41 was also obtained when the embankment is raised to Stage III. Given that a FS of 1.0 using the USCE method indicates negligible rockfill deformation, these results are considered satisfactory.

The results for the MDE cases are all greater than 1.0, indicating that deformations would not be expected during the extreme loading case. As a result, no further analyses would be required for this embankment option.

TABLE 10.5
STABILITY ANALYSIS RESULTS – GSS OPTION (STAGE III)

Case	FS	Allowable FS	Figure Number
UPSTREAM SLOPE			
Static Loading - End of Construction, 5m of wet season flood water	1.98	1.3	-
Seismic (USCE screening, OBE) - End of Construction, 5m of wet season flood water	1.51	1.0	D10
Seismic (MDE) - End of Construction, 5m of wet season flood water	1.12	1.0	-
DOWNSTREAM SLOPE			
Static Loading - End of Stage, 5m of wet season flood water	1.85	1.3	-
Seismic (USCE screening, OBE) - End of Stage, 5m of wet season flood water	1.41	1.0	-
Seismic (MDE) - End of Stage, 5m of wet season flood water	1.15	1.0	D11

11 EMBANKMENT OPTIONS ASSESSMENT

In order to finalise the selection of the preferred Main Embankment configuration, an assessment of earthworks quantities and capital costs over the life of the mine has been conducted. In addition, a review of construction logistics, risks and opportunities has been conducted.

11.1 Quantities

The two dominant cost items are those relating to Main Embankment fill construction and geomembrane installation. A summary of quantities involved in these two items is presented in **Table 11.1**.

A discussion of the quantity comparison, including the key differences (highlighting those which have not been included in the summary) follows **Table 11.1**.

It is evident that the GSS option would involve a reduction in embankment fill of 115,000 m^3 over the life of mine. Associated with this is a similar reduction in foundation stripping and preparation requirements.

Additional Clay Core option items not included in the comparison are the requirement for a diversion pipeline during the construction of Stage I (discussed in **Section 9**), and the mass concrete grout cap for the foundation curtain grouting.

Offsetting the reduction in earthworks quantities for the GSS option is the requirement for a reinforced concrete plinth and the geomembrane itself.

TABLE 11.1
SUMMARY OF MAIN EMBANKMENT FILL AND GEOMEMBRANE QUANTITIES

	Main Embankment Fill (m^3)		Geomembrane (m^2)	
	Clay Core Option	GSS Option	Clay Core Option	GSS Option
Stage I	220,600	128,100	-	6,345
Stage II	135,700	107,400	-	3,005
Stage III	123,500	128,200	-	3,420
Total	478,900	363,700	-	12,770

11.2 Capital Costs

A detailed assessment of capital costs over the life of mine has shown that the total cash outlay is similar for each embankment option. However, the GSS option was found to be less expensive in net present cost terms, and was also found to require significantly less start-up (Stage I) expenditure.

11.3 Embankment Construction

With respect to embankment construction logistics, a number of issues exist which have a bearing on the selection of the preferred option. These are as follows:

11.3.1 Zone 1 Earthfill

The clearest item of risk in the Clay Core embankment option is the source, availability and cost of Zone 1 Earthfill. The verbally advised doubling of the BGC unit rate is not considered to be conservative, as the actual haul requirements cannot be finalised, and hence has not been properly costed. Whilst the area on the east side of the Knapdales has been identified as a possible source of suitable material, the existence of the 60,000 m^3 required for Stage I has not been proven. This area will also be borrowed from extensively for other infrastructure earthworks.

Other, as yet unidentified borrow sources would be required for the construction of the Main Embankment Stages II and III.

11.3.2 Expandability

Whilst the Clay Core option has been configured for downstream raising, further expansion beyond the final Stage III would be difficult from an engineering perspective, and would cost

significantly more than the GSS option. With the latter configuration, the raising potential is limited only by the topography of the TSF valley.

11.4 Preferred Embankment Configuration

On the basis of capital costs, construction efficiency, materials availability and future expandability, the GSS option has been selected as the preferred configuration for the Dugald River TSF Main Embankment.

12 MAIN EMBANKMENT – DESIGN OVERVIEW

12.1 Overview

Based on the findings of **Section 11**, the Dugald River TSF Main Embankment will consist of a rockfill embankment fitted with an exposed, PVC geocomposite sealing system (GSS). Details of the GSS are provided in a preliminary Technical Proposal submitted by Carpi, a Swiss/Italian specialist geomembrane contractor. A copy of the Carpi submission is presented in **Appendix G**.

A summary of the rationale used in the selection of the adopted geomembrane sealing system for the upstream face of the Main Embankment is presented in **Appendix H**.

The general embankment configuration will be as described in **Section 9.3**, and the typical section and material details shown in **Figure 9.2**.

A general layout of the Main Embankment is presented as **Figure 12.1**. The embankment footprints and GSS details are shown for Stages I, II and III (as defined in **Section 8.4**).

12.2 Geomembrane Sealing System

The GSS adopted for the Dugald River TSF Main Embankment is practically identical to the recently installed Sar Cheshmeh waterproofing system described in **Appendix H**.

12.2.1 PVC Geocomposite

The PVC geocomposite will consist of SIBELON CNT 3750, a 2.5mm thick PVC geomembrane, heat-coupled during manufacturing to a 500g/m^2 non-woven polypropylene geotextile. The GSS will be a drained system, incorporating a porous concrete curb base layer and a granular drainage layer.

12.2.2 Base Layer and Face Anchorage

The PVC geocomposite will be attached to the upstream face of the embankment using the Carpi-patented method incorporating a base layer of porous extruded concrete curbs and continuous vertical lines of PVC anchor strips.

The general layout of the face anchorage system is shown in **Figure 12.1**, and various details are presented in **Figure 12.2**.

400mm high, trapezoidal-shaped extruded curbs will form the base layer for the GSS and confine the Zone 2 drainage layer. They will be constructed of porous concrete using a specially adapted paving machine.

Details of the face anchoring and geocomposite attachment procedure are presented in the Carpi Drawings 1 and 2 of **Appendix G**. The PVC geocomposite will be anchored to the dam by heat-welding it to anchor strips embedded in the curbs during curb construction. The anchor strips will be made with SIBELON CNT 3750, the same material as the waterproofing PVC geocomposite. The PVC anchor strips will be placed over each line of extruded curbs at a maximum spacing of 6m.

The rectangular anchor strips will be 0.5m wide and of sufficient length so as to cover completely the curbs (upstream and downstream sides) and overlap the anchor strip placed underneath. Each strip will be heat-welded to the underlying strip, resulting in continuous vertical anchorage lines at 6m spacing, embedded in the face of the embankment.

12.2.3 Perimeter Anchorage

Perimeter anchorage of the PVC geocomposite will be of the mechanical tie-down type on the abutments and crests of the raise, as shown in **Figures 12.1** and **12.2**. Details of the mechanical anchoring are presented in the Carpi Drawing 3 of **Appendix G**. At the crests of each stage, the geocomposite will be anchored using mass concrete anchor beams, with tie-down fastening for Stage I an III, and embedment beneath a mass concrete anchor beam for the final Stage III.

Anchorage to the abutments will be via stainless steel batten strips bolted to a reinforced concrete plinth. The plinth will be 3m wide, 0.4m deep, with a final (Stage III) length of some 295m. The plinths will be constructed of 32 MPa reinforced concrete, with 2m anchor dowels at 2m centres.

Due to the foundation conditions revealed by the preliminary geotechnical investigation (refer to **Section 6.4**), curtain grouting will be conducted beneath the plinth. Further investigations during detailed design, as well as inspections of the foundation at the time of construction, will confirm the extents of the grouting works.

13 CIVIL WORKS

13.1 Overview

The TSF civil works layouts for Stages I, II and III are shown in **Figures 13.1 – 13.3**. Embankment rockfill (Zones 3A and 3B) will be locally quarried from designated areas upstream and downstream of the embankment, with nominal areas shown in the Figures. It is proposed that geotechnical investigations be done in these areas during detailed design to confirm material suitability.

It is possible that the granular drainage/GSS support layer material (Zone 2), consisting of a well graded sand-gravel-cobble mix, may be selectively won from the rockfill quarries. This would likely require screening to produced the required blend with a maximum particle size of 150mm. Alternatively, material could be produced elsewhere on site, or imported from commercial quarry operations.

During the construction of Stage I, rockfill will be quarried in the area to the north of the embankment (refer to **Figure 13.1**) to create a saddle cut for the purpose of future tailings beach management.

The Stage I civil works will also involve the stripping and stockpiling of topsoil and all potentially seed-bearing materials from the floor of the TSF valley, for the purposes of final closure and rehabilitation of the facility.

13.2 TSF Perimeter Works

In addition to the Main Embankment, civil works will also be required on the northern and eastern sides of the TSF, in order to constrain the tailings extents to within the current MMG lease tenure. Where necessary, these works will be constructed within transportation lease corridors, as shown in **Figure 8.2**.

On the eastern side, Decant Access Embankments 1 and 2 will be constructed of general rockfill during Stage I, as shown in **Figure 13.1**. The Embankment 1 crest level of RL 243m will be coincident with the final tailings level, and will infill the steep gully to provide a platform for the construction of Embankment 2 and drain catchment runoff into the TSF. Embankment 2 will have a crest level of RL 248.75m, and will be the formation upon which the Decant Access and return pipeline will be constructed.

The Stage II civil works program during Year 5 will include the construction of the North-West and North-East Discharge Bunds, as shown in **Figure 13.2**. The bunds will be between 8m and 15m high and will be constructed using Zone 3A rockfill. The North-East Bund will also include general rockfill infilling of the valley behind it, in order to provide catchment drainage and a formation for the access road and tailings discharge pipeline.

The Stage III civil works will include the raising of the North-West and North-East Discharge Bunds to a final crest level of RL 252m, as shown in **Figure 13.3**.

The total quantity associated with the TSF Perimeter civil works is estimated to be 153,900 m^3. A summary of the quantities is provided in **Table 13.1**. In the event of the lease tenure constraints being resolved, it is important to note that most of the above works would not be required.

TABLE 13.1
SUMMARY OF TSF PERIMETER WORKS QUANTITIES

	Eastern Decant Access Embankment (m^3)		Northern Discharge Bunds (m^3)	
	Zone 3A	General (Bulk) Rockfill	Zone 3A	General (Bulk) Rockfill
Stage I	22,100	54,000	-	-
Stage II	-	-	19,500	10,100
Stage III	-	-	26,200	32,000
Total	22,100	54,000	35,700	42,100

13.3 Seepage Collection Pond

A small, lined seepage collection and evaporation pond will be constructed downstream of the Main Embankment, in order to monitor and prevent embankment or foundation seepage from discharging off-site. The nominal location of the collection pond is shown in **Figure 12.1**, with a typical section in **Figure 9.2**.

Construction of the collection pond will require detailed excavation of surface gravels and weathered rock, to form a basin nominally 0.9m deep and 4m wide across the base of the gully.

Inlet and side slopes will be gently graded. A retaining bund with a nominal crest at RL 206m will be constructed at the downstream side.

Zone 1 clayey earthfill will form the pond liner and the core of the retaining bund. This material will need to be imported from the eastern side of the Knapdale Ranges, moisture conditioned and compacted. A cover of Zone 2 granular material will be placed over the liner to prevent it from drying out or eroding.

14 TAILINGS MANAGEMENT

Tailings management within the Knapdale Valley TSF will be relatively straight-forward, which is one of the beneficial features of the adopted scheme. The tailings beaching effect discussed in **Section 8.5** will be exploited together with the long, narrow configuration of the valley to create a sub-aerially deposited, essentially desaturated tailings storage.

Tailings deposition will occur from the northern and southern ends of the valley via end-point discharge from the points shown in **Figure 8.2**. The multiple discharge points (2 in the north, 4 in the south) will allow the filling of the numerous small valleys which would otherwise become "dead spots" where ponded water would otherwise become trapped.

Two discharge points (one at each end) will generally be operating together in order to maintain the decant pond adjacent to the Main Embankment where the return pump will be located. Based on the adopted tailings properties and production rates, the maximum discharge head of beach will be approximately RL 262m at the southern end, and RL 251m at the Northern Discharge Bunds. The maximum tailings depth within the TSF will be approximately 34m.

The tailings beach development with time is shown in **Figures 14.1 – 14.3**. Depicted are the estimated tailings extents at Years 0.8, 3.6, 6.8, 10.1, 15.1 and 21.0, which correspond to 5m to 10m head of beach increments. The final layout of **Figure 8.2** shows the beach towards the end of the mine life (Year 26). The data from these beach layouts form the basis of the filling relationships and embankment staging requirements discussed in **Section 8.4**.

15 WATER BALANCE

15.1 Methodology

For the purpose of this study, the water balance model for the TSF has been developed and run on a daily basis over the life of mine, using actual daily records. The aim of this approach was to further investigate the behaviour of the decant pond during periods of sustained high rainfall, which was modelled on a monthly basis in the conceptual design **[Ref. 8]**. The model was prepared on the basis of the conventional mass balance approach:

$$\Delta \text{ Storage Volume} = \text{Inputs} - \text{Outputs}$$

Inputs have included tailings bleed and catchment runoff, whilst outputs were limited to decant return and evaporation, with seepage assumed to be zero given the expected low permeability of the tailings and valley floor. For the purposes of the Feasibility Study, consolidation water inputs were neglected.

15.2 Tailings Bleed

Bleed water is the difference between the water in the tailings slurry as it leaves the thickener, and the retained water at the sedimented density. Bleed water is considered to arrive instantaneously at the surface of the tailings, where it then flows down the beach to the decant pond. Bleed is a function of the tailings production rate, the tailings discharge solids content, and the tailings sedimented density. These data are discussed in **Sections 3.1** and **7.1**.

Further reductions in tailings water content (i.e. beyond the sedimented density) due to beach evaporation and consolidation have been assumed to be losses.

The design discharge solids content of 51% was used (refer to **Section 3.2**). The resultant theoretical bleed water available is hence just under 0.46 m^3/tonne of tailings. However, the actual volume arriving at the decant pond must take into account the effect of evaporation from what is termed the "active wet beach". This concept is discussed further below.

15.3 Catchment Runoff Overview

The rainfall data that has been used to compute catchment runoff for the water balance simulations is discussed in **Section 4.1**.

In the water balance model, runoff from the following catchment areas report to the decant pond:

- The TSF "Catchment Surrounds"
- The TSF "Dry Beach Area"
- The TSF "Active and Passive Wet Beach Area"
- The TSF "Decant Pond Area"

The "Decant Pond Area" is a variable relating to the pond storage volume.

The "Wet Beach Area" is a function of the "Total Beach Area", the "Decant Pond Area" and the initial and final settled densities of the deposited tailings. The area is subdivided into "Active" and Passive" wet beach areas, with the former considered to be the area covered by the previous day's deposited tailings to a nominal depth of 0.03m, and susceptible to evaporation.

15.4 Catchment Yield

15.4.1 Catchment Surrounds

In an attempt to provide a rational basis for determination of runoff from the catchment surrounds the Simplified Boughton method **[Ref. 18]** has been used. The Simplified Boughton method is appropriate for small ungauged catchments and is based upon a three parameter model (S, F and B) where:

S is the surface storage capacity of the catchment in mm,

F is the daily infiltration capacity in mm/day controlling percolation from the surface store to the groundwater store, and

B is a baseflow factor in the range 0 to 1, which determines the portion of the daily depletion of groundwater that appears as baseflow runoff.

The parameter B was set to zero, as there is not considered to be any significant baseflow, as discussed in the hydrogeological summary provided in **[Ref. 9]**.

The other parameters were derived from a previous Boughton yield study conducted for the nearby Century zinc mine TSF **[Ref. 19]**, for which yields are known and the Boughton model calibrated to suit.

The values of S and F were then checked against typical values recommended by Boughton, and adjusted to ensure that they were appropriate with regard to catchment cover and soil type. The adopted parameters and resultant overall average yield factor are shown in **Table 15.1**.

TABLE 15.1
CATCHMENT YIELD PARAMETERS

Location	Boughton Parameters			Overall Average Yield Factor
	S	F	B	
Catchment Surrounds	33.5	4	0	0.28
Tailings "Dry Beach"	18	3	0	0.42
Tailings "Wet Beach"	Not applicable			1.0
Decant Pond				1.0

15.4.2 Tailings Dry Beach

Runoff from the tailings dry beach area was also based upon the Boughton model for the nearby Century zinc mine TSF **[Ref. 19]**, with the aim of producing a long term yield of 40 to 50%. These values were also checked against the range recommended by Boughton for the catchment cover and soil condition, and are shown in **Table 15.1**.

15.4.3 Remaining Areas

The remaining areas within the water balance model are the Decant Pond and the Wet Beach Area. These were each assigned yield factors of 1.0, as shown in **Table 15.1**.

15.5 Model Outputs

15.5.1 Decant Return Water

The decant return system in the model is set to pump back all the excess water in the pond up to the maximum capacity of the pump, provided that the pond volume is larger than the minimum pond storage volume.

The water balance has been conducted using the peak pumping rate of decant return water from the TSF to the plant. The rate is based on the results of the conceptual design water balance **[Ref. 8]**, which found that maximising the use of TSF return water in the various process streams will yield significant benefit to the mine. The peak return rate scenario, assuming that dust sprays and mine service water streams are designated as TSF decant return water, is estimated to be 69 m^3/hour (1,656 m^3/day).

15.5.2 Evaporation

The evaporation data that has been used for the water balance simulations is discussed in **Section 4.1.2**. For the purposes of this study, it is assumed that the evaporation occurs from the "Pond Area" and from the "Active Wet Beach". A pan factor of 0.8 was adopted to enable assessment of evaporation from a free water surface.

15.5.3 Spillage and Seepage

For this model, both spillway discharge and seepage into the TSF impoundment have been assumed to be zero (refer to **Section 16**). This means that all the excess water due to rainfall will collect in the "Pond" and will either be evaporated or pumped back via decant return system.

15.6 Decant Pond Geometry

15.6.1 Derivation

The life of mine water balance model for the Knapdale Valley TSF is relatively complicated. This is due to the decision to locate the decant pond on the tailings beach, meaning that all of the contributing catchment areas outlined in **Section 15.3** are inter-related. The decant pond area – volume relationship is a function of tailings level and hence time. In order to accommodate this, the following procedure was adopted:

(i) Tailings beaches were developed for head of beach increments of 5m, beginning at RL 220m, and the relevant discharge Year calculated. From this data, a relationship was derived to express the tailings beach area as a function of time.

(ii) The decant pond area – volume – RL characteristics were modelled for every beach.

(iii) Quadratic equations were fitted to the area – volume, and area – RL curves for each pond model. A single relationship was then derived to describe the three quadratic equation coefficients. This in turn was then used to express the pond area and level as a function of time.

(iv) With the total beach area, opening pond area, and active wet beach (refer to **Section 15.3**) known, the passive wet beach and dry beach areas where calculated for each time step. This allowed the evaporation, runoff and resultant closing pond calculations to proceed.

15.6.2 Volume

The maximum pond volume was a variable set to be 3,250 ML, which is in excess of the Design Storage Allowance (DSA) discussed in **Section 8.3**.

The minimum pond operating volume variable was set at zero, in order to model the likelihood that during sustained dry weather, no decant return will be possible.

The opening pond volume variable was set to be zero, although it is possible that water may accumulate in the TSF post construction. Opening volumes as high as 250 ML were hence trialled, however the model was not found to be sensitive to this parameter.

15.7 Model Runs

The 121 year rainfall database was divided into ten overlapping 26 year periods, in order to cover a range of different possible rainfall scenarios during normally expected climatic conditions, over the life of the mine. Specifically included were the runs representing the mean, maximum and minimum 26 year average rainfall periods, and the most recent period ending in 2008-2009.

The run periods are summarised in **Table 15.2**. The periods are expressed in "Water Years", which means the annual rainfall is summed from July to January, in order to avoid splitting the wet season periods over which most rain occurs. Refer also to **Chart 4.1** for a graphical representation of the rainfall database.

TABLE 15.2
WATER BALANCE PERIODS – RUNS 1 - 10

RUN	Water Year Period		Av. Annual Rainfall (mm)	Rank (1)	P (2)	Description
	From	To				
1	1893	1918	564	1	1	Period with highest average annual rainfall, and the highest 24r, 72hr, 1 week, 2 week rainfall (1910).
2	1921	1946	423	97	99	Period with lowest average annual rainfall.
3	1984	2009	546	10	10	Period with the highest 1 month, 2 month and annual rainfall (2008).
4	1960	1985	453	87	89	Period with low average annual rainfall, but the highest 5 year sequence (1972 – 1977).
5	1888	1913	551	5	5	Period including the highest 5 year moving average rainfall, and the driest year (1899).
6	1944	1969	464	75	77	Period including the mean rainfall year (1944).
7	1906	1931	520	24	25	Period with high average annual rainfall, but ending with the 10% driest year (1931)
8	1927	1952	462	80	82	Period with the 10% lowest average annual rainfall.
9	1951	1976	485	59	60	Period approximating the mean average annual rainfall.
10	1975	2000	527	21	21	Period ending with the highest 5 year rainfall sequence (1995 - 2000).

(1) Rank in terms of Average Annual Rainfall over the 26 year period (total count = 97)
(2) Exceedence probability of 26 year period Average Annual Rainfall (expressed as a percentage)

15.8 Results

A simplified flow diagram of the TSF water balance model is shown in **Figure I1** of **Appendix I**. The Flow Diagram shows the average and maximum values from the ten water balance runs.

An Outcome Table detailing the inputs, outputs and results for each run, together with minimum, maximum and average values, is included as **Figure I2**.

The key outcomes are summarised in **Table 15.3**, together with some statistics relating to the availability and continuity of supply of decant return water.

TABLE 15.3
TSF DAILY WATER BALANCE - KEY OUTCOMES

RUN	Pond Volume (ML)		Pond Surface Area (hectares)		Average Decant Return Water Rate (m^3/day)	Decant Return Days < 100 m^3/day (% of Total)	Decant Pond Days < 1 m^3 (% of Total)
	Average	Maximum	Average	Maximum			
RUN 1	346	2,506	16	66	1,282	2.2	29.4
RUN 2	97	1,131	7	48	1,019	2.6	51.3
RUN 3	406	3,063	19	70	1,312	4.2	26.8
RUN 4	219	1,791	12	62	1,141	7.6	39.1
RUN 5	434	2,560	17	61	1,255	3.3	30.8
RUN 6	177	1,350	11	45	1,160	4.5	37.8
RUN 7	258	2,552	13	53	1,171	3.9	37.3
RUN 8	141	1,373	9	47	1,088	2.8	45.4
RUN 9	307	1,853	14	52	1,216	2.2	34.4
RUN 10	331	2,185	15	65	1,269	4.5	30.2
Average	**272**	**2,036**	**13**	**57**	**1,191**	**3.8**	**36.2**

In **Figures I3** to **I10** of **Appendix I** the daily rainfall pattern, decant return water flow, and average pond volume have been plotted for Runs 1, 2, 3 and 9 of the water balance. These Runs were selected as they represent the full range of rainfall severity which could be expected during the life of mine.

Runs 1 and 2 are the maximum and minimum 26 year rainfall sequences on record, whilst Run 3 shows the capability of the TSF scheme to contain runoff from the highest 1 month, 2 month and annual rainfall (the 2008 Water Year). Run 9 has been included as it approximates the mean 26 year data set.

When looking at the decant return and pond volume plots (as well as the last two columns of **Table 15.3**), it is important to recognise that the water balance has been conducted on the decant pond, with decant return as an output from the system. It is hence better to consider the average pond volume data as "average daily excess water", when comparing the apparent frequency of zero pond volumes with zero decant return days.

Decant will in reality be pumped back as it arrives and accumulates, meaning that if the total inflows less evaporation for a particular day are less than the peak daily return rate, the average excess water for that day will be reported as zero.

15.9 Decant Pond Water

15.9.1 Expected Maximum Volume

It is evident from the results summary that wet season rainfall will produce significant volumes of runoff water, which will pond in the TSF. Given the relatively low maximum decant pumping rate, high wet season runoff will likely result in many months of sustained high pond volumes covering a large proportion of the tailings beach, as can be seen in **Figures I3**, **I5**, **I7**and **I9**.

Based on the modelling, the maximum excess water volume accumulating in the TSF was approximately 3,000 ML, and resulted from the recent 2008-09 wet season, in which 1252mm fell over a 6 week period.

Given that the rainfall for the 1 in 100 year, 2 month DSA is 1089mm (refer to **Section 4.2**), it is evident that 2008-09 was an extreme sequence of rainfall. However, given the DSA procedure conservatively presumes zero catchment losses, the adopted DSA volume of 3,250 ML would comfortably accommodate such a flood event.

A pond volume in excess of 2,000 ML occurred in 5 of the 10 water balance runs, however this was produced by just four different Water Years (1891, 1911, 1991 and 2008). From the statistical analyses for the DSA, it was found that the above four Water Years are the top four ranked periods, with 2 month rainfalls ranging from 990mm (1991) to 1,300mm (2008).

It is evident from **Table 15.3** (Runs 1, 3, 5, 7 and 10) that the effect of these rainfall periods is pronounced. All these runs report a maximum excess pond water volume of approximately 2,000 ML. The next highest pond volume was in the range 1,790 ML to 1,850 ML, which was generated by Runs 4 and 9, both of which included the highest five year sequence of rainfall, which occurred over 1972 to 1975.

In order to assess the effect such a volume of water would have on the TSF, **Table 15.4** shows the resultant pond depth and area when 2,000 ML is applied to the tailings beaches shown in **Figures 14.1 – 14.3**.

It can be seen that the pond depth to store 2,000 ML will range from 6m to 10m at the Main Embankment, which is why it has been designed as a water retaining embankment.

When comparing the results with the monthly water balance from the conceptual design **[Ref. 8]**, and the original tailings storage feasibility study **[Ref. 1]**, it is evident the pond volumes are now significantly greater. This is considered to be due to the use of a daily model which is better able to capture the peaks, the overall average five percent higher rainfall produced by the SILO data drill (refer to **Section 4.1**), and the use of the Boughton Model which generates more representative catchment yields.

TABLE 15.4
TSF DAILY WATER BALANCE – EFFECT OF MAXIMUM POND VOLUME (2,000 ML)

Year	Tailings RL (m)		Pond Depth At Main Embankment (m)	Area (ha)	
	Southern Head of Beach	At Main Embankment		Tailings Beach	Pond Surface
0.8	225	214.2	9.8	20	35
3.6	235	221.4	7.6	40	46
6.8	245	226.7	6.8	57	53
10.1	250	230.2	6.6	66	55
15.1	255	234.1	6.2	78	61
21.0	260	238.5	6.1	89	62
26.0	262	240.3	6.1	93	64

15.9.2 Effect on Storage Concept

Table 15.5 presents an assessment of the water balance results with respect to the frequency and duration of the pond water volume rising above 600 ML. Whilst this is a significant quantity of water, it can nevertheless be reasonably expected throughout the life of the TSF.

TABLE 15.5
TSF DECANT POND – FREQUENCY & DURATION OF VOLUME ≥ 600 ML

Run	1	2	3	4	5	6	7	8	9	10	Average
Occurrences	11	3	9	9	8	6	7	5	9	10	**8**
Total Years	5.4	0.8	6.1	3.3	7.0	2.2	3.4	2.0	5.6	6.5	**4.2**
% of Mine Life	21	3	23	13	27	8	13	8	21	25	**16**

A pond volume of 600 ML will have a surface area ranging from 20 hectares at the beginning of deposition, to 35 hectares at the end of mine life, as shown in **Figures 8.2** and **14.1 – 14.3**. This range of areas is equivalent to the tailings beach area up until Year 3. The results show that such a volume may generally be expected to be exceeded on relatively few occasions, for a total duration of between 10% and 25% of the mine life.

By Year 10 a volume of 600 ML will inundate less than half the tailings beach. After this time, generally sub-aerial tailings deposition conditions can hence be expected.

As discussed in **Section 7.2.3**, the tailings are expected to have relatively rapid consolidation characteristics, even when sub-aqueous deposition over the life of mine is assumed.

Given the conservative design density adopted for sizing the TSF and staging the Main Embankment construction, the possibility of sustained flooding of the beach is not expected to have any long term effect on the tailings storage concept or the adopted overall tailings insitu density.

15.10 Decant Return Water

One of the prime benefits of the adopted TSF concept is that it will provide a significant source of water for use within the mine process plant. Much work was done during the conceptual design phase **[Ref. 8]** to demonstrate the benefit of maximising the decant return rate by using TSF water in as many plant applications as possible.

It was also found that the higher rate would provide benefit to tailings and water management aspects of the TSF. However, **Table 15.3** shows that in all water balance life of mine runs, there are periods where there is no decant return water available to the plant, meaning that water will be required from other sources (assumed to be Lake Julius pipeline Raw Water).

From a sample of water balance runs which cover the range of life of mine rainfall expectations, **Table 15.6** shows the overall average decant return water quantity that could be expected to be available for use in the Process Plant. The Total Annual Plant Requirement in the plant is assumed to be 1,189 ML.

TABLE 15.6
TSF DECANT RETURN WATER

Water Balance Run	Overall Average Decant Return			% of Total Annual Plant Requirement
	m^3/day	m^3/month	ML/year	
Run 1 (1 %ile rainfall)	1,282	38,460	468	39.4
Run 2 (99 %ile rainfall)	1,019	30,570	372	31.3
Run 3 (59 %ile rainfall)	1,216	36,480	444	37.3
Average (All Runs)	**1,191**	**35,730**	**435**	**36.6**

It is thus a reasonable expectation that the TSF will be able to provide a third of the water required annually for use within the Process Plant.

16 WATER MANAGEMENT

16.1 Decant Pond Operation

As discussed in **Section 8.2**, the natural topography of the Knapdale Valley TSF, coupled with the tailings deposition methodology, will allow decant water management to occur from a static location in the centre of the TSF, adjacent to the Main Embankment. This is demonstrated in the beach development layouts shown in **Figures 14.1 – 14.3** and **8.2**.

The decant return system will consist of a pump mounted on a floating pontoon towards the eastern side of the TSF, where the decant return pipeline and access road will be located. It will be tethered at the toe of the active tailings beach, and incrementally shifted east along the decant access road at a reducing frequency to suit the decreasing tailings rate of rise.

It will be an important operational aspect to manage the tailings beach deposition in a manner which maintains the decant pond centrally around the decant pontoon.

The water balance modelling has shown that large fluctuations in pond level can be expected, and that the pond may dry up for extended periods of time. These outcomes will need to be catered for in the final design of the decant return system and tethering arrangements.

16.2 Flood Containment and Emergency Spillways

In accordance with **[Ref. 5]** for a High Hazard TSF, the design criteria for an emergency spillway is that it has sufficient capacity to pass the critical duration, 1 in 10,000 year Annual Exceedence Probability (AEP) flood, assuming that the tailings are at the minimum freeboard level at the end of the particular TSF stage.

However, as explained in **Section 8.4**, the design flood capacity of each TSF Stage will be dominated by DSA containment requirements. The minimum required freeboard for each Main Embankment stage is between 8m and 11m, in order to store the 3,250 ML DSA volume.

The 1 in 10,000 year rainfall for various durations is shown in **Table 16.1**, together with the DSA and the resultant volumes generated from the TSF catchment.

TABLE 16.1
COMPARISON OF 1 IN 10,000 YEAR AND DSA FLOOD DATA

Event	1 in 10,000 Year AEP						DSA (1 in 100 Year)
Duration	2 hr	6 hr	12 hr	24 hr	48 hr	72 hr	2 month
Rainfall (mm)	316	470	580	675	810	920	1,089
Runoff Volume (ML)	1,058	1,574	1,943	2,261	2,696	3,082	3,250

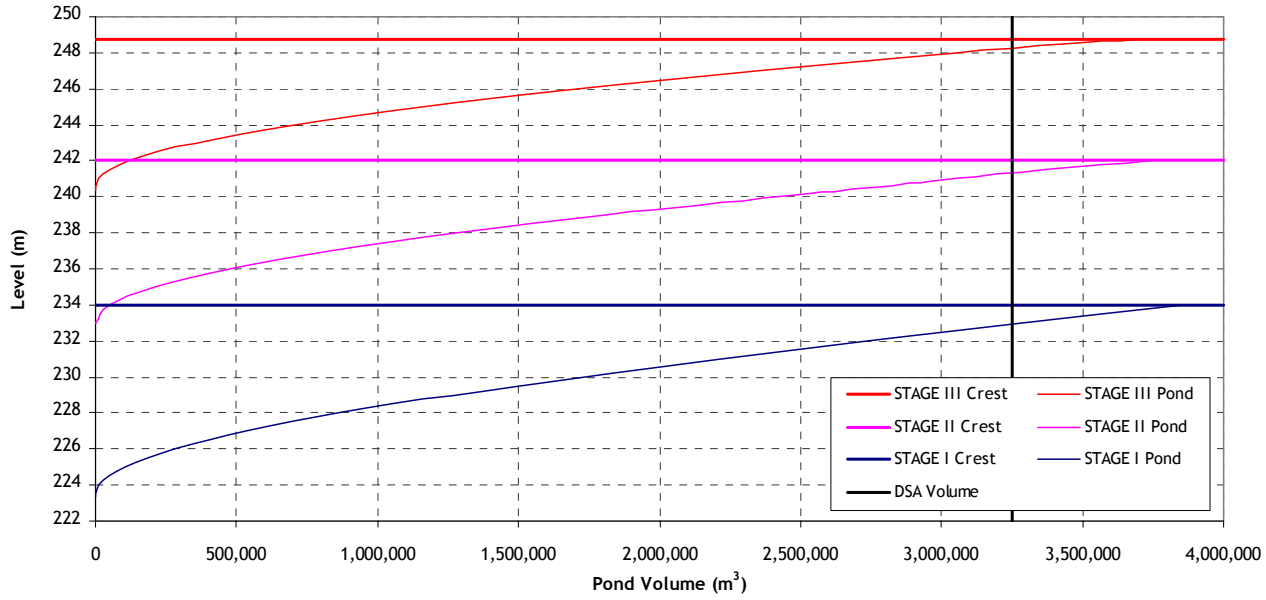
For the purposes of this study, the 1 in 10,000 year rainfall data have been derived using the preliminary PMP estimation procedures and the extreme rainfall extrapolation method described in Australian Rainfall and Runoff **[Ref. 20]**.

The 1 in 10,000 year volumes have been calculated assuming zero catchment losses, whilst the DSA volume estimation approach is discussed in **Section 8.3**.

Spillway design is generally conducted using the numerical reservoir routing approach. The critical rainfall duration is the storm event which produces the peak spillway discharge, which in turn is a function of the flood attenuation provided by the pond geometry.

The decant pond storage relationship at the end of each stage is shown in **Chart 16.1**. It is considered that the critical duration flood for the TSF would be in the range 6 to 12 hours, depending on what pond level was assumed at the beginning of the storm event.

CHART 16.1
TSF DECANT POND STORAGE AT END OF EACH STAGE



It can be seen from **Chart 16.1** that significant capacity exists beyond the DSA at minimum freeboard level for each stage. This can be demonstrated by assuming the critical duration spillway design event was 12 hours. From **Table 16.1** and **Chart 16.1**, it is evident the TSF would have sufficient flood capacity at the end of each stage to store the resultant runoff volume, even if the initial pond volume was as high as 1,500 ML.

However, for the purposes of this study, it is considered a sound defensive design policy to include an emergency spillway for each stage, to prevent the embankment from overtopping during a flood event exceeding the design AEP. These spillways will consist of 15m wide channels cut into the Main Embankment abutments, as shown in **Figures 13.1 - 13.3**. The spillway discharge capacity at a peak flood height of 0.5m is estimated to be 10 m^3/s.

16.3 Impoundment Seepage Containment

The Knapdale Valley TSF concept does not include impoundment lining, preferring to rely on the natural characteristics of the site, and the proposed TSF operational methodology as a means of impoundment seepage containment. This has been based upon the following:

Site Characteristics:

- The Knapdale Range does not have an identified groundwater resource. Groundwater is considered to exist locally in the defects within the rock mass.
- The adjacent groundwater resource (Cabbage Tree Creek catchment) to the west of the Knapdale Range is of poor quality and not considered significant.

- As shown in **Figure 8.2** and Section 2 of **Figure 16.1**, the Cabbage Tree Creek resource is separated from the TSF by 500m to 600m of Knapdale Ranges quartzite, rising to levels generally at least 40m above the final tailings surface.
- From investigations within the valley drainage outlet, the permeability of the quartzite rock mass is a function of the degree of jointing and fracturing. Moderate permeability (of the order of 10^{-6} m/sec) rock is limited to the upper 5m of the subsurface profile, with 10^{-7} m/sec or less over the 5m to 15m depth interval. As the rock mass defect spacing increases beyond a depth of 15m, the permeability continues to reduce.
- Given that the valley drainage outlet is considered to be a zone of structural weakness within the Knapdale Quartzite, the western ridge line is expected to consist of a less fractured, and hence lower permeability rock mass than that which was investigated within the drainage outlet.
- The bedding of the quartzite dips steeply to the west. The bedding is typically many metres thick, with no evidence of preferential flow paths along the bedding planes.

TSF Operational Methodology:

- Tailings will be beached from both ends of the valley, forming a low permeability barrier over the valley floor, limiting seepage flux into the underlying rock mass. As a result, decant water will only come into contact with the impoundment at the edges of the tailings surface.
- From consolidation modelling (refer to **Section 7.2**), the deposited tailings will have a saturated permeability profile averaging between 10^{-7} and 10^{-8} m/s.

Operational Expectations:

The following is an overview of the expected seepage containment regime during the operation of the TSF. Reference is made to the sections and elevations presented in **Figure 16.1**.

- During TSF operation, it is expected that the near-surface (upper 5m) rock mass will slowly saturate. This will predominantly occur at the decant pond edges as the tailings level rises.
- The zone of saturation will, over time, expand along preferential seepage paths into the underlying (5m to 15m depth) less permeable foundation zone. However, flow will become unsaturated beyond this depth, due to the decrease in rock mass fracturing and jointing.
- The only means of seepage within this locally saturated zone exiting the TSF valley will be through the drainage outlet on the western side. At this location the water-retaining Main Embankment will be constructed, including a 15m deep grout curtain at the upstream toe, which will fully penetrate the upper 15m of the foundation profile.
- The zone of saturation will be confined to the valley floor beneath the tailings level, as evident in **Figure 16.1**. Seepage will not be able to flow out of the valley elsewhere along the western valley profile, due to the height of the western valley ridge line.

16.4 TSF Perimeter Works

The TSF perimeter works embankments will incorporate valley infill where possible to minimise water management requirements. At the Decant Access Embankment on the east side, and the North-East Discharge Bund, TSF catchment runoff will flow onto the tailings beach an accumulate in the decant pond.

The exception is the North-West Discharge Bund, where infilling the valley is not practical, given the significant earthworks requirement (greater than 50,000 m^3) and the small catchment area of just 12 hectares. As can be seen in **Figures 13.2** and **13.3**, the North-West Discharge Bund will in fact be two separate embankments constructed in narrow valleys down-slope of a natural saddle feature at RL 246m. A connecting channel will be constructed between the two embankments to fix the maximum water level ponding behind them to that of the saddle.

In order to prevent sustained wet season ponding of runoff behind the North-West Discharge Bund, pumping will be required. A daily water balance has been conducted to evaluate the pumping requirements, using a model based on that described for the TSF water balance in **Section 15**. Runs 1, 2 and 9, representing the maximum, minimum and mean 26 year rainfall sequences on record, were used in the balance.

A dewatering pump capacity of 20 litres/sec was assumed, which is equivalent to the 69 m^3/hour capacity of the TSF decant return pump. The dewatering pump would be a portable, diesel powered, 5.5 kW pump, utilising 100mm diameter lay-flat hose to lift the ponded water over the Discharge Bund into the TSF.

The water balance modelling has shown that without pumping, water will pond behind the Discharge Bund for years at a time. This is unacceptable as it will mean water is continually ponding over the lease boundary and will prevent access to the tailings discharge point. However, with the 20 litres/sec dewatering pump in place, the following results were obtained:

- Overall average pumping days (proportion of total) = 3%
- Overall average zero pond days (proportion of total) = 97%
- Longest period of sustained ponding/pumping = 30 days

Given the above water balance results, the 20 litres/sec pump capacity is considered adequate to maintain the transportation lease corridor downstream of the North-West Discharge Bund in a dewatered state for the majority of the mine life.

17 SURVEILLANCE AND MONITORING

17.1 Monitoring

Monitoring requirements for the Knapdale Valley TSF will be relatively straight-forward due to the configuration of the storage. A system of sub-regional groundwater monitoring bores will be installed downstream of the Main Embankment to the west of the TSF, as part of a site-wide groundwater monitoring strategy. It is proposed that these will be read on a monthly basis.

The purpose of these bores will be to:

- Initially, provide data on the presence, depth, quality and flow direction of groundwater in the area.

- During TSF operation, provide an indication of broad scale groundwater fluctuations, such that any impacts on the groundwater regime brought about by the TSF can be monitored.

Given that the Main Embankment will be constructed of free-draining rockfill with a GSS on the upstream face, a phreatic surface will not develop, even if a concentrated leak in the GSS were to occur.

Standpipe piezometers will hence not be required in the completed Main Embankment, as any seepage would flow along the foundation, and accumulate in the collection pond downstream of the embankment. The collection pond will be inspected as part of routine weekly surveillance, however it is expected to remain dry (i.e. not register any seepage) under design conditions.

Survey monuments will be installed on the crest and downstream berms of each stage of the Main Embankment to monitor settlement of the fill materials.

17.2 Surveillance

Surveillance requirements for the Knapdale Valley TSF will involve routine daily and weekly inspections, as well as mandatory annual audits. The focus of such surveillance will be as follows:

Daily Inspections –

Focus on operational issues to do with the TSF, including inspections of the tailings pipelines, discharge point management, decant pond location and decant system operation.

Weekly Inspections –

Focus on issues that may develop over time and may impact on the safety of the TSF or the environment. These include detailed inspections of the Main Embankment and all appurtenant structures, tailings beach development and decant pond level, and surveillance of all monitoring installations.

Annual Audits –

These are conducted by a qualified dams engineer, and focus on the identification of deficiencies by visual examination of the TSF embankments and all appurtenant structures, as well as a review of all surveillance and monitoring data.

17.3 Operation and Maintenance Manual

An Operation and Maintenance Manual will be prepared for the TSF in accordance with the regulatory requirements for High Hazard tailings facilities. This will include instructions and forms to cover all necessary monitoring, daily and weekly routine inspections and surveillance activities.

Tailings deposition and decant management procedures will also be documented. The Manual will contain a section on emergency response, and will be an integral part of the overall risk management plan for the facility itself and the mine overall.

18 CLOSURE AND REHABILITATION

18.1 Overview

The intent of tailings deposition management will be to form a final low point at the Main Embankment, and hence a self-shedding profile for closure. Closure of the facility for Feasibility

Study purposes is the subject of studies by others, however the general approach to closure will incorporate the following:

- The tailings surface will be capped with a low water flux cover system consisting of a waste rock layer covered with topsoil and revegetated. Topsoil stripped from within the impoundment area at the time of construction will have been stockpiled for this purpose.

- The downstream slope of the Main Embankment will be flattened to a slope suitable for perpetuity, and revegetated in a similar manner to the tailings surface. The downstream slope will in effect be reconstructed as a broad spillway chute sized to pass the peak flood resulting from the Probable Maximum Precipitation (PMP).

The above closure and rehabilitation concept is depicted in **Figure 18.1**.

Two of the significant advantages of the Knapdale Valley TSF are that the final tailings surface forms a "natural" profile that sheds rainfall without the need for any re-shaping, and that access to the surface should be available relatively quickly after the end of operations.

18.2 Closure Design Objectives

As discussed in **Section 7.3**, the tailings will be potentially acid forming. Closure must therefore ensure that a suitable protective cover be placed over the tailings to inhibit the adverse environmental impacts of such potential acid generation. The consolidation modelling in **Section 7.2** has shown that much of the tailings surface profile will be unsaturated at closure, and that a degree of oxidation will have already occurred. The cover must therefore achieve certain objectives:

(i) Control and minimise the transport mechanism either upwards or downwards for oxidation products within the tailings,

(ii) Be capable of supporting vegetation, and

(iii) Be resistant to erosion by wind and/or rainfall runoff.

A conceptual cover strategy for Feasibility Study purposes, based on current available guidelines and mine sites in similar climates would include the following general configuration and nominal thicknesses, in sequence from the tailings surface:

- Capillary Break – mainly coarse, non acid forming waste rock (0.3 m depth)
- Sealing Layer – non-acid forming, low permeability compacted earthfill (0.5m depth)
- Mine spoil cover – non-acid forming, rockfill (1.0m depth)
- Topsoil – suitable seed-bearing material (0.1 – 0.2m depth)

The actual final depth of the capping layers and materials required will need to be determined by numerical infiltration modelling and/or field trials during the operational phase of the project when there will be a better understanding of the types of cover materials available on site. The depth of the cover must be sufficient to limit infiltration into the underlying tailings, whilst providing a generally stable moisture regime within the cover year-round.

19 CLOSURE

An Executive Summary is provided at the front of this report.

The reader's attention is also drawn to the "Conditions of Investigation and Report" which appear on the title page of this report.

ATC WILLIAMS

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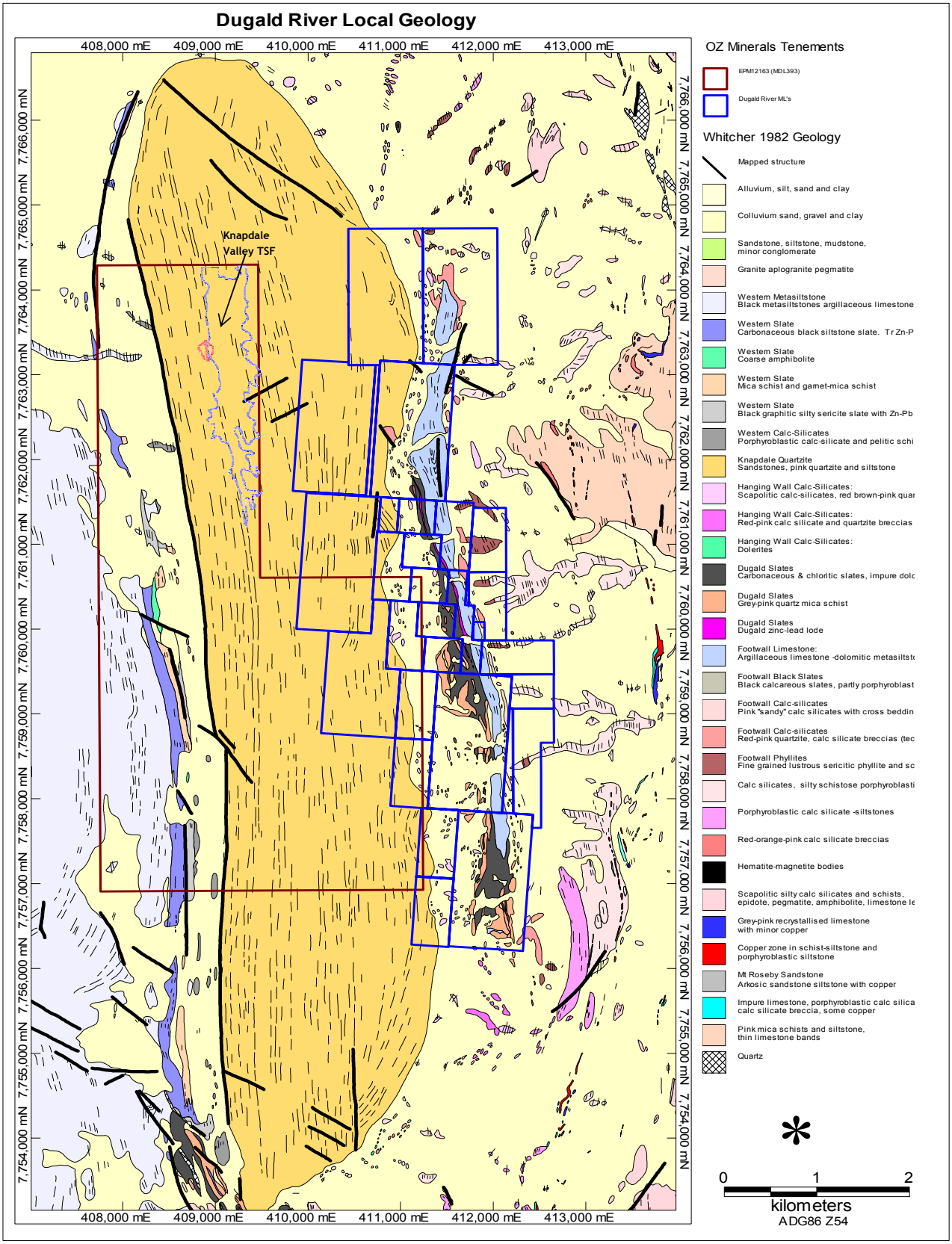
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FIGURES



MMG DUGALD RIVER

DUGALD RIVER PROJECT

FEASIBILITY STUDY

KNAPDALE VALLEY TAILINGS STORAGE FACILITY

LOCAL GEOLOGY

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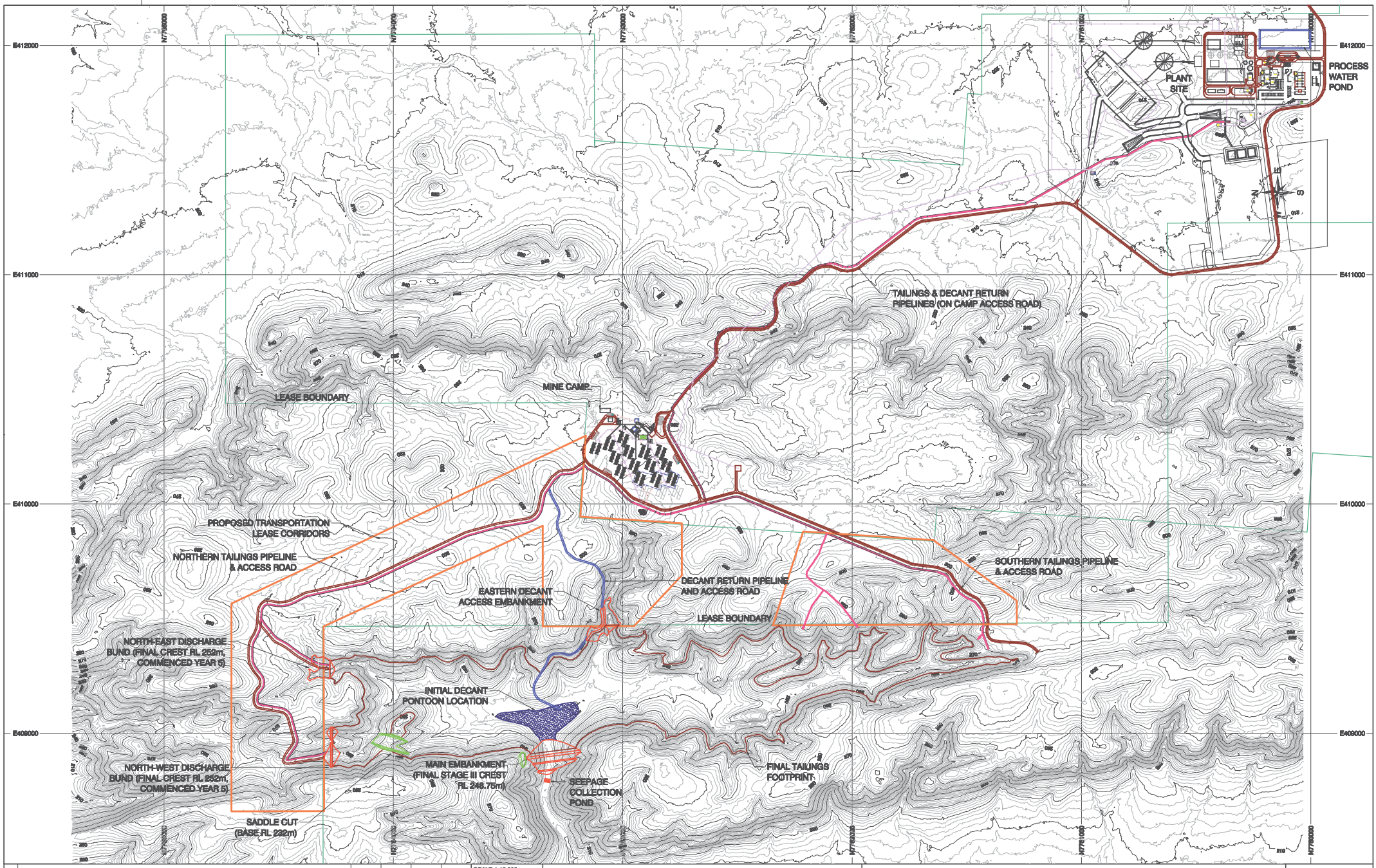
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Date: 30/06/2010

FIGURE 6.1

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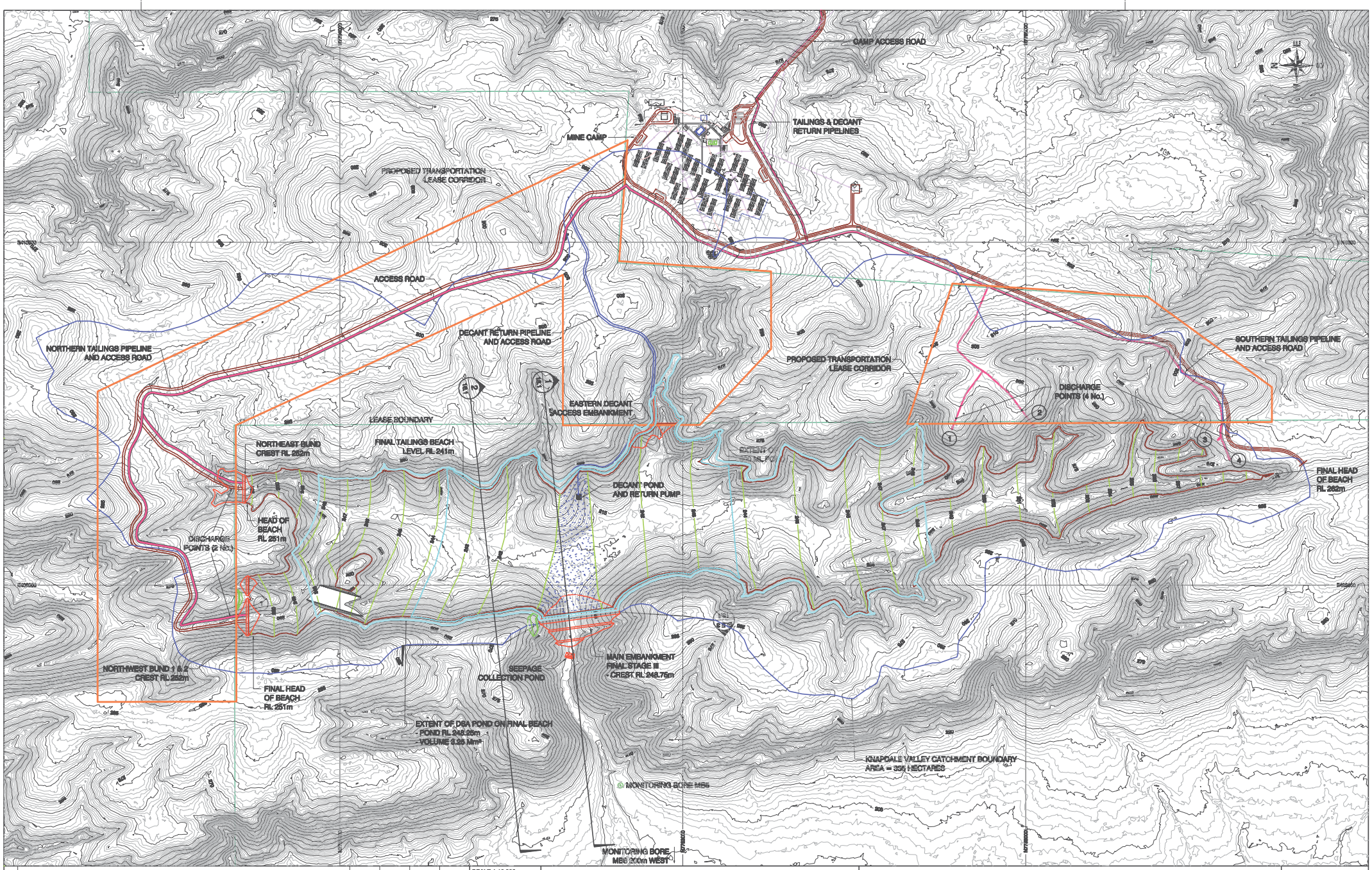
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DUGALD RIVER PROJECT FEASIBILITY STUDY

KNAPDALE VALLEY TAILINGS STORAGE FACILITY
OVERALL SITE PLAN

FIGURE 8.1

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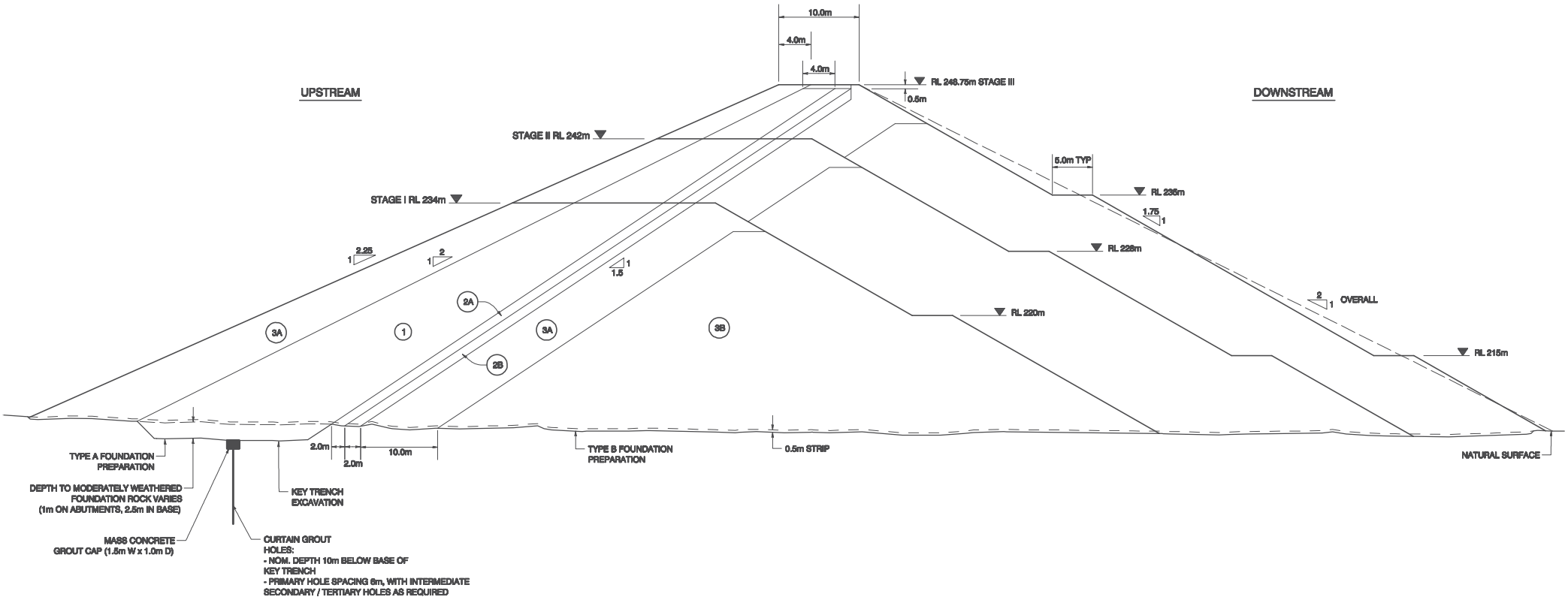
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KNAPDALE VALLEY TAILINGS STORAGE FACILITY
GENERAL LAYOUT - END OF STAGE III FILLING

FIGURE 8.2

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SUMMARY OF EMBANKMENT ZONE MATERIALS

ZONE	NAME	MATERIAL/SOURCE	PLACEMENT	COMPACTION
1	Earthfill Core	CLAY, Clayey SAND, Clayey GRAVEL. Sourced from designated borrow area adjacent to Process Plant.	0.2m horizontal layers (compacted thickness) Moisture: (OMC - 2%) TO (OMC + 2%)	>= 95% Std Maximum Dry Density (Hilf Method)
2A	Fine Filter	Well-Graded SAND/GRAVEL mix. Maximum particle size 5mm. Maximum fines content 5% by weight. Sourced from screened, processed granular material (imported or produced on site)	0.4m horizontal layers (compacted thickness)	4 passes 10t smooth drum roller - vibration off
2B	Intermediate Filter	Well-Graded SAND/GRAVEL/COBBLE mix. Maximum particle size 100mm, Maximum fines content 5% by weight. Sourced from screened, processed granular material (imported or produced on site)	0.4m horizontal layers (compacted thickness)	4 passes 10t smooth drum roller - vibration on
3A	Transition Rockfill	Moderately weathered to fresh Quartzite rockfill. Maximum particle size 400mm. Sourced from designated TSF rockfill quaries.	0.4m horizontal layers (compacted thickness)	8 passes 10t smooth drum roller - vibration on
3B	General Rockfill	Slightly weathered to fresh Quartzite rockfill. Maximum particle size 800mm. Sourced from designated TSF rockfill quaries.	0.8m horizontal layers (compacted thickness)	8 passes 10t smooth drum roller - vibration on

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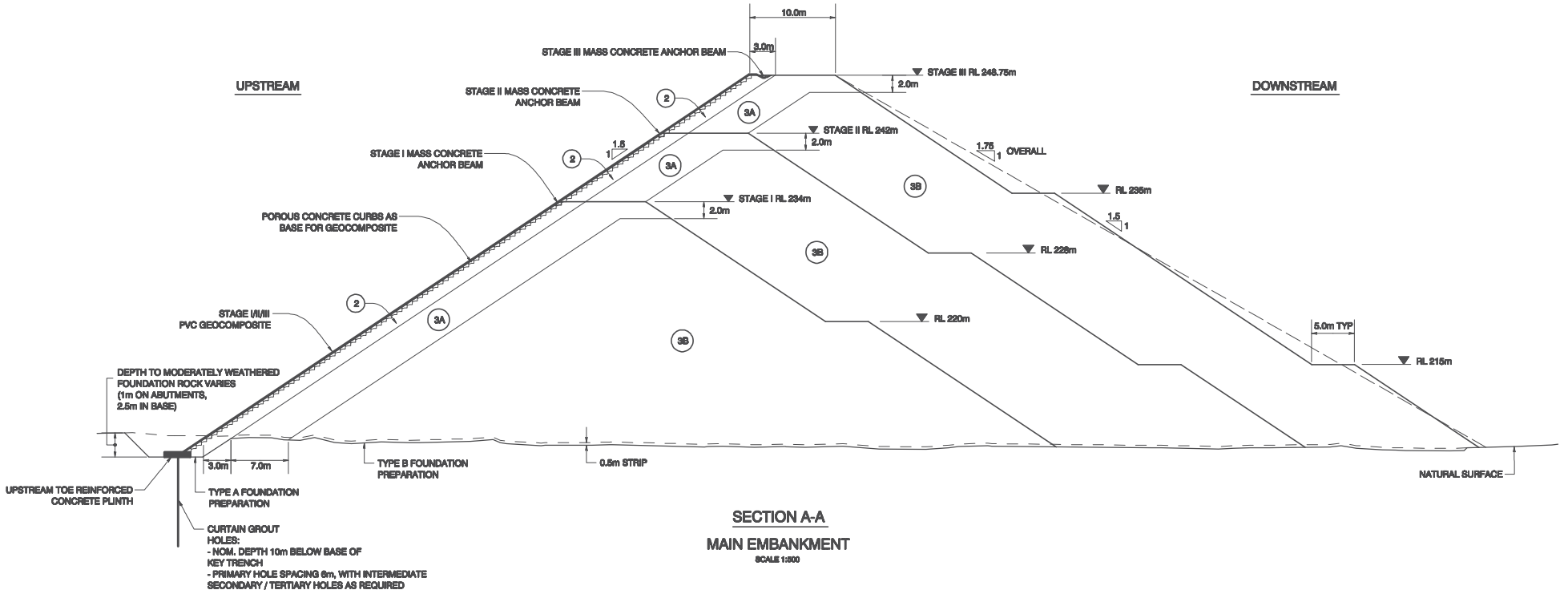
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DUGALD RIVER PROJECT FEASIBILITY STUDY

KNAPDALE VALLEY TAILINGS STORAGE FACILITY
MAIN EMBANKMENT
CLAY CORE OPTION - TYPICAL SECTION

FIGURE 9.1

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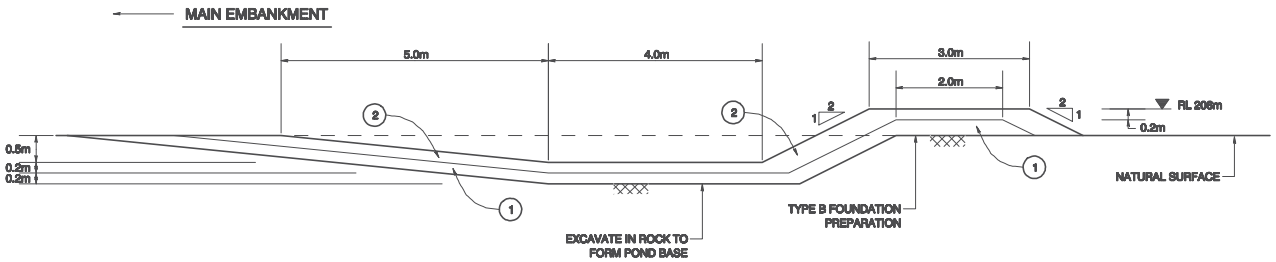
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SECTION A-A
MAIN EMBANKMENT
SCALE 1:500

SUMMARY OF EMBANKMENT ZONE MATERIALS

ZONE	NAME	MATERIAL/SOURCE	PLACEMENT	COMPACTION
1	Earthfill	CLAY, Clayey SAND, Clayey GRAVEL. Sourced from designated borrow area adjacent to Process Plant.	0.2m horizontal layers (compacted thickness) Moisture: (OMC - 2%) TO (OMC + 2%)	>= 95% Std Maximum Dry Density (Hilf Method)
2	Drainage/GSS Support Layer	Well-Graded SAND/GRAVEL/COBBLE mix. Maximum particle size 150mm, Maximum fines content 5%. Sourced from select, screened rockfill from designated TSF quarries.	0.4m horizontal layers (compacted thickness)	4 passes 10t smooth drum roller - vibration on
3A	Transition Rockfill	Moderately weathered to fresh Quartzite rockfill. Maximum particle size 400mm. Sourced from designated TSF rockfill quaries.	0.4m horizontal layers (compacted thickness)	6 passes 10t smooth drum roller - vibration on
3B	General Rockfill	Slightly weathered to fresh Quartzite rockfill. Maximum particle size 800mm. Sourced from designated TSF rockfill quaries.	0.8m horizontal layers (compacted thickness)	6 passes 10t smooth drum roller - vibration on



SECTION B-B
SEEPAGE COLLECTION POND
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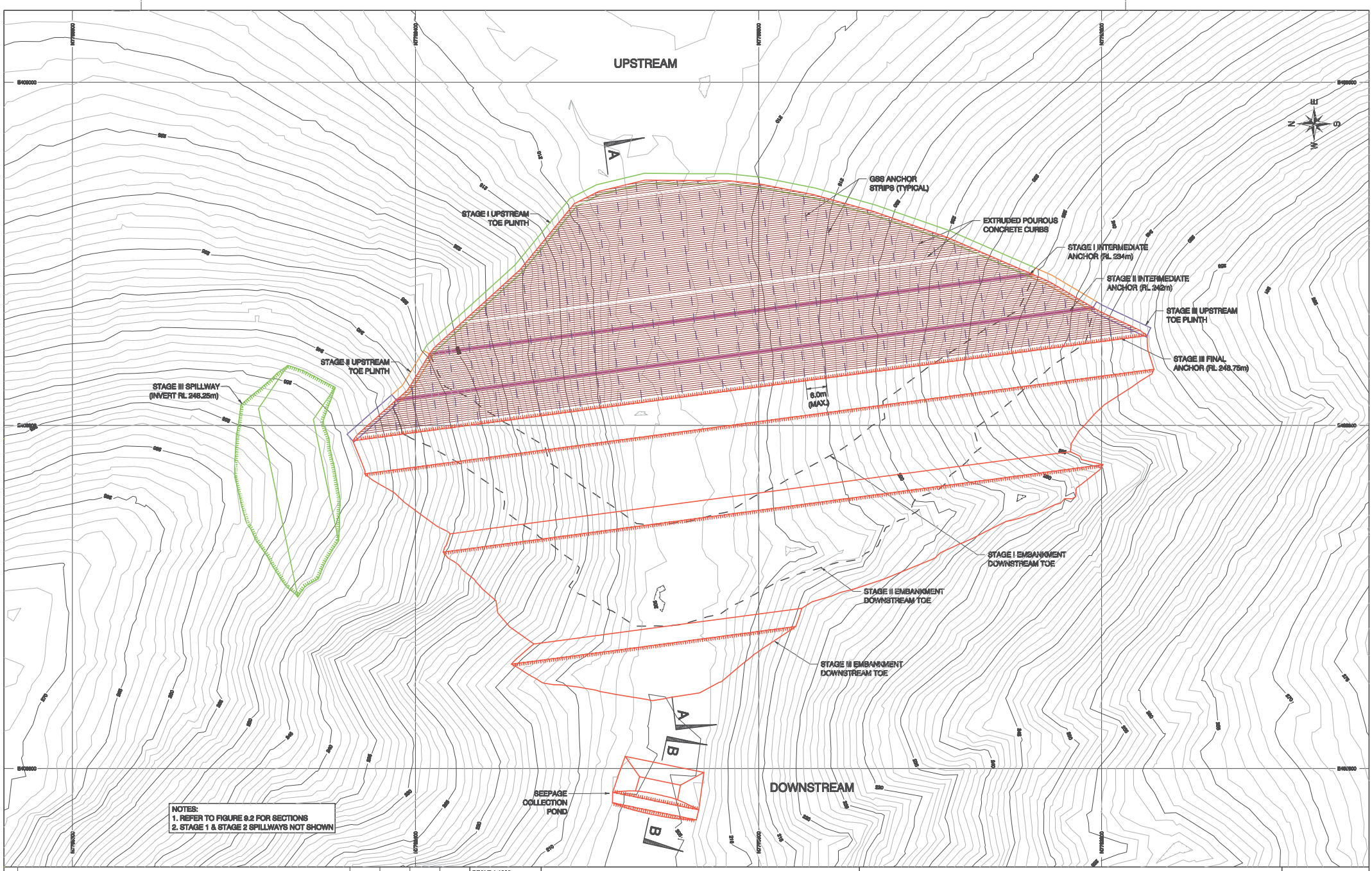
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DUGALD RIVER PROJECT FEASIBILITY STUDY

KNAPDALE VALLEY TAILINGS STORAGE FACILITY
MAIN EMBANKMENT GSS OPTION & SEEPAGE COLLECTION POND
TYPICAL SECTIONS

FIGURE 9.2

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DUGALD RIVER PROJECT FEASIBILITY STUDY

KNAPDALE VALLEY TAILINGS STORAGE FACILITY
MAIN EMBANKMENT
GENERAL LAYOUT

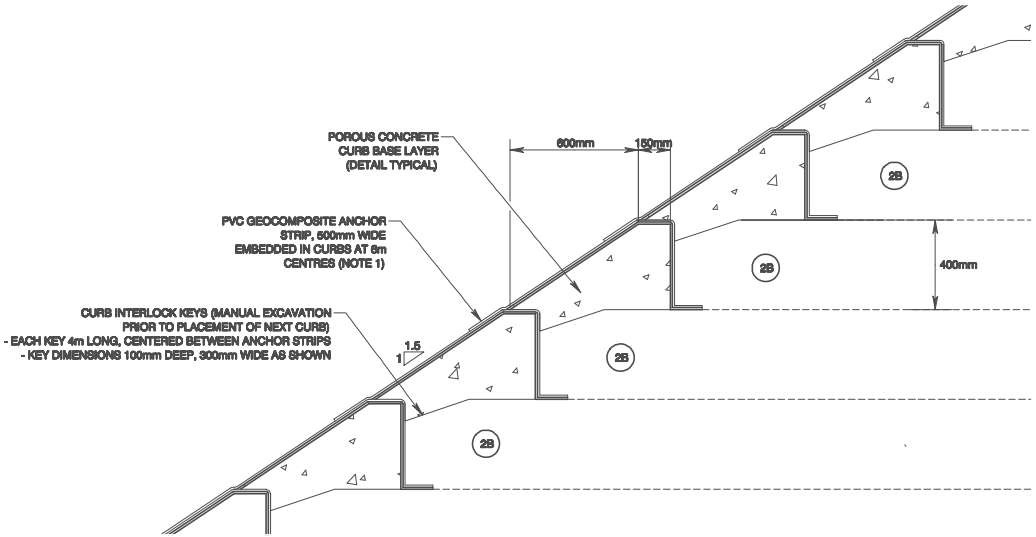
FIGURE 12.1

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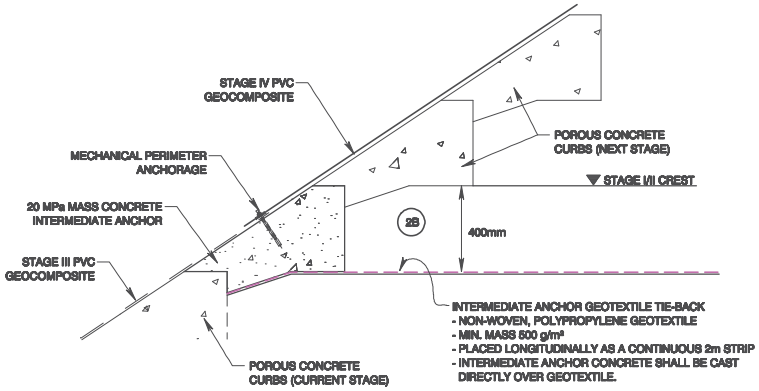
NOTES

1. THE ANCHORING METHODOLOGY FOR THE GSS SHOWN IN THE DRAWINGS, HEREAFTER REFERRED TO AS THE CARPI SYSTEM, HAS A PATENT OWNED BY THE CARPI TECH ITALIA SRL (FORMERLY KNOWN AS SIBELON SRL.) ARONA, ITALY OF THE CARPI GROUP.



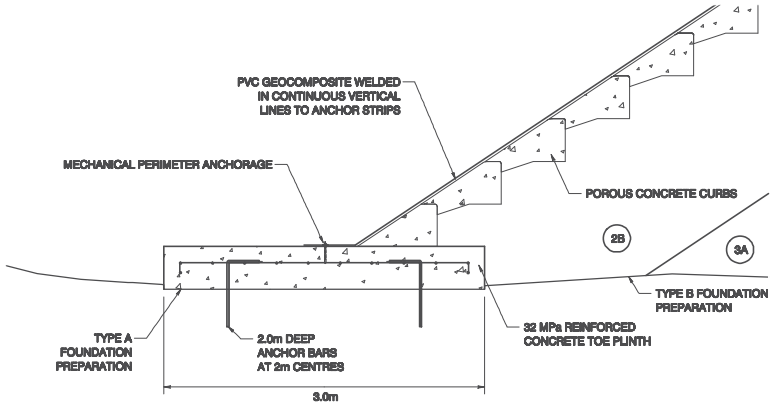
UPSTREAM FACE - GEOCOMPOSITE BASE LAYER

SCALE 1:25



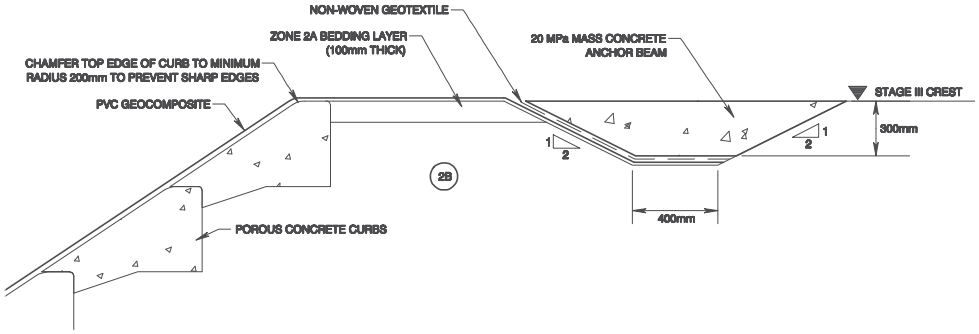
STAGE I & II INTERMEDIATE ANCHOR

SCALE 1:25



UPSTREAM TOE - PLINTH

SCALE 1:50



STAGE III CREST ANCHOR BEAM

SCALE 1:25

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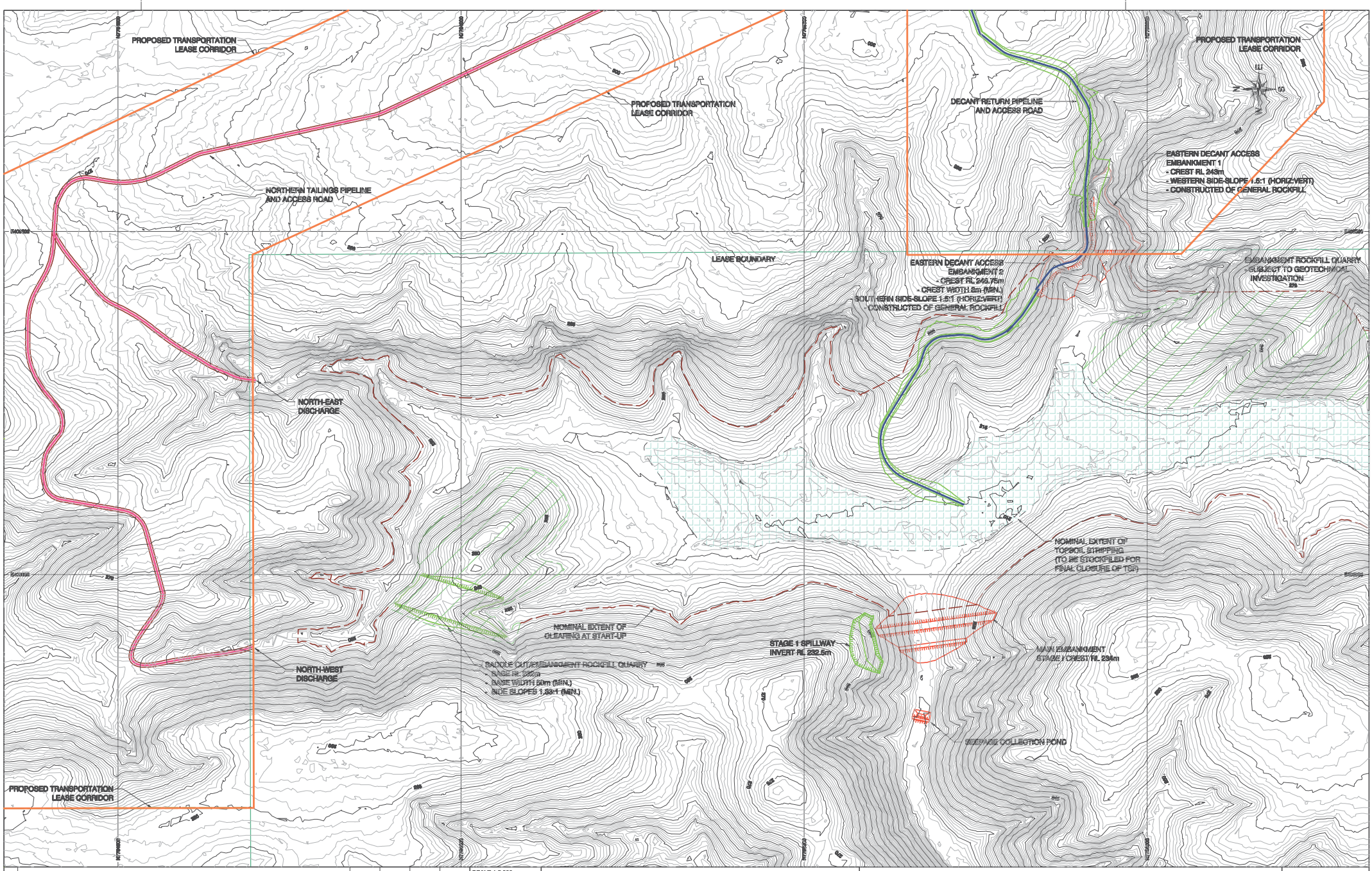
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DUGALD RIVER PROJECT FEASIBILITY STUDY

KNAPDALE VALLEY TAILINGS STORAGE FACILITY
MAIN EMBANKMENT
GSS ANCHORAGE AND FACE DETAILS

FIGURE 12.2

CLIENT No.
CAD REF. 108003
REV. No. 1 SHT SIZE A3
SHEET 1 OF 1

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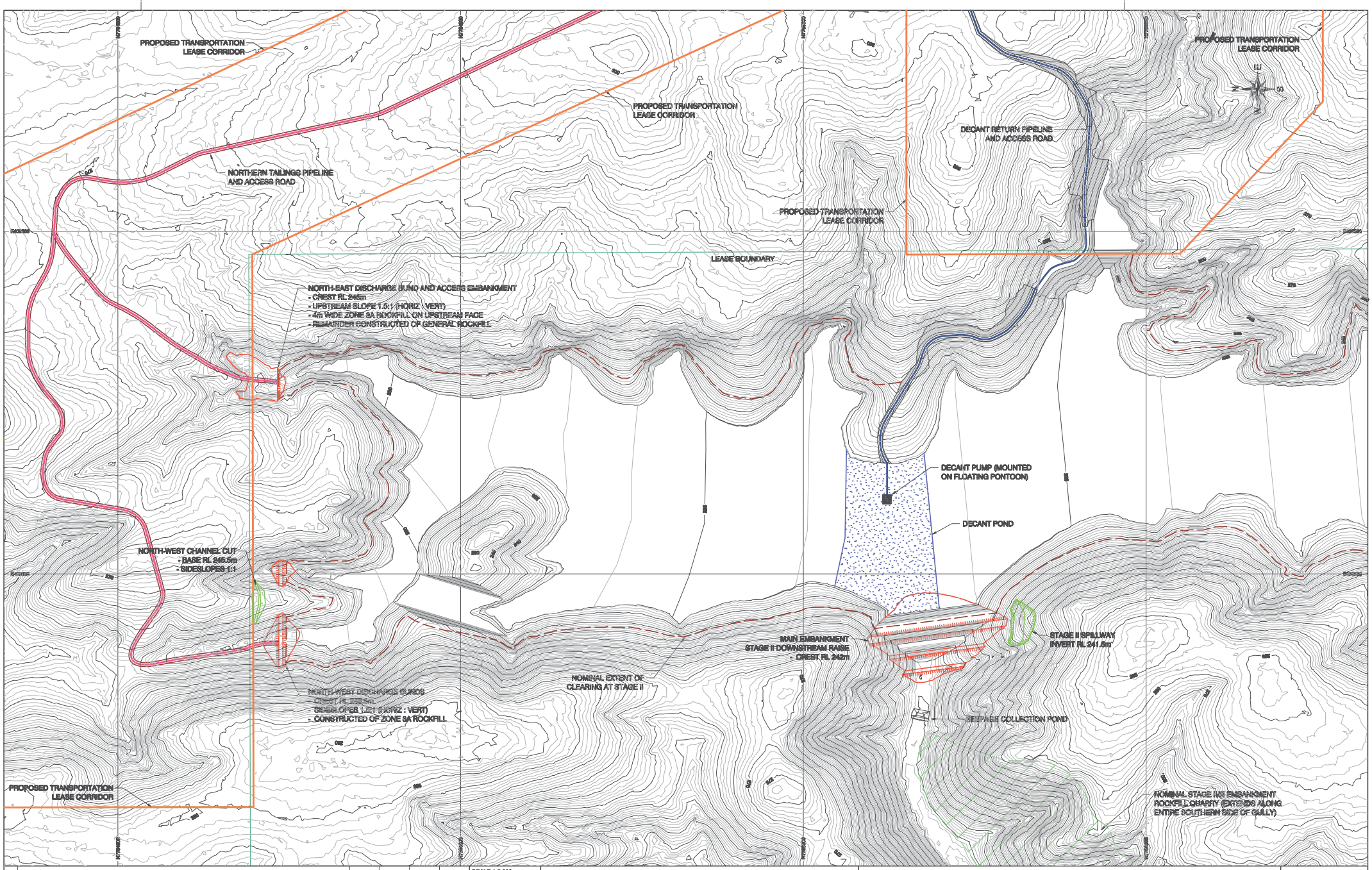
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DUGALD RIVER PROJECT FEASIBILITY STUDY

KNAPDALE VALLEY TAILINGS STORAGE FACILITY
STAGE I CIVIL WORKS

FIGURE 13.1

CLIENT No.	
CAD REF.	108003
REV. No.	1
SHT SIZE	A3
SHEET	1 OF 1

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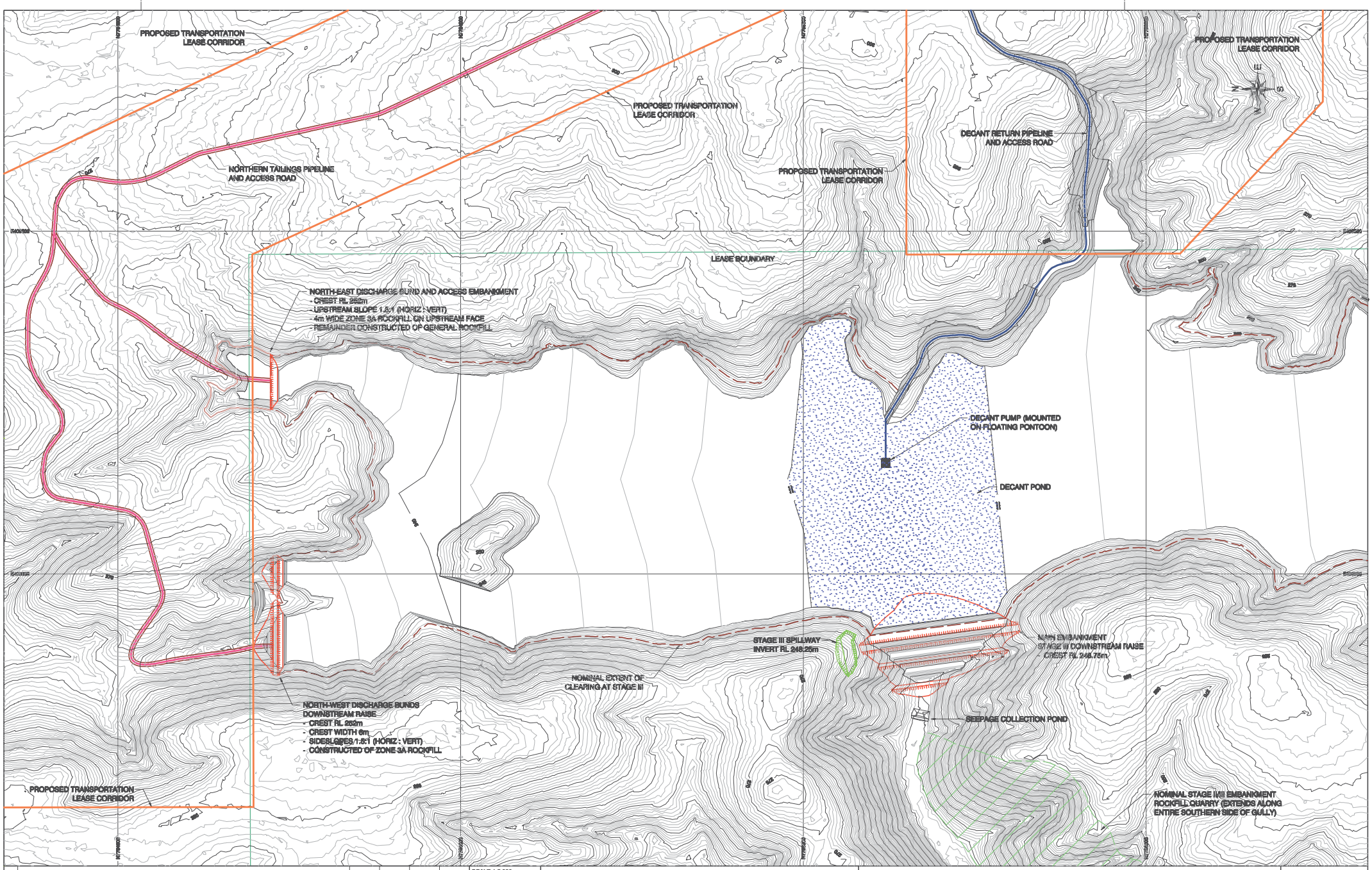
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DUGALD RIVER PROJECT FEASIBILITY STUDY

KNAPDALE VALLEY TAILINGS STORAGE FACILITY
STAGE II CIVIL WORKS

FIGURE 13.2

CLIENT No.
CAD REF. 108003
REV. No. 1 SHT SIZE A3
SHEET 1 OF 1

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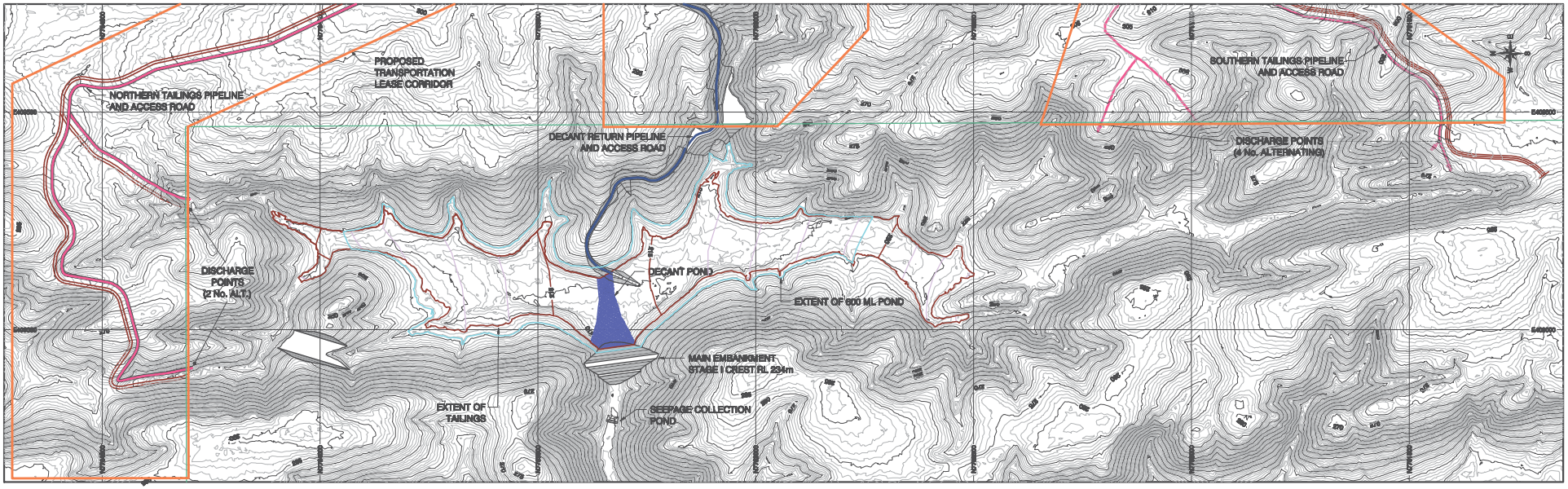
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DUGALD RIVER PROJECT FEASIBILITY STUDY

KNAPDALE VALLEY TAILINGS STORAGE FACILITY
STAGE III CIVIL WORKS

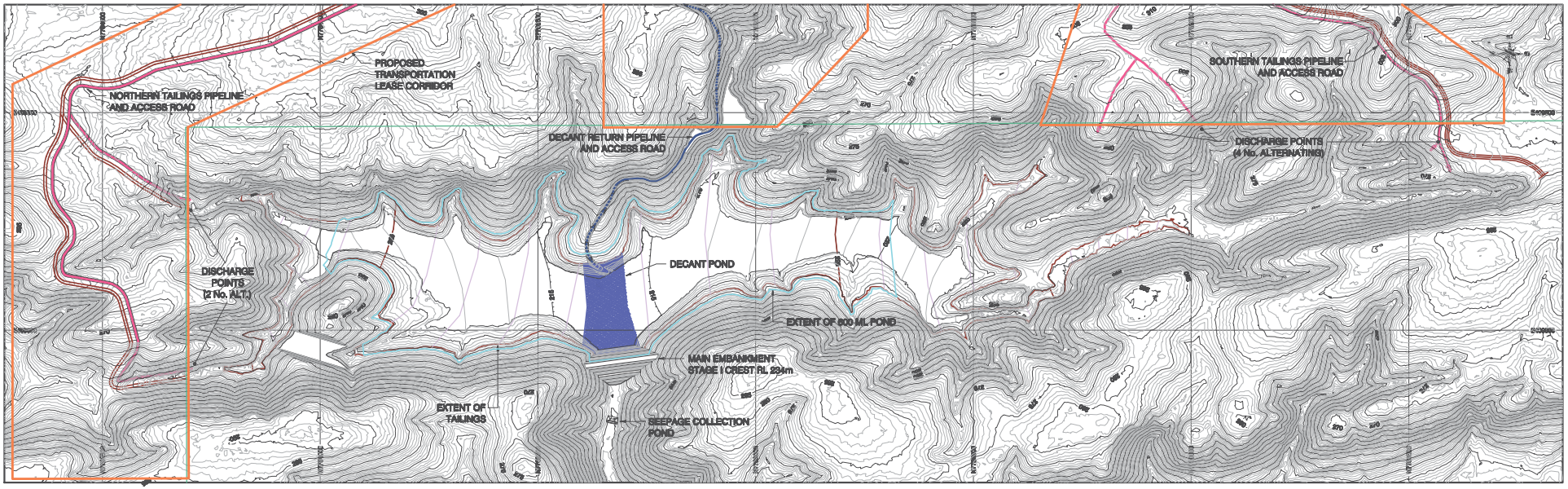
FIGURE 13.3

CLIENT No.
CAD REF. 108003
REV. No. 1 SHT SIZE A3
SHEET 1 OF 1

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YEAR 0.8 - SOUTHERN TAILINGS HEAD OF BEACH 225m



YEAR 3.6 - SOUTHERN TAILINGS HEAD OF BEACH 235m

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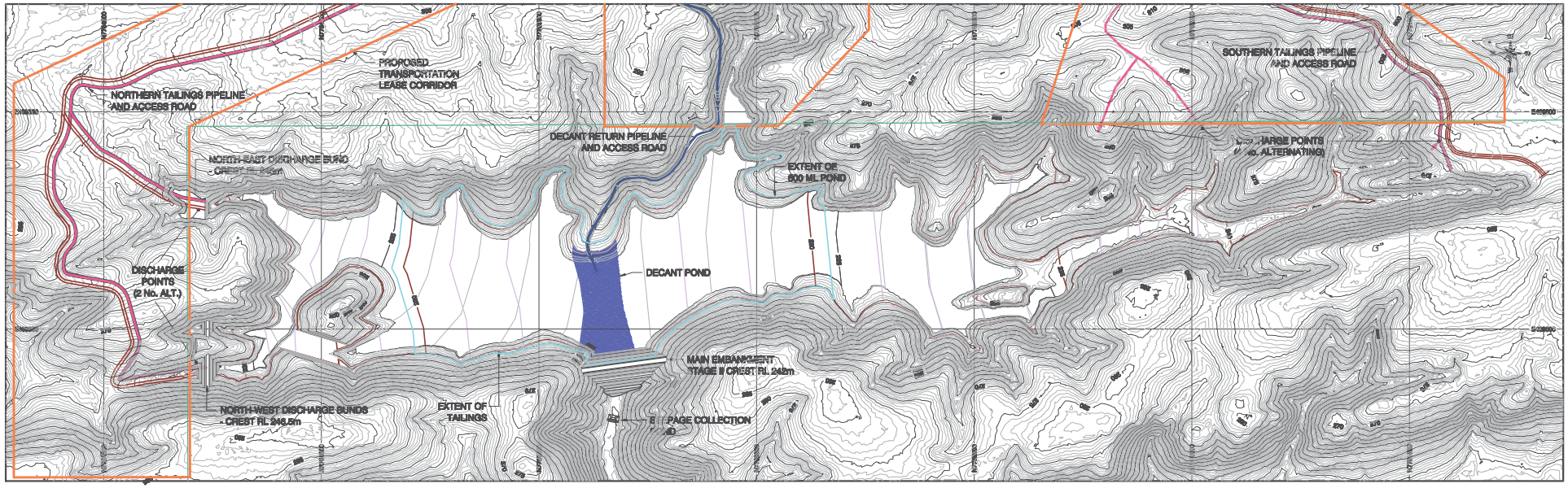
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KNAPDALE VALLEY TAILINGS STORAGE FACILITY
TAILINGS BEACH DEVELOPMENT
YEARS 0.8 AND 3.6

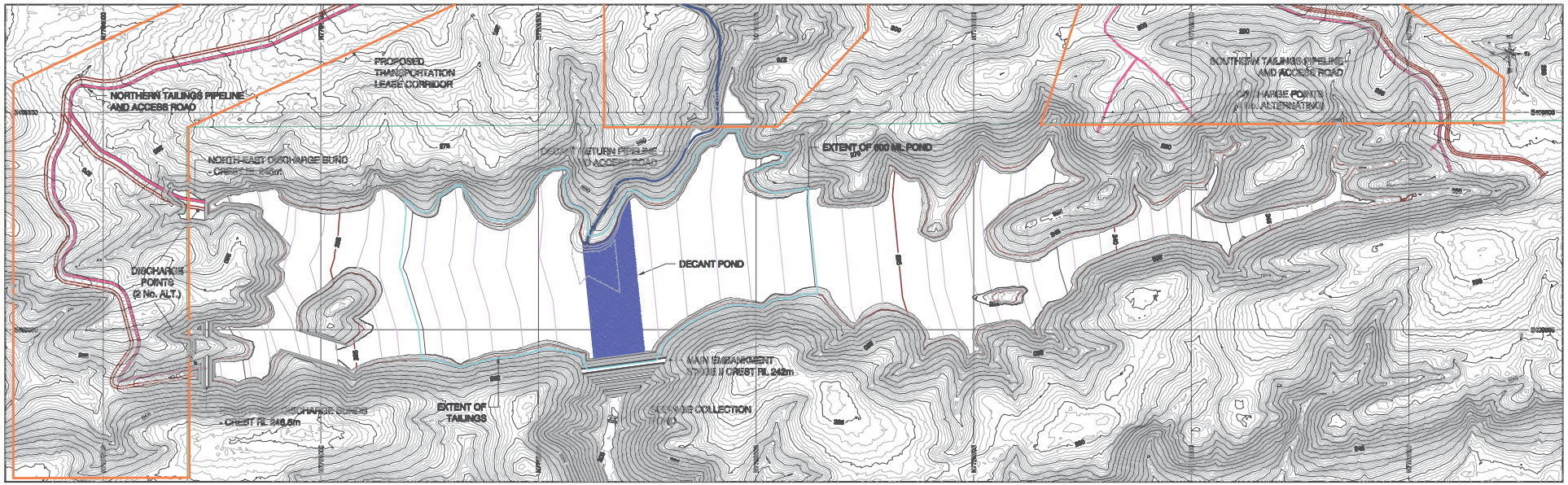
FIGURE 14.1

CLIENT No.
CAD REF. 108003
REV. No. 1 | SHT SIZE A3
SHEET 1 OF 1

File J:\2008\108003 Dugald River\02 FS Update 2010\Terramodel\Site A2 Beach Staging - Environmental.pro (Terramodel) Fri 30 Jul 2010 11:08:54



YEAR 6.8 - SOUTHERN TAILINGS HEAD OF BEACH 245m



YEAR 10.1 - SOUTHERN TAILINGS HEAD OF BEACH 250m

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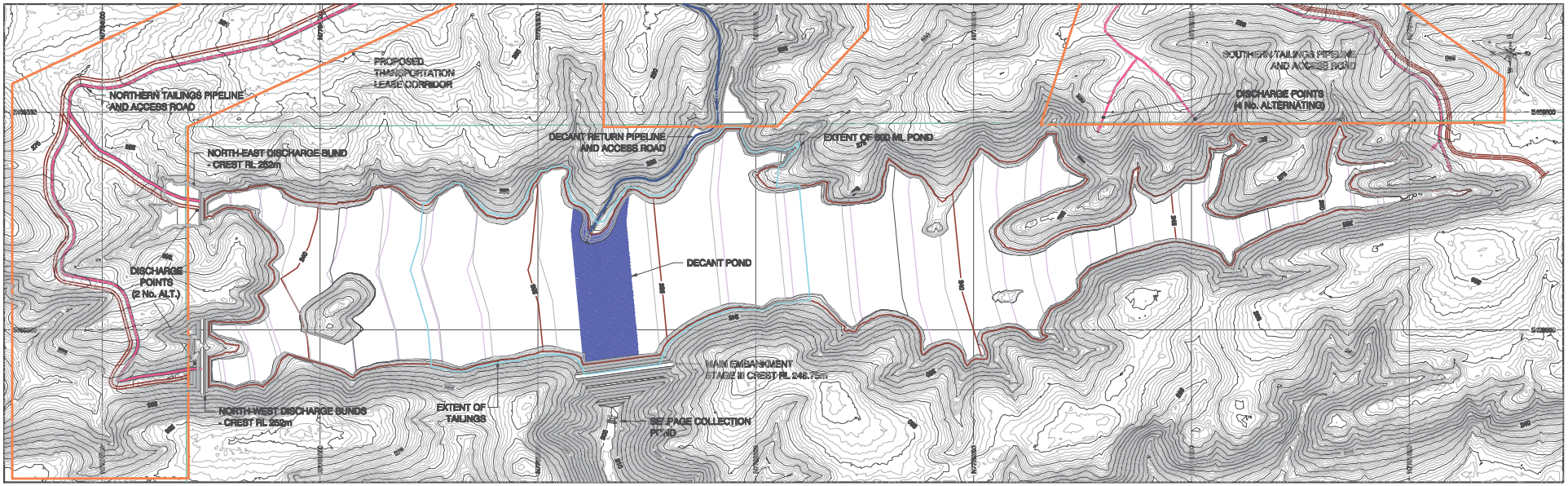
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DUGALD RIVER PROJECT FEASIBILITY STUDY

KNAPDALE VALLEY TAILINGS STORAGE FACILITY
TAILINGS BEACH DEVELOPMENT
YEARS 6.8 AND 10.1

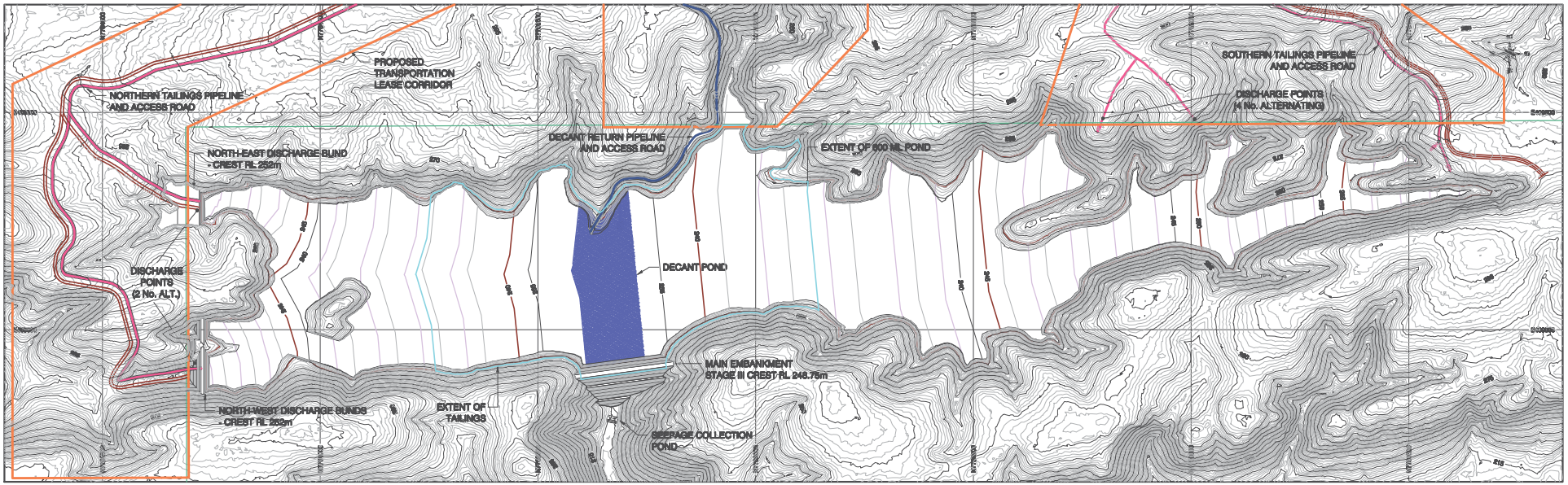
FIGURE 14.2

CLIENT No.
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SHEET 1 OF 1

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YEAR 15.1 - SOUTHERN TAILINGS HEAD OF BEACH 255m



YEAR 21.0 - SOUTHERN TAILINGS HEAD OF BEACH 260m

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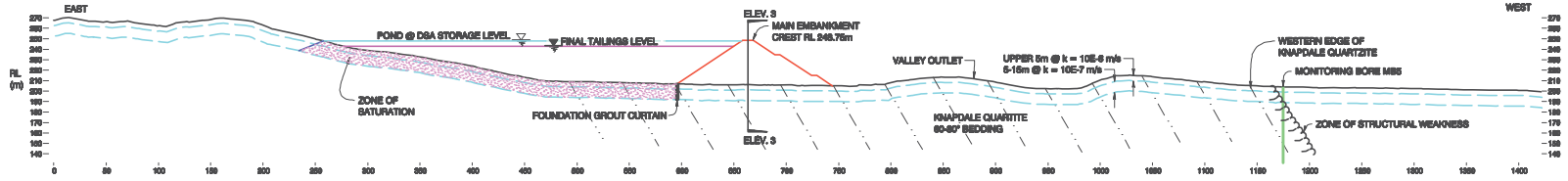
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KNAPDALE VALLEY TAILINGS STORAGE FACILITY
TAILINGS BEACH DEVELOPMENT
YEARS 15.1 AND 21.0

FIGURE 14.3

CLIENT No.
CAD REF. 108003
REV. No. 1 SHT SIZE A3
SHEET 1 OF 1

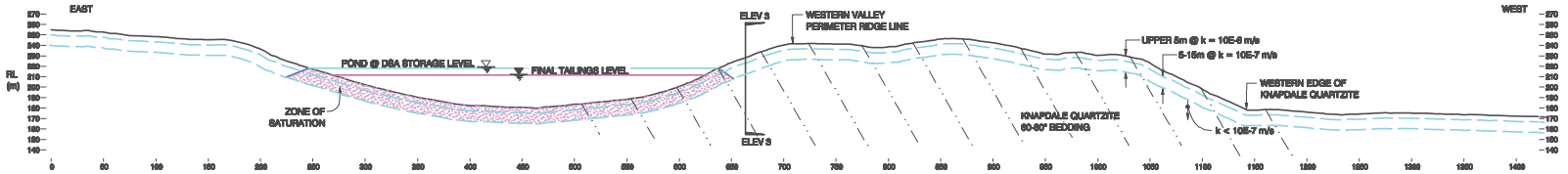
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SECTION 1/8.2

KNAPDALE VALLEY (MAIN EMBANKMENT)

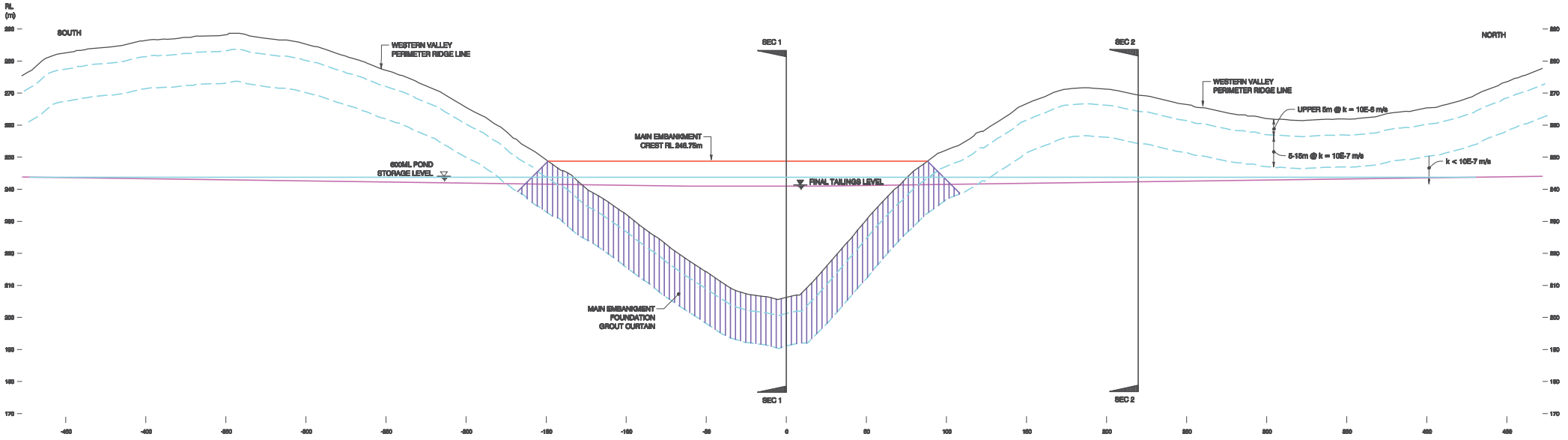
SCALE 1:5000



SECTION 2/8.2

KNAPDALE VALLEY (220m NORTH OF MAIN EMBANKMENT)

SCALE 1:5000



ELEVATION 3/8.2

KNAPDALE VALLEY (ALONG WESTERN SIDE OF TSF)

SCALE 1:2500 (H)
1:1250 (V)

REFER TO FIGURE 8.2 FOR SECTION AND ELEVATION LOCATIONS

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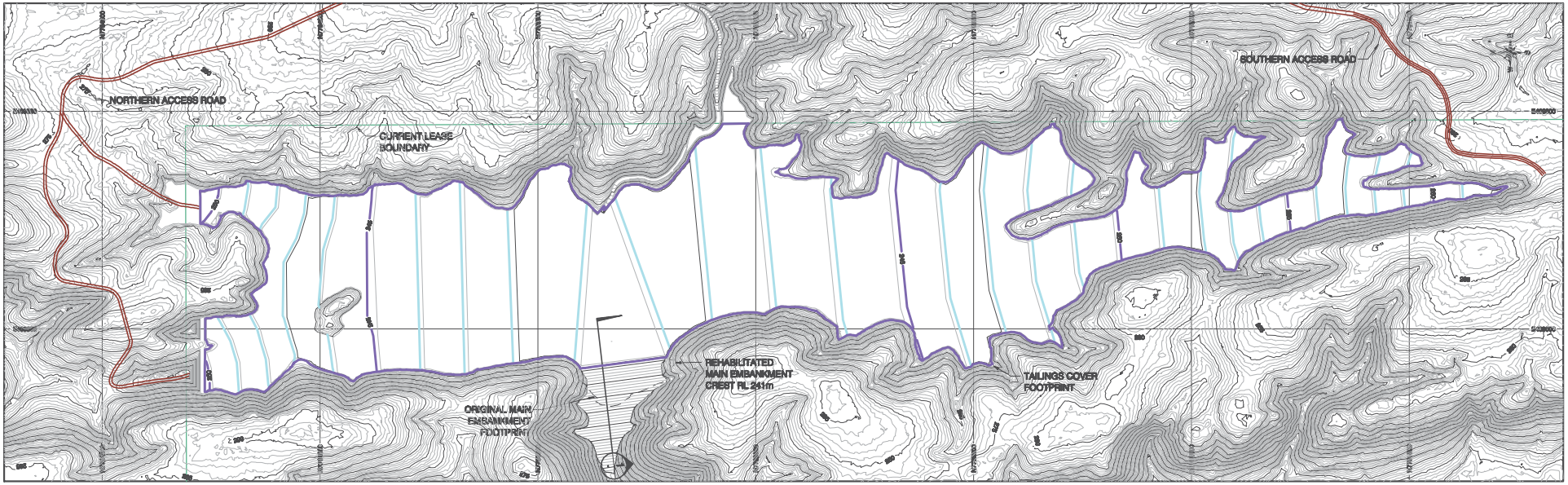
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DUGALD RIVER PROJECT FEASIBILITY STUDY

KNAPDALE VALLEY TAILINGS STORAGE FACILITY
VALLEY CROSS SECTIONS & ELEVATIONS

FIGURE 16.1

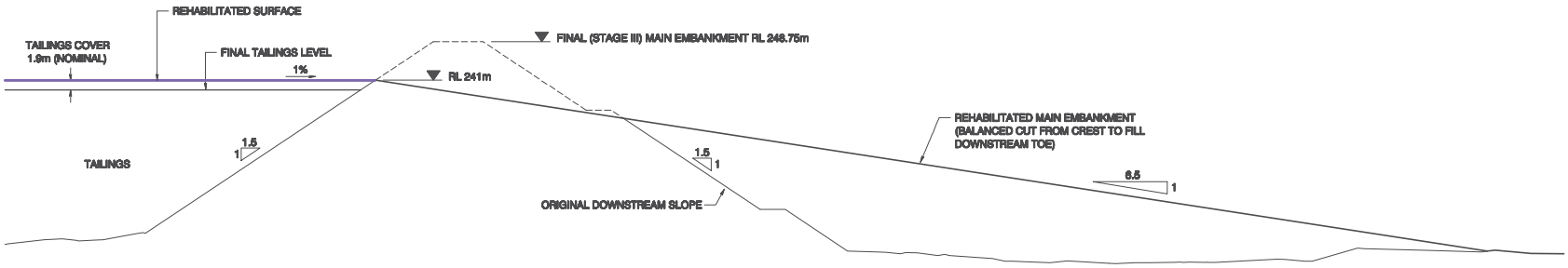
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REV. No. 0 | SHT SIZE A3
SHEET 1 OF 1

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FINAL CLOSURE PLAN

SCALE 1:10,000



SECTION 1/- REHABILITATED MAIN EMBANKMENT

SCALE 1:1,000

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KNAPDALE VALLEY TAILINGS STORAGE FACILITY
CLOSURE AND REHABILITATION CONCEPT

FIGURE 18.1

CLIENT No.
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APPENDIX A

Australian Tailings Consultants

Consulting Engineers to the Mining Industry

Prop. M.P.A. Williams and Associates Pty Ltd A.B.N. 64 005 931 288
222-225 Beach Road, Mordialloc, Vic. 3195. Australia
P.O. Box 5286, Mordialloc, Vic. 3195. Australia
Tel: 61 (03) 8587 0900 Fax: 61 (03) 8587 0901
E-mail: mel@mpaw.com.au

OZ MINERALS LIMITED

LABORATORY TESTING OF TAILINGS

DUGALD RIVER PROJECT FEASIBILITY STUDY

QUEENSLAND

Job No. 108003.01

REF: 108003R05
September, 2008

IMPORTANT NOTICE

Refer next page for Conditions of Investigation and Report

- Paul Williams B.Sc., FIEAust., M.I.C.E., F.Aus IMM
- Trevor Osborne MIEAust.
- Keith Seddon B.E., M.Sc., MIEAust., M.AustIMM., M.I.A.H.
- Steven Murphy B.E. (Civil) M Eng. Sc, MIEAust, RPEQ.

ACEA
The Association of Consulting Engineers Australia

CONDITIONS OF INVESTIGATION AND REPORT

CONDITIONS OF REPORT

1. This report has been prepared by us for the purposes stated herein. We do not accept responsibility for the consequences of extrapolation, extension or transference of the findings and recommendations of this report to different sites, cases or conditions.

2. This report is based in part on information which was provided to us by the client and/or others and which is not under our control. We do not warrant or guarantee the accuracy of this information.

3. We believe the conclusions and recommendations contained herein were reasonable and appropriate at the time of issue of the report. However, the user is cautioned that fundamental input assumptions upon which this report is based may change with time. It is the user's responsibility to ensure that input assumptions remain valid.

4. This report must be read in its entirety. This notice constitutes an integral part of the report, and must be reproduced with every copy.

5. This report is prepared solely for the use of the person or company to whom it is addressed. No responsibility or liability to any third party is accepted for any damages howsoever arising out of the use of this report by any third party.

6. Unless specifically agreed otherwise in the contract of engagement, MPAW/ATC retains Intellectual Property Rights over the contents of this report. The client is granted a licence to use the Intellectual Property Rights for the purposes for which the report was commissioned.

GEOTECHNICAL INVESTIGATION

7. Geotechnical site investigation necessarily involves the investigation of the subsurface conditions at a site at a few isolated locations, and the interpretation and extrapolation of those conditions to elsewhere on the site not so investigated. This procedure has been adopted at the site that is the subject of this report and due care and skill has been applied in carrying out and reporting on the work. Thus the findings, conclusions and comments contained in this report represent professional estimates and opinions and are not to be read as facts unless the context makes it clear to the contrary. In general, statements of fact are confined to statements as to what was done and/or what was observed. Other statements have been based on professional judgement.

8. The scope of the work has been planned in the absence of any fore-knowledge of the site other than that stated in the report. Unless otherwise stated we consider that the number of locations investigated and the depths to which they have been investigated are reasonable bearing in mind the scale and nature of the project, and the defined purpose for which the investigation was undertaken.

9. We do not accept any responsibility for any variance between the interpreted and extrapolated conditions and those that are revealed by any means subsequently. Specific warning is also given that many factors, either natural or artificial, may render ground conditions different from those which pertained at the time of the investigation. Should there be revealed during the construction or at any other time any apparent difference from subsurface conditions described or assessed in this report, it is strongly recommended that such differences be brought to our attention so that its significance may be assessed and appropriate advice given.

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1 INTRODUCTION

A program of laboratory testing was undertaken on a sample of synthetic bulk floatation tailings from the Dugald River Project. This work was commissioned by OZ Minerals Limited and the objective was to provide information on the tailings properties for the feasibility study.

2 SAMPLE DETAILS

On 1st May 2008, ATC (Australian Tailings Consultants) received a single, plastic lined 205 litre drum from Amdel Mineral Laboratories which contained 39 heat sealed silver reflective plastic bags containing filter pressed tailings samples. On 2nd May 2008, ATC received an additional plastic bag of sample delivered in an overnight courier bag. The samples that were received are detailed in **Table 1**.

TABLE 1 - DETAILS OF THE SAMPLES RECEIVED BY ATC

Sample Bag Label	Filter Papers in Sample Bag	Initial Mass (g)	Final Mass of Bag and Filter Papers (g)	Wet Sample Mass removed (g)	Notes
N2856 B2 Pb Cl 3 Tail	2	212.0	46.6	165.4	
N2856 B2 Pb Cl 2 Tail	2	232.1	48.9	183.2	
N2856 B2 Zn Cleaner 2 Tail	2	469.5	50.1	419.4	
N2856 B2 Zn Cleaner 3 Tail	4	638.2	82.5	555.7	
N2856 B2 Zn Clnr 1 Tail	3	1827.7	74.4	1753.3	
N2856 B2 Zn Scav Tail	2	3249.8	54.0	3195.8	Small hole in bag
N2856 B2 Zn Scav Tail	2	2026.4	54.6	1971.8	
N2856 B2 Zn Scav Tail	1	2280.8	33.9	2246.9	
N2856 B3 Zn Clnr 2 Tail	2	295.7	47.9	247.8	
N2856 B3 Zn Clnr 3 Tail	3	479.0	63.7	415.3	
N2856 B3 Pb Clnr 3 Tail (Balance)	1	248.5	33.6	214.9	
N2856 BB3 Final Tails 1/5	0	3244.3	16.5	3227.8	
N2856 BB3 Final Tails 2/5	0	1710.0	27.0	1683.0	
N2856 BB3 Final Tails 3/5	1	1561.4	47.1	1514.3	
N2856 BB3 Final Tails 4/5	1	2638.9	54.1	2584.8	Large hole in bag
N2856 BB3 Final Tails 5/5	1	3294.1	36.0	3258.1	
N2856 B4 Zn Clnr 2 Tail	1	427.9	36.0	391.9	
N2856 B4 Pb Cleaner 2+3 Tail	1	306.6	46.6	260.0	
N2856 B4 Final Tails 1/5	1	1448.0	31.1	1416.9	
N2856 B4 Final Tails 2/5	0	2011.0	15.4	1995.6	
N2856 B4 Final Tails 3/5	1	1929.6	28.2	1901.4	
N2856 B4 Final Tails 4/5	1	3417.1	41.8	3375.3	
N2856 B4 Final Tails 5/5	1	2931.5	33.4	2898.1	
N2856 B5 Zn Clnr 2 Tail	2	499.1	47.5	451.6	
N2856 B5 Zn Clnr 3 Tail	2	569.1	49.3	519.8	
N2856 B5 Final Tails (Balance Wet) 1/4	1	3998.9	47.7	3951.2	Hole in bag

TABLE 1 (CONTINUED)

Sample Bag Label	Filter Papers in Sample Bag	Initial Mass (g)	Final Mass of Bag and Filter Papers (g)	Wet Sample Mass removed (g)	Notes
N2856 B5 Final Tails (Balance Wet) 2/4	0	4196.0	34.1	4161.9	Hole in bag
N2856 B5 Final Tails (Balance Wet) 3/4	1	1746.8	33.2	1713.6	
N2856 B5 Final Tails (Balance Wet) 4/4	1	2305.0	38.1	2266.9	
N2856 B6 Zn Clnr 2 Tail	1	247.6	34.5	213.1	
N2856 B6 Pb Cl 3 Tails	1	131.4	31.7	99.7	
N2856 BB6 Zn Cl 3 Tail	2	263.7	46.2	217.5	
N2856 BB6 Final Tails 1/5	1	2055.0	36.5	2018.5	
N2856 BB6 Final Tails 2/5	0	3089.6	16.7	3072.9	
N2856 BB6 Final Tails 3/5	2	3217.4	55.3	3162.1	
N2856 BB6 Final Tails 4/5	1	2091.6	45.7	2045.9	
N2856 BB6 Final Tails 5/5	2	1685.0	59.0	1626.0	
N2856 FL08 B2 Prefloat Clnr 1 Con	2	603.8	34.5	569.3	
N2856 B2 Prefloat Cleaner 2 Con	2	649.5	47.3	602.2	
N2856 B2 Prefloat Cleaner 3 Con	1	310.0	28.4	281.6	
	Total Wet Sample Mass Removed From Bags			62850.5	

3 SCOPE OF WORK

The scope of the test work on the sample without flocculation was as follows:

- Conductivity and pH
- Atterberg Limits
- Particle Density
- Particle size distribution

Testing on the flocculated sample included the following:

- Initial Settled Density
- Shrinkage Limit Density
- Segregation Threshold
- Rheology
- Rowe Cell Consolidation

2 SAMPLE PREPARATION

As sample decant was not provided, Melbourne tap water was used for all sample preparation.

All sample bags were weighed, opened and emptied into a 65 litre tub. The bags were rinsed clean with Melbourne tap water and excess water was carefully squeezed out. If filter papers were

present, the filter papers were scraped clean using a spatula and the bag and filter paper were re-weighed to determine the removed sample mass. Once all the sub-samples had been combined, Melbourne tap water was added and the sample was mixed to a uniform slurry to create the all-in Pb/Zn Bulk Float Tailings sample. This slurry was then sampled for the basic properties testing.

A further sub-sample was removed for flocculation in accordance with the recommendations contained in the "Superflo Thickener Test Data Report" prepared by Outotec Pty. Ltd.

The sample prepared for flocculation consisted of 21,041g of slurry at a solids content of 63.9% which was diluted to 13.5% solids before being flocculated with SNF AN905VHM at the rate of 5g per tonne of dry solids.

3 CONDUCTIVITY AND PH

Conductivity readings were taken on the Pb/Zn Bulk Float Tailings sample, the Melbourne tap water used for sample makeup, and the decant produced after the sample had settled. Measurements were conducted using a HI9033 multi range conductivity meter calibrated with commercial laboratory standard solution in the appropriate range prior to use. pH was also measured using a calibrated HI 9026 pH meter.

The conductivity and pH results are presented in **Table 2**.

TABLE 2 - CONDUCTIVITY AND pH RESULTS

Sample Description	Test Temperature °C	Conductivity µS/cm	pH
Pb/Zn Bulk Float Tailings sample	20.2	614	8.62
Melbourne tap water	18.7	71.0	7.71
Sample Decant	20.9	1013	8.10

4 ATTERBERG LIMITS

A sub-sample of the Pb/Zn Bulk Float Tailings was tested in accordance with the following Australian standards:
AS 1289.3.1.1 – Liquid limit (Standard Casagrande method)
AS 1289.3.2.1 – Plastic Limit
AS 1289.3.3.1 – Calculation of the Plasticity Index.
AS 1289.3.4.1 – Linear Shrinkage

The results of the testing of the Pb/Zn Bulk Float Tailings sample are as follows:

- Liquid limit 21
- Plastic Limit 15
- Plasticity Index 6

A NATA accredited test report has been included in **Appendix A**.

5 PARTICLE DENSITY

The particle density was determined in accordance with AS 1289.3.5.1.

The result of the particle density testing of the Pb/Zn Bulk Float Tailings sample was 2.96 t/m^3.

A NATA accredited test report has been included in **Appendix A**.

6 PARTICLE SIZE DISTRIBUTION

A particle size determination was carried out on a sub-sample of the Pb/Zn Bulk Float Tailings sample according to AS 1289.3.6.2 and AS 1289.3.6.3, with the exception that the sieving analysis was carried out to 38 μm and the hydrometer analysis was performed on material finer than 38 μm.

The result of this analysis has been plotted in **Figure 1**.

A NATA accredited test report has been included in **Appendix A**.

7 SEGREGATION THRESHOLD

This test is to estimate the percent solids at which separation of the coarser fraction during static settling first occurs. This is known as the segregation threshold.

The procedure used was to agitate a sample of slurry in a glass cylinder and allow it to settle. The solids content was varied by decanting or adding decant water as required and the test was repeated until some sign of segregation was noted. Two sub-samples of equal volume were then taken using a small pipette, one from the bottom of the cylinder and the other from just below the surface.

These samples were put into separate test tubes and both were diluted, agitated and decanted to separate the coarser particles. The volumes of the coarser particles remaining were compared and the whole test repeated after solids adjustment, until the volumes were judged to be equal. The slurry in the cylinder was then tested for solids content and this was the threshold value.

The Segregation Threshold of the Pb/Zn Bulk Float Tailings sample was 46% solids.

8 INITIAL SETTLED DENSITY

The procedure foe estimating the initial settled, or sedimented density, is as follows:

A sub-sample of the material to be tested at the required initial solids content is poured into a large diameter pan to a nominal target depth. The settlement of the surface of the tailings over time is recorded until settlement is judged to be complete.

A total of four tests were performed on the Pb/Zn Bulk Float Tailings sample. Two tests were performed at 50% nominal initial solids content with nominal initial sample depths of 25mm and 50mm. Two tests were also performed at 55% nominal initial solids content with nominal initial sample depths of 25mm and 50mm.

The settlement results for these tests are plotted in **Figures 2 and 3**. The data is also presented in **Table 3** below.

TABLE 3 - INITIAL SETTLED DENSITY RESULTS

Sample	Solids Content %		Sample Depth mm			$\frac{H_F}{H_O} \times 100\%$	Settled Dry Density t/m³	Bleed Water	
	Initial	Final	Initial Ho	Final H_F	ΔH			% of Initial Water	m³/t Dry Solids
Flocculated Pb/Zn Bulk Float Tailings sample	49.9	66.4	49.7	31.3	18.4	63.0	1.18	49.5	0.50
	49.9	62.9	24.3	16.8	7.5	69.1	1.08	41.3	0.41
	55.0	66.9	49.8	35.9	13.9	72.1	1.20	39.5	0.32
	55.0	65.1	25.9	19.6	6.3	75.7	1.14	34.4	0.28

9 SHRINKAGE LIMIT DENSITY

This test is carried out to determine the maximum dry density that could result from the evaporative drying of the tailings on a beach.

The shrinkage limit density of the Pb/Zn Bulk Float Tailings sample was 1.63 t/m^3.

The results are also presented in **Figure 4.**

10 RHEOLOGY

The rheology testing was carried out using a Thermo Haake VT550 Viscotester and MV2P Couette flow bob in cup sensor system.

Testing of the Pb/Zn Bulk Float Tailings sample was performed at nominal solids contents of 50%, 52.5% and 55%.

Although the MV2P system is factory grooved to limit slippage, some wall slippage is evident in the flow curves and there was also a lot of turbulence evident at high shear rates due to the low viscosity of the samples at the solids contents that were tested.

Herschel – Bulkley modelling of the data was performed in order to provide a theoretical line of best fit to the experimental data and provide yield strength parameters only.

The Herschel – Bulkley pseudo plastic model has the equation:

$$\tau = \tau_y + K\dot{\gamma}^n$$

Where: τ = Shear Stress
τ_y = Yield Stress
K = Consistency Coefficient
$\dot{\gamma}$ = Shear Rate
n = Flow Behaviour Index

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. The data that exhibited slippage at low shear rates and data that was affected by turbulence was excluded from the inputs to calculate the model fit.

A copy of the flow curves and shear vane plots for the Pb/Zn Bulk Float Tailings sample is included in **Appendix B**.

The data derived from the flow curves is plotted on **Figures 5,** and **6**. The plastic viscosity has been defined as the gradient of the tangent of the rheogram at a shear rate of 100 sec^{-1}, while the intercept of this tangent at 0 S^{-1} shear rate is shown as the tangent intercept stress. The yield stress values have been derived from the Herschel – Bulkley models.

11 ROWE CELL CONSOLIDATION

The Rowe cell is a large diameter (254mm) consolidation cylinder capable of measuring large sample deflections over a range of applied pressures from 1kPa to 640kPa. 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.

A sample of Pb/Zn Bulk Float Tailings sample at a solids content of 53.5% was placed in the cell to a depth of 98.1mm and allowed to settle for 21 hours. Consolidation of the sample was then carried out in 10 stages from 1kPa to 640kPa with permeability directly measured at the end of each stage.

The results are presented in **Figures 7, 8** and **9** which are plots of e/log p, log C_v/log p and e/log k respectively, where e is the void ratio, p is effective pressure, C_v is the coefficient of consolidation and k is the permeability.

AUSTRALIAN TAILINGS CONSULTANTS

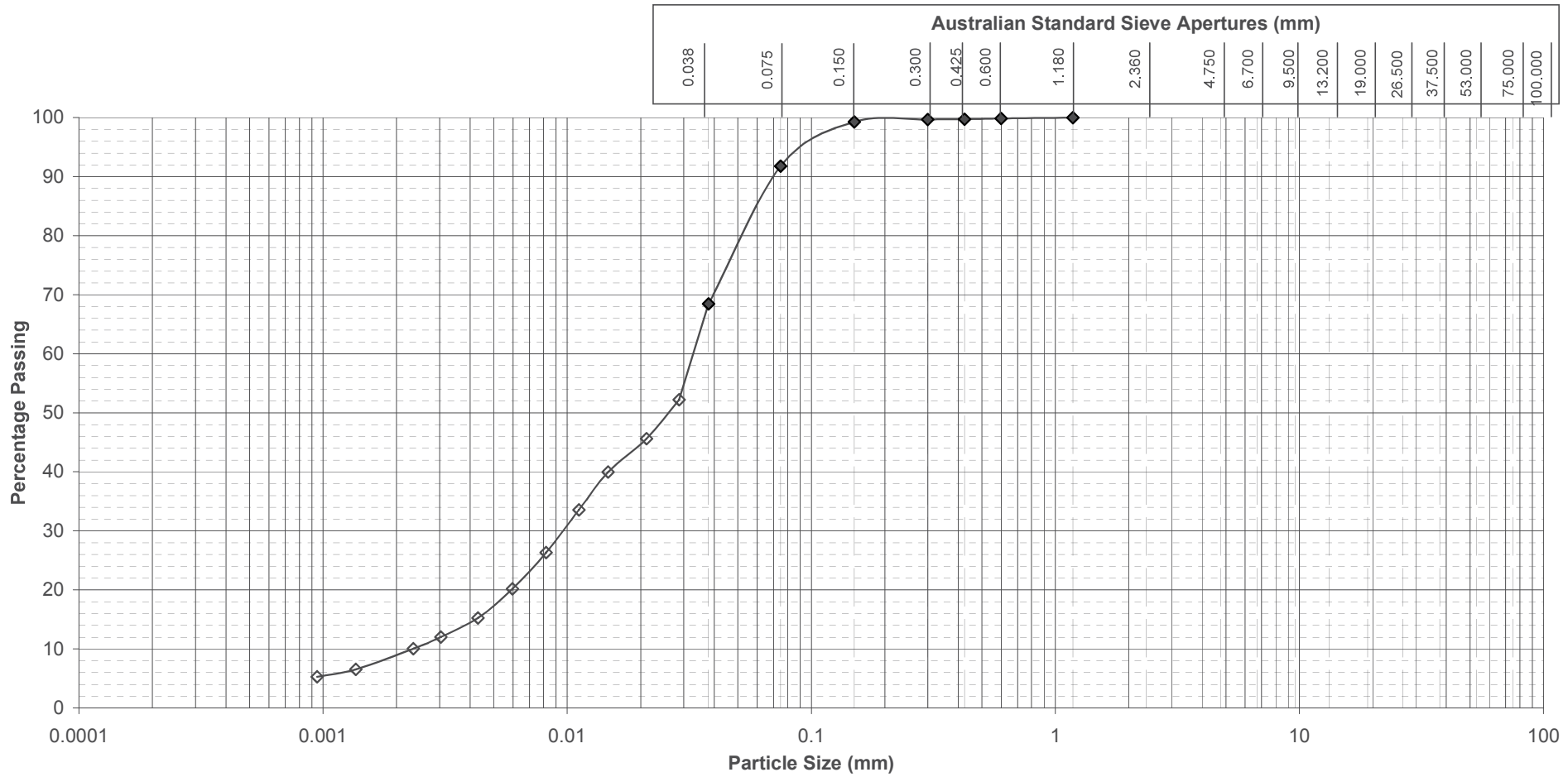


PETER LAM

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AS 1289.3.6.3 – 2003 – Soil classification tests – Determination of the particle size distribution of a soil – Standard method of fine analysis using a hydrometer. ISBN 0 7337 5325 6

FIGURES



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OZ MINERALS LIMITED

DUGALD RIVER PROJECT - FEASIBILITY STUDY

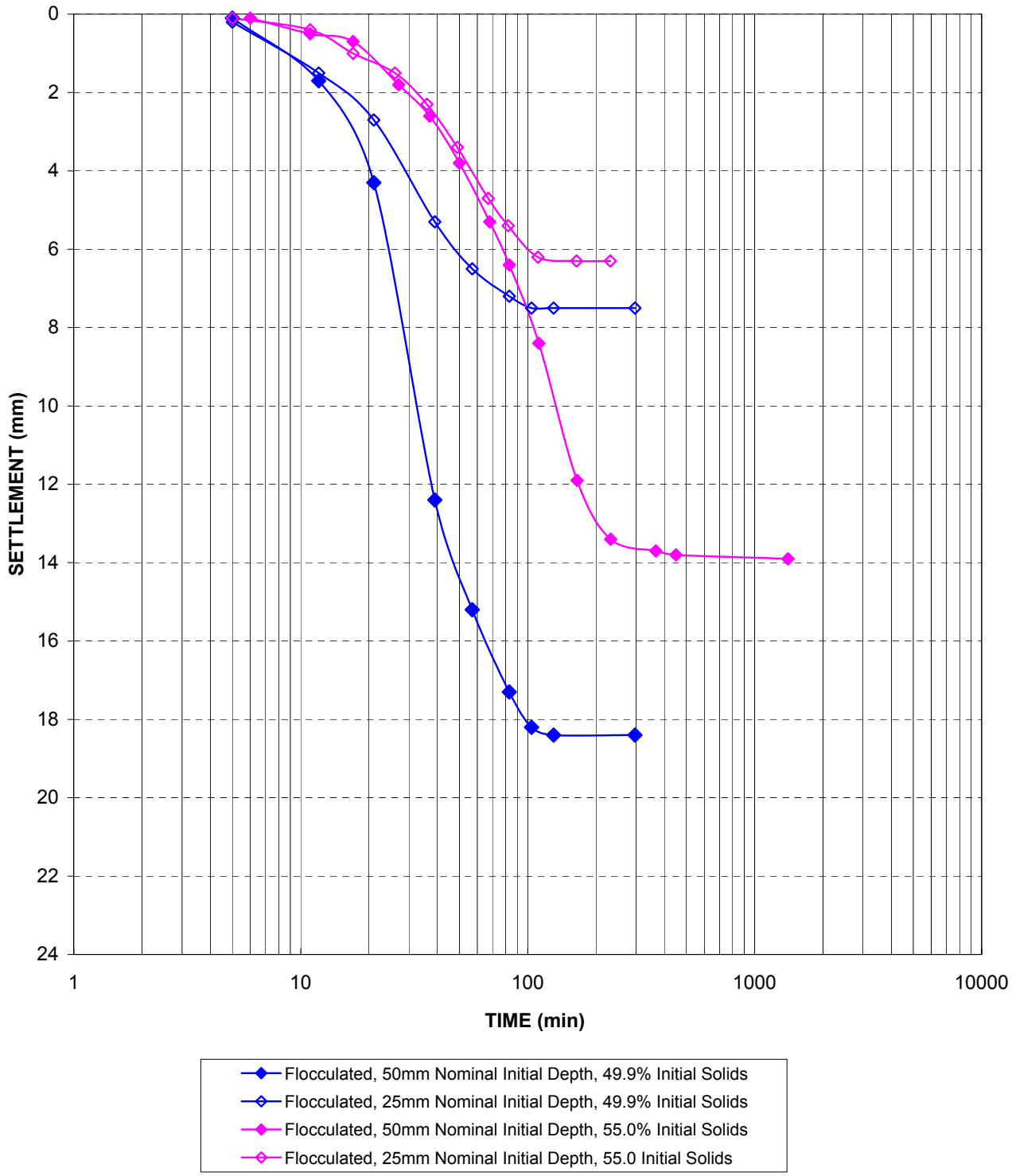
Pb/Zn BULK FLOATATION TAILINGS

Sieve and Hydrometer Analysis - Sample No.05308

Date: 2/09/2008 **Job No:** 108003.01

FIGURE 1

Settlement (All Samples)
50% and 55% Nominal Initial Solids Content



OZ MINERALS LIMITED

DUGALD RIVER PROJECT - FEASIBILITY STUDY

Pb/Zn BULK FLOATATION TAILINGS

SETTLING TEST RESULTS

Sample No. 05408

Flocculated Tailings

Australian Tailings Consultants

Civil and Geotechnical Engineers

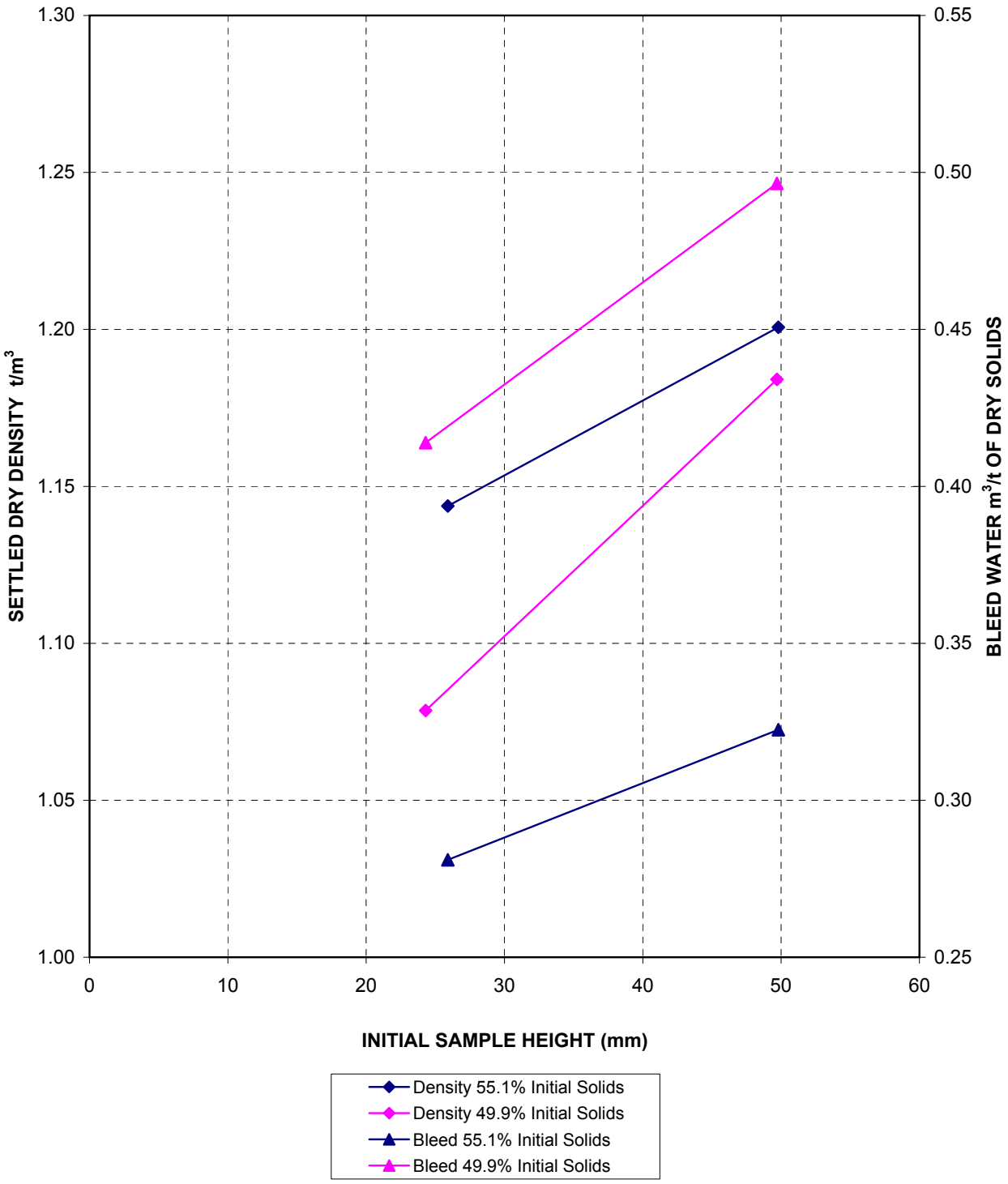
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Job No: 108003.01

Date: 2/09/2008

FIGURE 2

Density and Bleed (All Samples)
50% and 55% Nominal Initial Solids Content



OZ MINERALS LIMITED

DUGALD RIVER PROJECT - FEASIBILITY STUDY

Pb/Zn BULK FLOATATION TAILINGS

SETTLING TEST RESULTS

Sample No. 05408

Flocculated Tailings

Australian Tailings Consultants

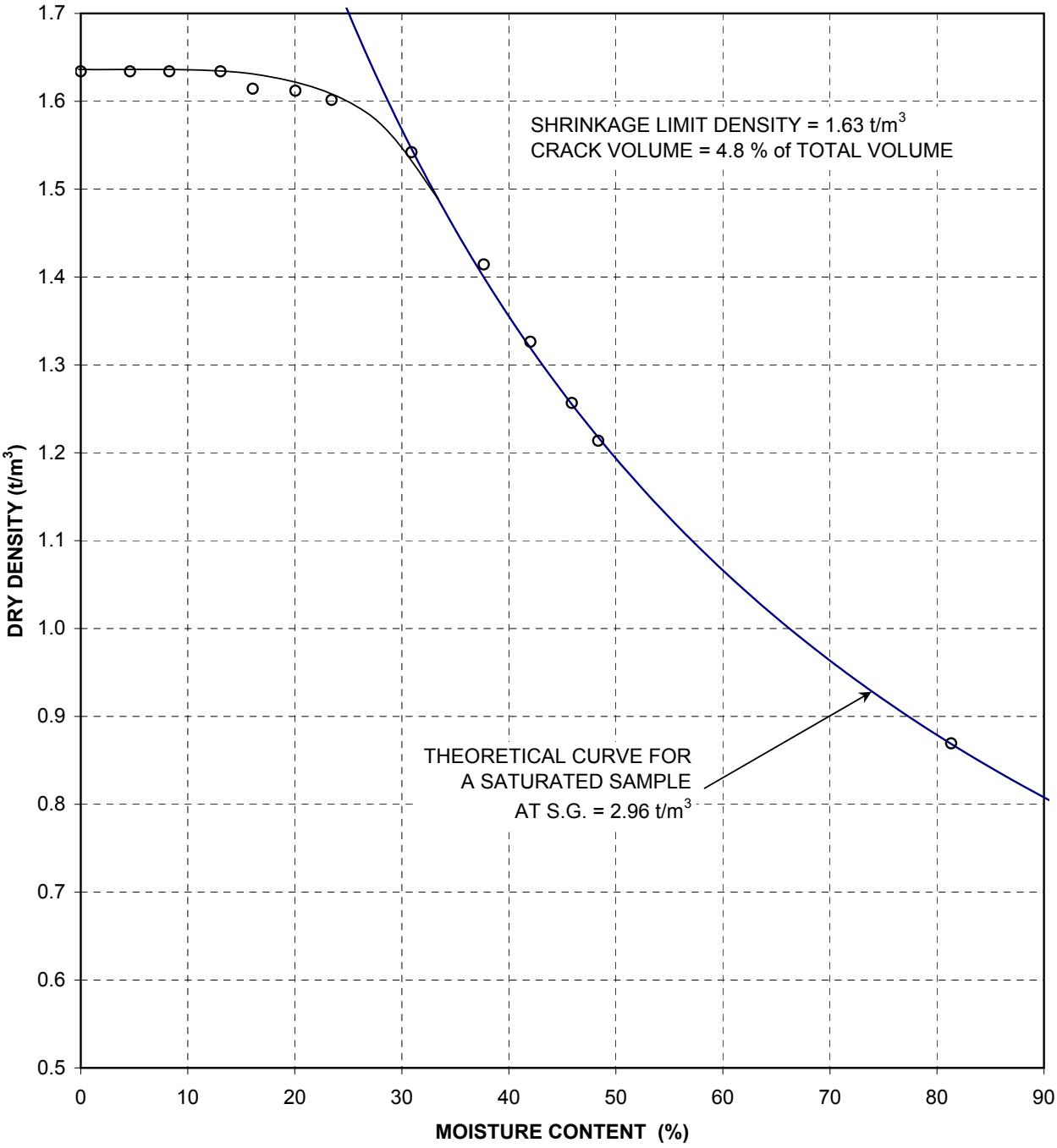
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Job No: 108003.01

Date: 2/09/2008

FIGURE 3



OZ MINERALS LIMITED

DUGALD RIVER PROJECT - FEASIBILITY STUDY

Pb/Zn BULK FLOATATION TAILINGS

SHRINKAGE LIMIT DENSITY

Sample No. 05408

Flocculated Tailings

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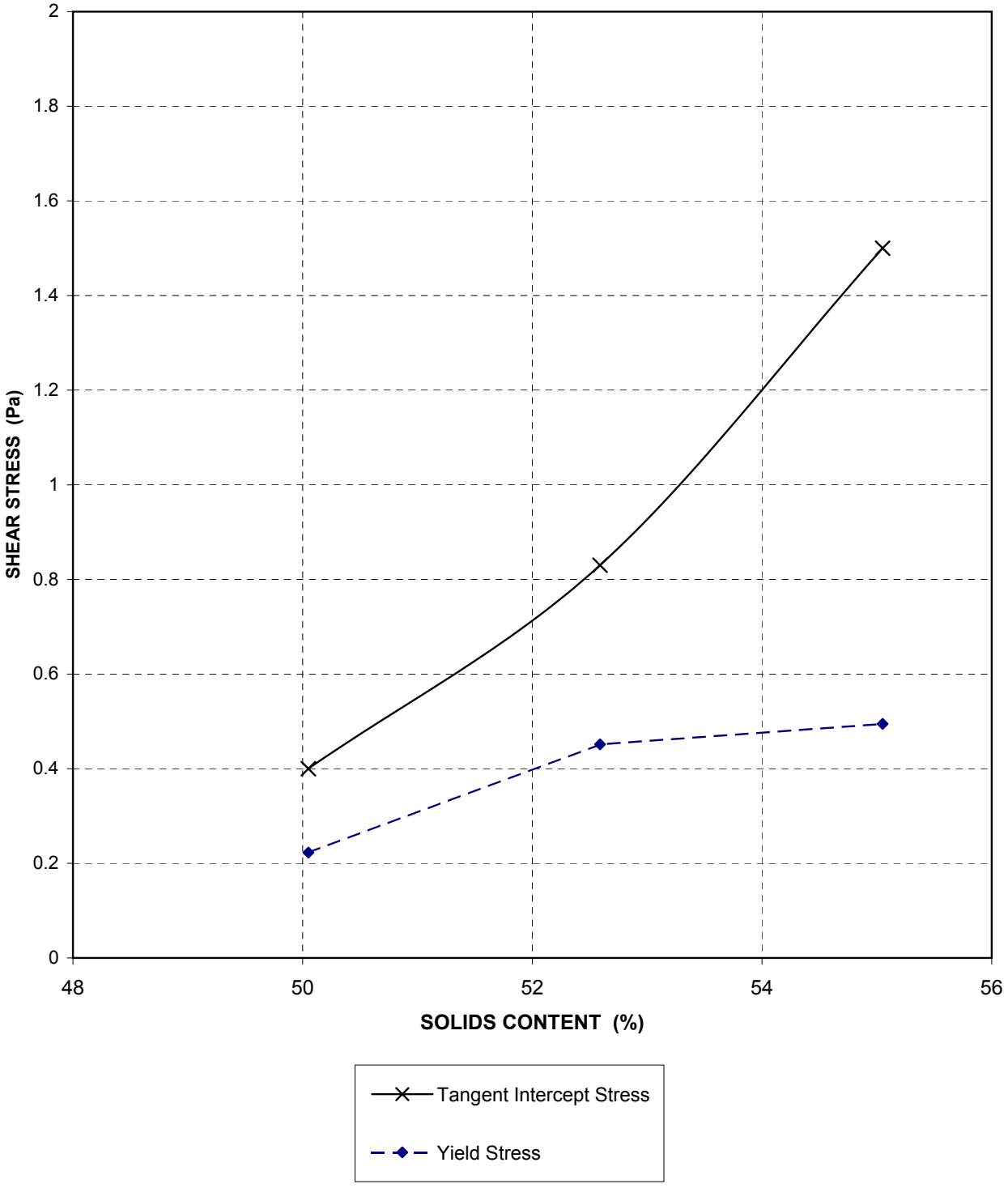
Job No: 108003.01

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FIGURE 4

J:\2008\108003 Dugald River\Documents\108003R05 Lab Report\Figures.xls

Shear Stress vs. Solids Content



OZ MINERALS LIMITED

DUGALD RIVER PROJECT - FEASIBILITY STUDY

Pb/Zn BULK FLOATATION TAILINGS

RHEOLOGY

Sample No. 05408

Flocculated Tailings

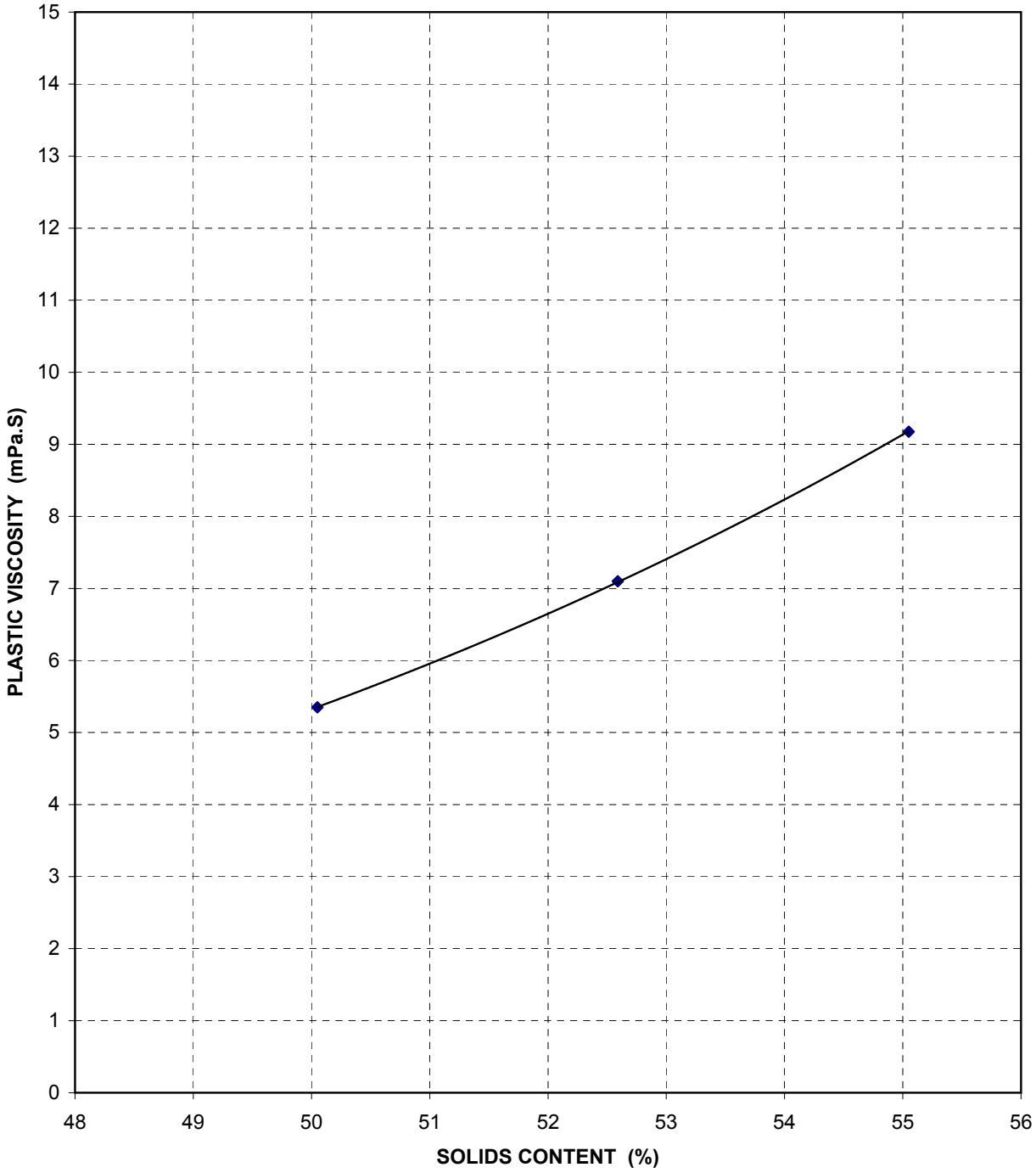
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Job No: 108003.01

Date: 2/09/2008

FIGURE 5

Plastic Viscosity vs. Solids Content



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DUGALD RIVER PROJECT - FEASIBILITY STUDY

Pb/Zn BULK FLOATATION TAILINGS

RHEOLOGY

Sample No. 05408

Flocculated Tailings

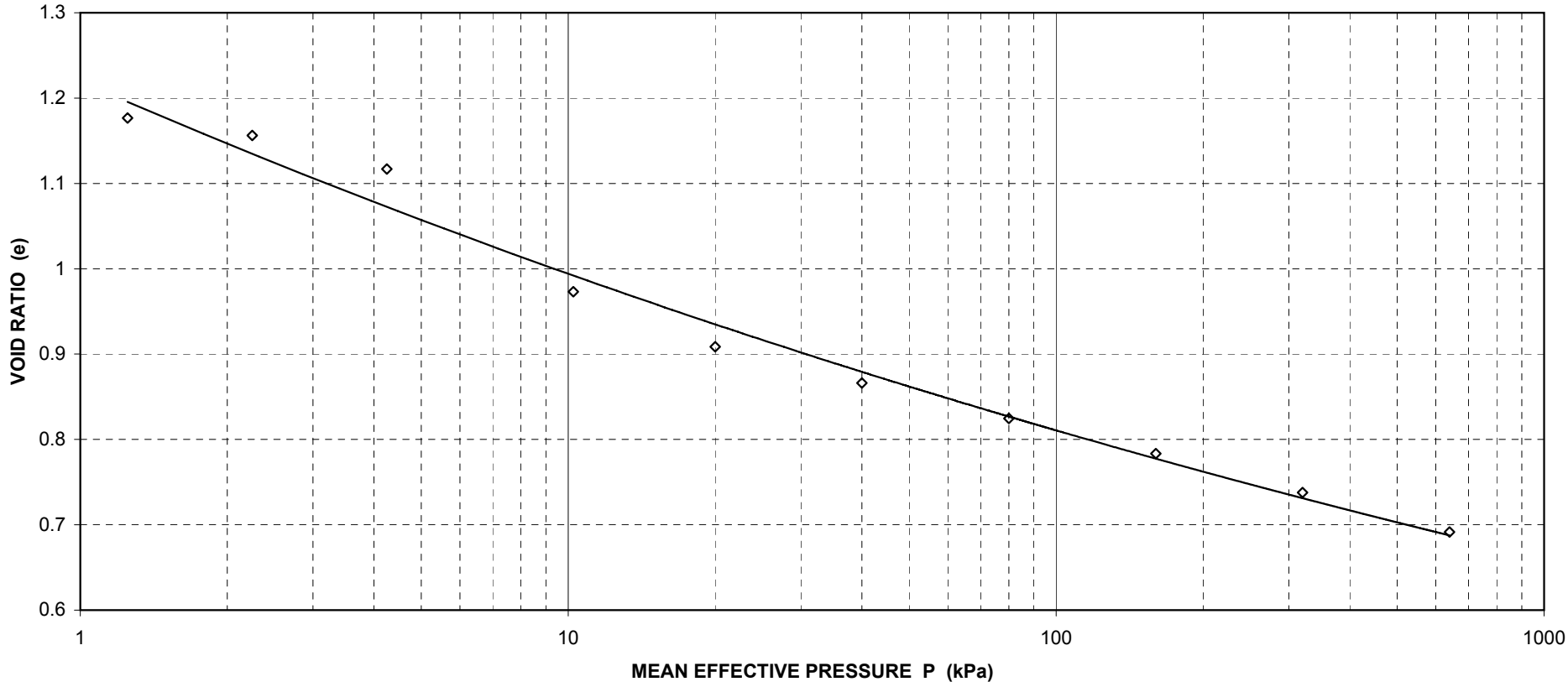
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Job No: 108003.01

Date: 2/09/2008

FIGURE 6

Void Ratio vs. Mean Effective Pressure (e / log P)
(Flocculated Tailings)



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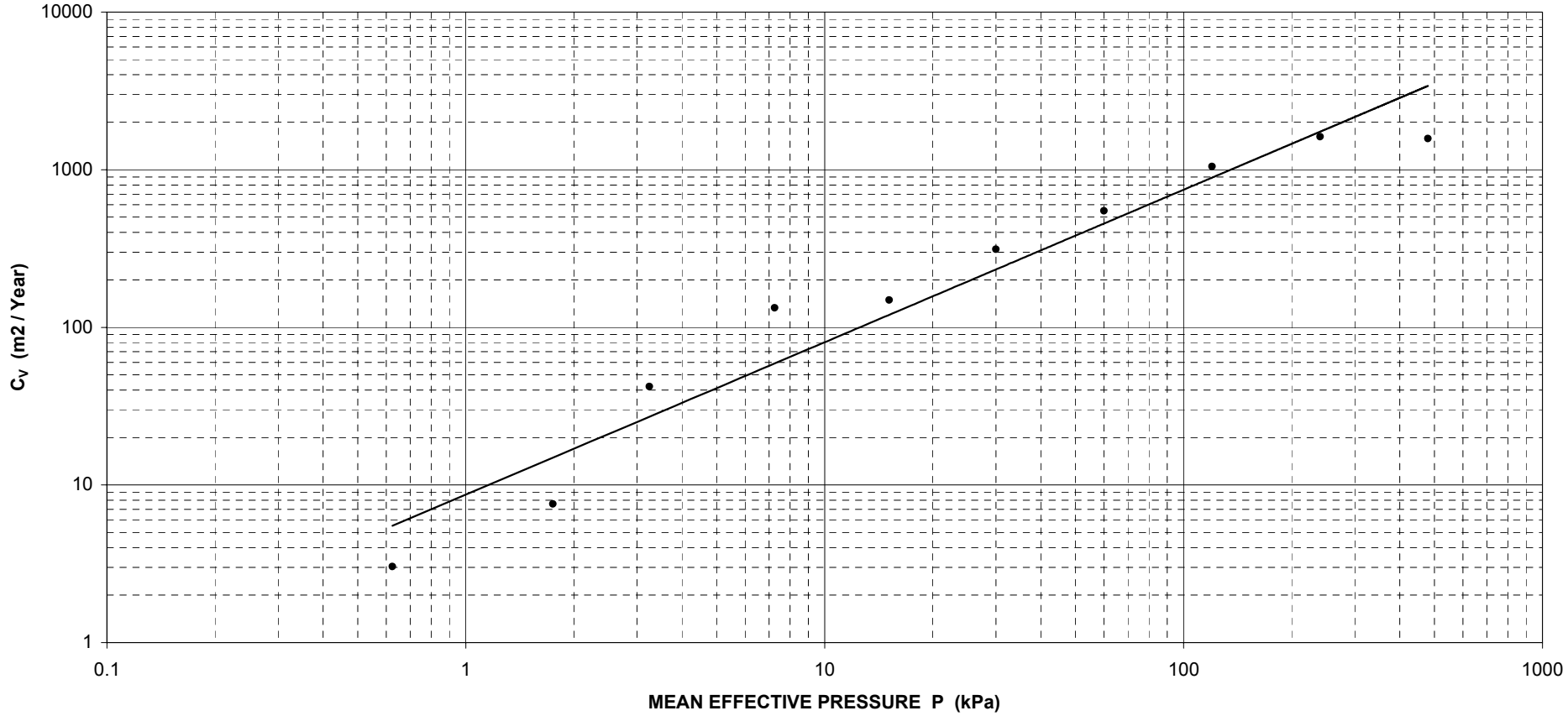
DUGALD RIVER PROJECT - FEASIBILITY STUDY

Pb/Zn BULK FLOATATION TAILINGS

Rowe Cell Consolidation - Sample No.05408

Date:	2/09/2008	**Job No:**	108003.01	**FIGURE 7**

Coefficient of Consolidation vs. Mean Effective Pressure (Log C_V / Log P)
(Flocculated Tailings)



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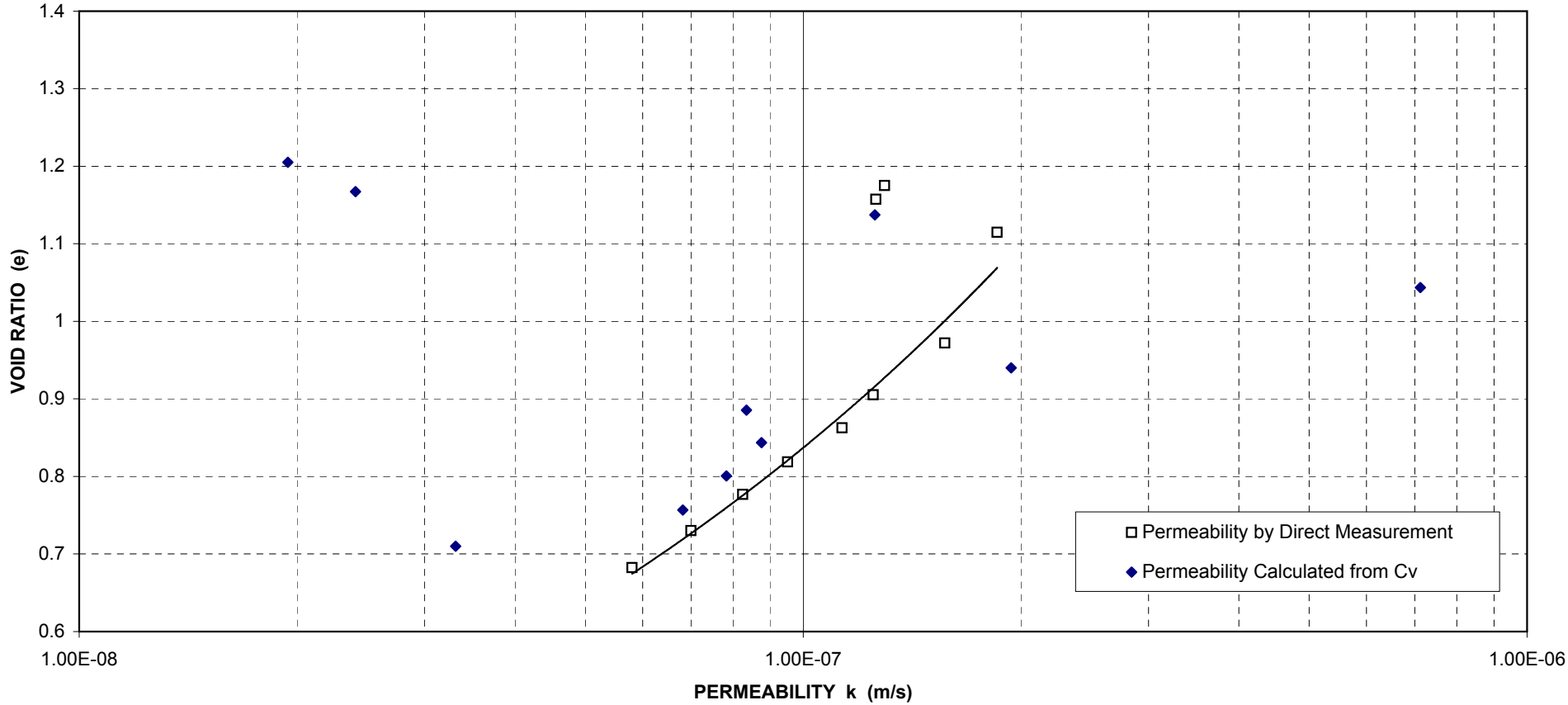
DUGALD RIVER PROJECT - FEASIBILITY STUDY

Pb/Zn BULK FLOATATION TAILINGS

Rowe Cell Consolidation - Sample No.05408

Date:	2/09/2008	**Job No:**	108003.01	**FIGURE 8**

Void Ratio vs. Permeability (e / log k)
(Flocculated Tailings)



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DUGALD RIVER PROJECT - FEASIBILITY STUDY

Pb/Zn BULK FLOATATION TAILINGS

Rowe Cell Consolidation - Sample No.05408

Date:	2/09/2008	**Job No:**	108003.01	**FIGURE 9**

APPENDIX A

PARTICLE SIZE DISTRIBUTION

NATA

☐ AS 1289.3.6.1 ☑ AS 1289.2.1.1

☑ AS 1289.3.6.2

☑ AS 1289.3.6.3

REPORT No. : R11708

JOB No. : 108003.01

CLIENT: Oz Minerals Limited — REGISTER No. : 05308

CLIENT ADDRESS: Freshwater Place, Level 29, 2 Southbank Blvd, Vic, 3006

PROJECT: Dougald River Project — **LOCATION:** Queensland

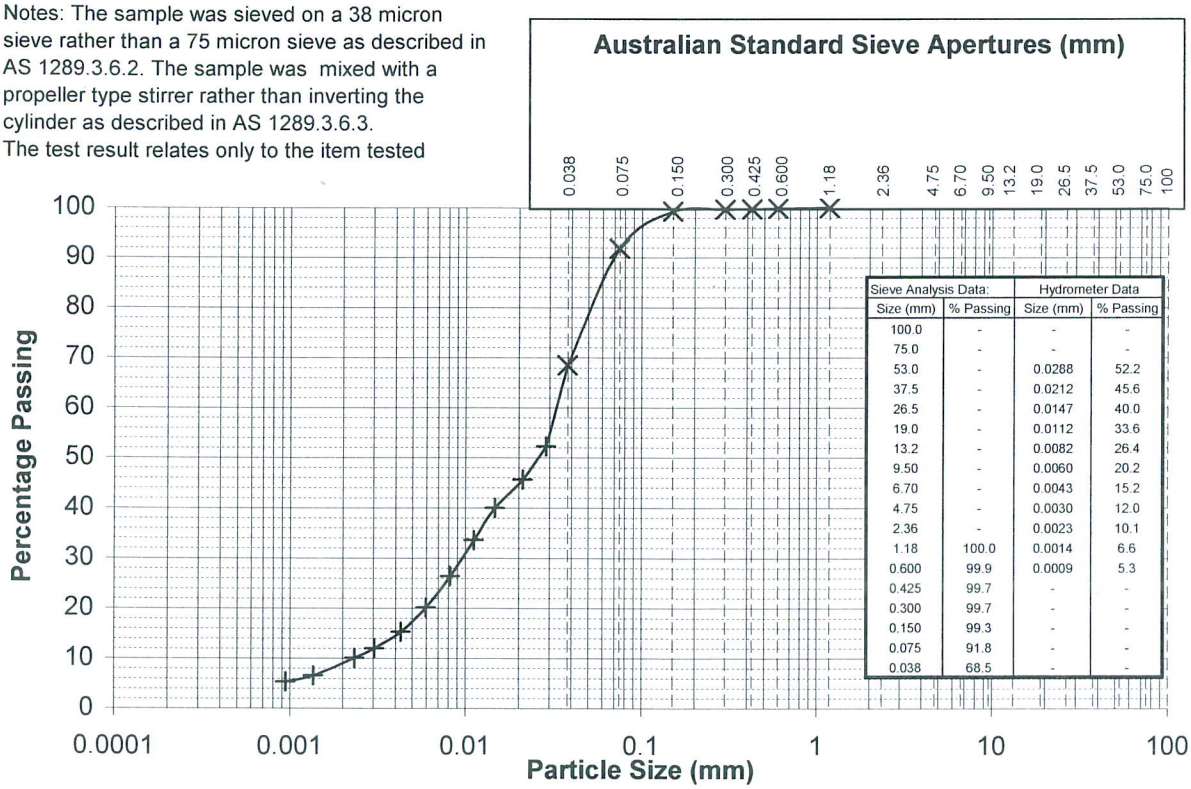
SAMPLE DESCRIPTION : Pb/Zn Bulk Float Tailings — BOREHOLE ☐ TEST PIT ☐ — No. : — DEPTH :

Dispersion Method Used: Mechanical Stirrer. Hydrometer Type Used: ASTM 152H

☐ Sampled by MPA Williams & Associates Pty. Ltd.

☑ Sample provided by the client.

Notes: The sample was sieved on a 38 micron sieve rather than a 75 micron sieve as described in AS 1289.3.6.2. 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
100.0	-	-	-
75.0	-	-	-
53.0	-	0.0288	52.2
37.5	-	0.0212	45.6
26.5	-	0.0147	40.0
19.0	-	0.0112	33.6
13.2	-	0.0082	26.4
9.50	-	0.0060	20.2
6.70	-	0.0043	15.2
4.75	-	0.0030	12.0
2.36	-	0.0023	10.1
1.18	100.0	0.0014	6.6
0.600	99.9	0.0009	5.3
0.425	99.7	-	-
0.300	99.7	-	-
0.150	99.3	-	-
0.075	91.8	-	-
0.038	68.5	-	-

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	

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NATA ACCREDITED LABORATORY NUMBER: 3372
This document is issued in accordance with NATA's accreditation requirements.
Accredited for compliance with ISO/IEC 17025

ACCREDITED FOR TECHNICAL COMPETENCE

Approved Signatory ..... Date 3-9-2008

Name Of Signatory PETER LAM

CLASSIFICATION TEST RESULTS

NATA REPORT No.	R11808
JOB No.	108003.01

CLIENT : Oz Minerals Limited

CLIENT ADDRESS : Freshwater Place, Level 29, 2 Southbank Blvd, Vic, 3006

PROJECT : Dugald River Project | LOCATION : Queensland

REGISTER NUMBER	SAMPLE DESCRIPTION	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)	LINEAR SHRINKAGE (%)	SAMPLE CURLED (CU) / CRUMBLED (CR)
05308	Pb/Zn Bulk Float Tailings	21	15	6		

☐ Sampled by MPA Williams & Associates Pty. Ltd. in accordance with AS 1289.1.2.1 Clause ?

☒ Sample provided by the client.

Note: The test result relate only to the items tested.

TEST METHODS :

LIQUID LIMIT	☐	AS 1289. 3.1.1	(Standard method)
	☒	AS 1289. 3.1.2	(Subsidiary method)
PLASTIC LIMIT	☒	AS 1289. 3.2.1	
PLASTICITY INDEX	☒	AS 1289. 3.3.1	
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	

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NATA ACCREDITED LABORATORY NUMBER: **3372**
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ACCREDITED FOR TECHNICAL COMPETENCE

Approved Signatory ..... Date 3-9-2008.

Name Of Signatory ..... PETER LAM

DETERMINATION OF THE SOIL PARTICLE DENSITY OF A SOIL - TEST RESULTS
AS 1289 3.5.1

NATA REPORT No. : R11908

JOB No. : 108003.01

CLIENT : Oz Minerals Limited

CLIENT ADDRESS : Freshwater Place, Level 29, 2 Southbank Blvd, Vic, 3006

PROJECT : Dugald River Project

LOCATION : Queensland

REGISTER NUMBER	SAMPLE DESCRIPTION	TEST TEMPERATURE (°C)	% OF SAMPLE >2.36mm	PARTICLE DENSITY (g/cm^3)
05308	Pb/Zn Bulk Float Tailings	23.2	0	2.96#

NOTES :

☐ Sampled by MPA Williams & Associates 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.

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Accredited for compliance with ISO/IEC 17025

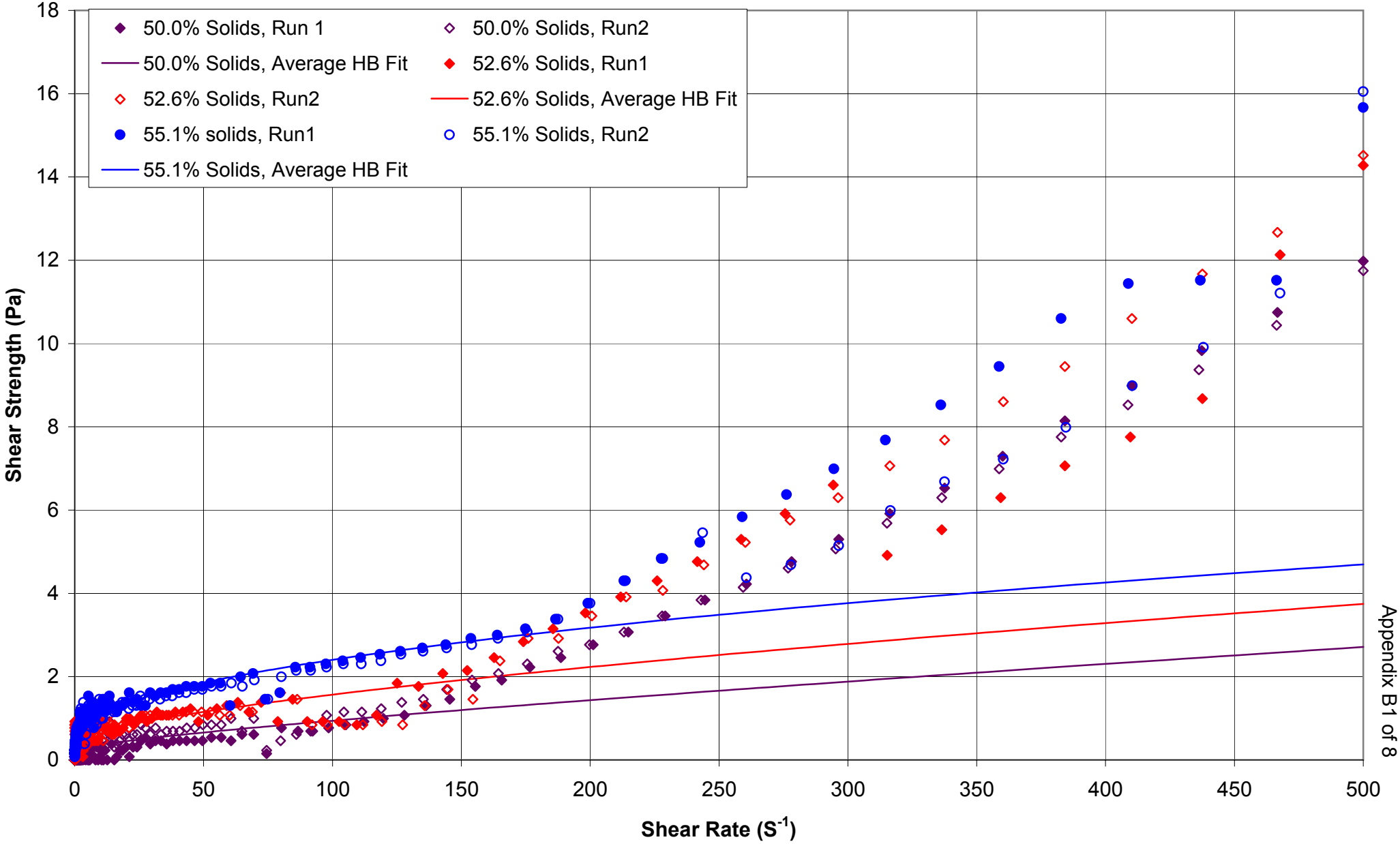
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Approved Signatory ..... Date 3-9-2008

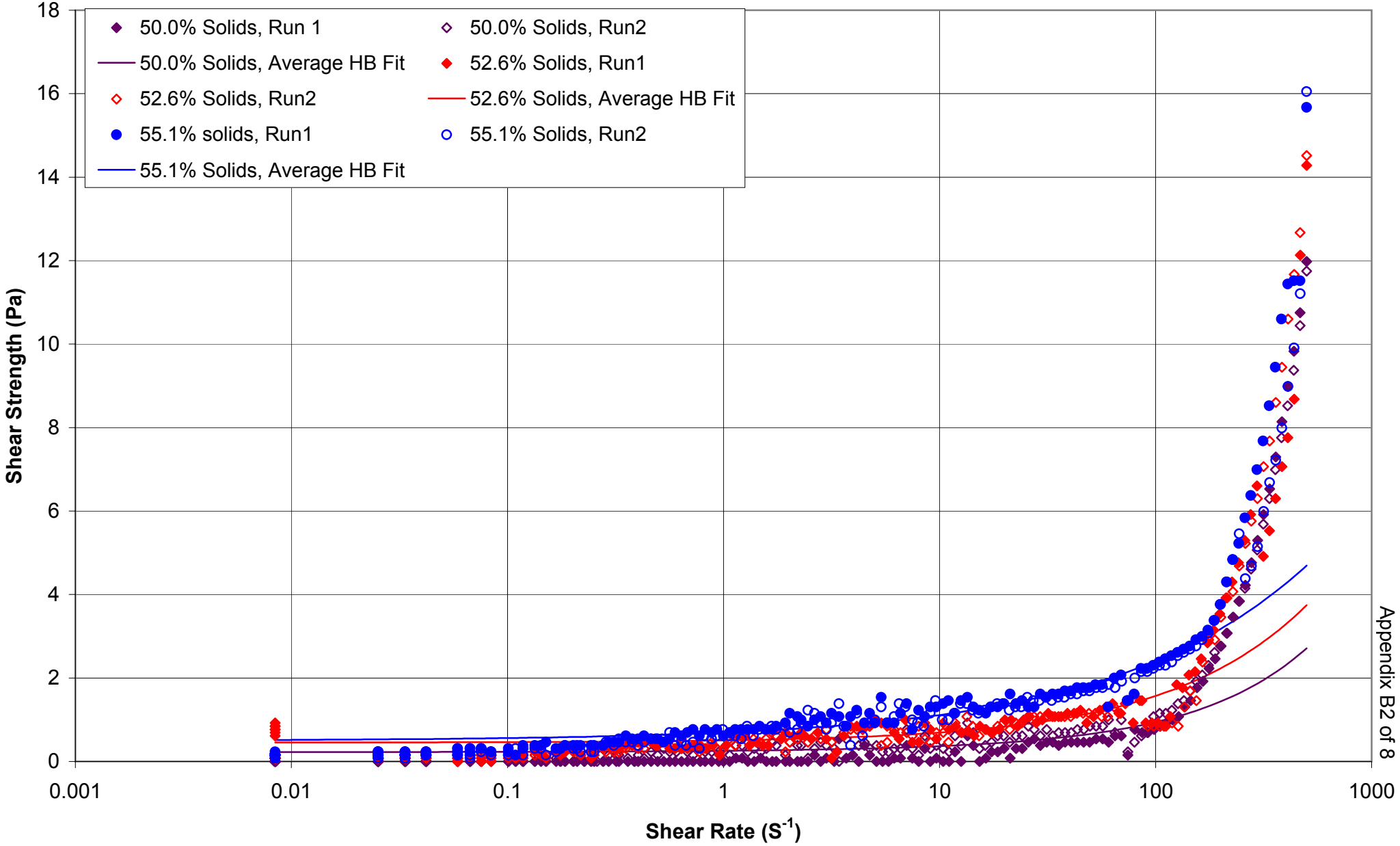
Name Of Signatory PETER LAM

APPENDIX B

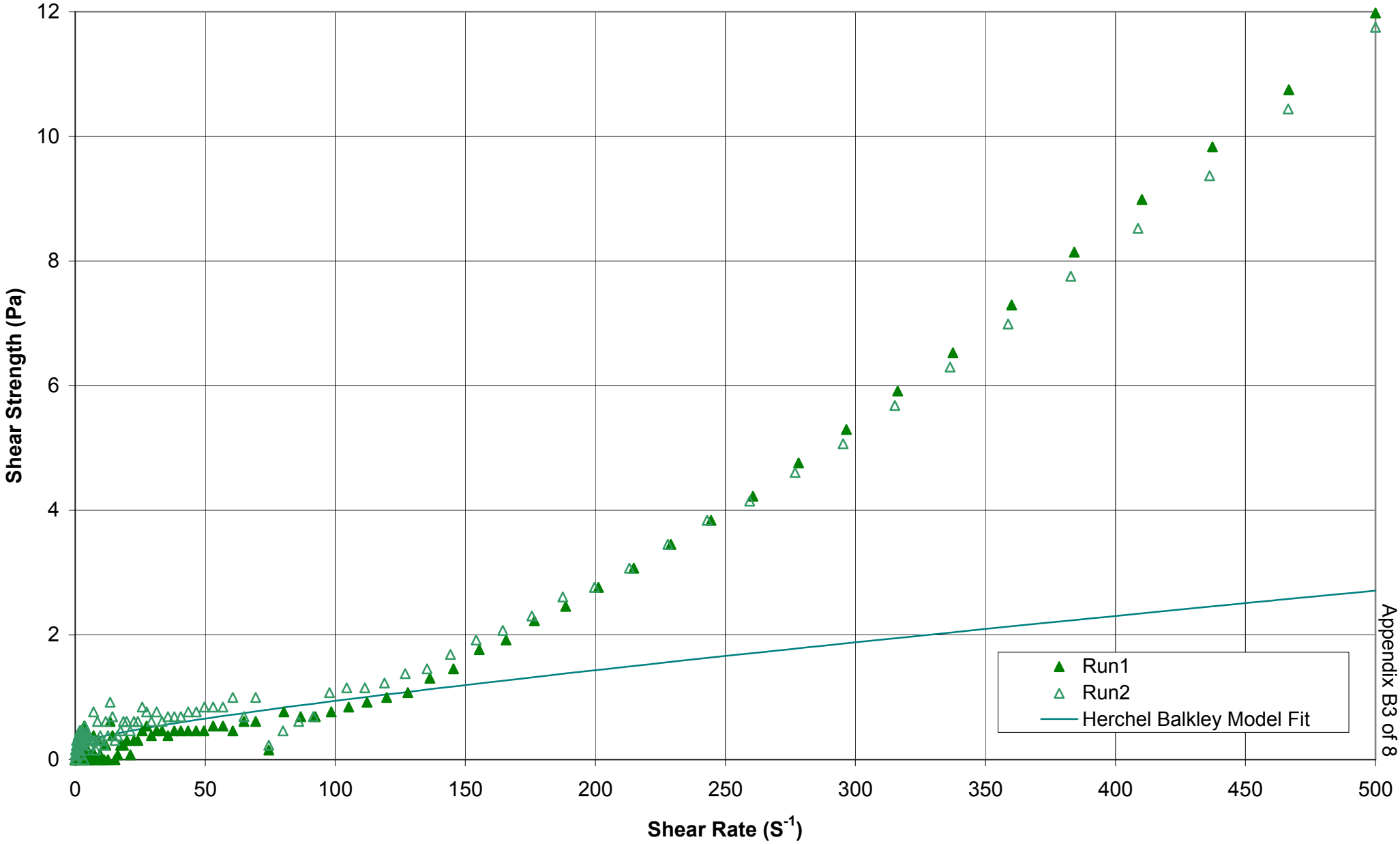
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Flocculated Tailings
ALL FLOW CURVE RESULTS



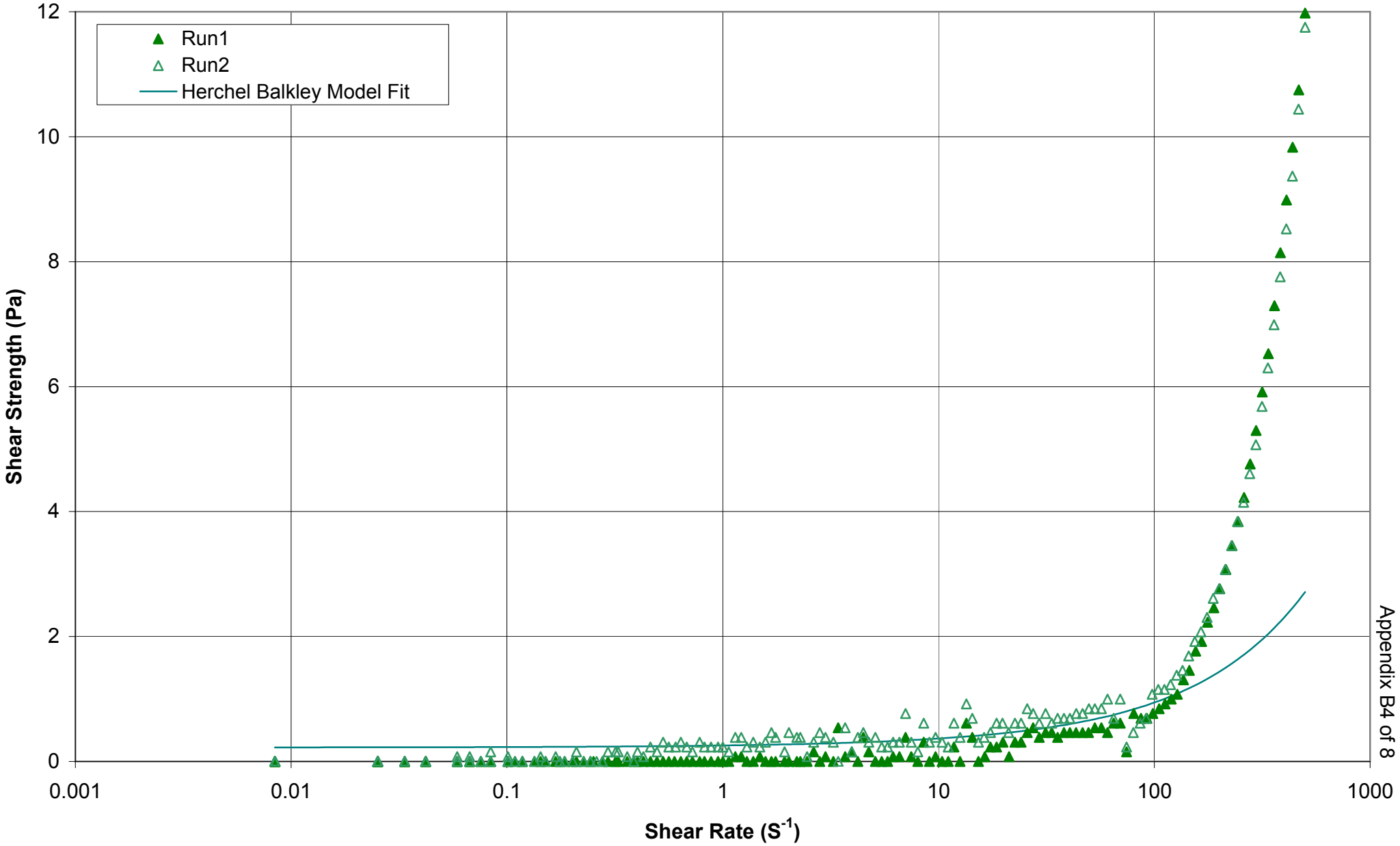
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Flocculated Tailings
ALL FLOW CURVE RESULTS



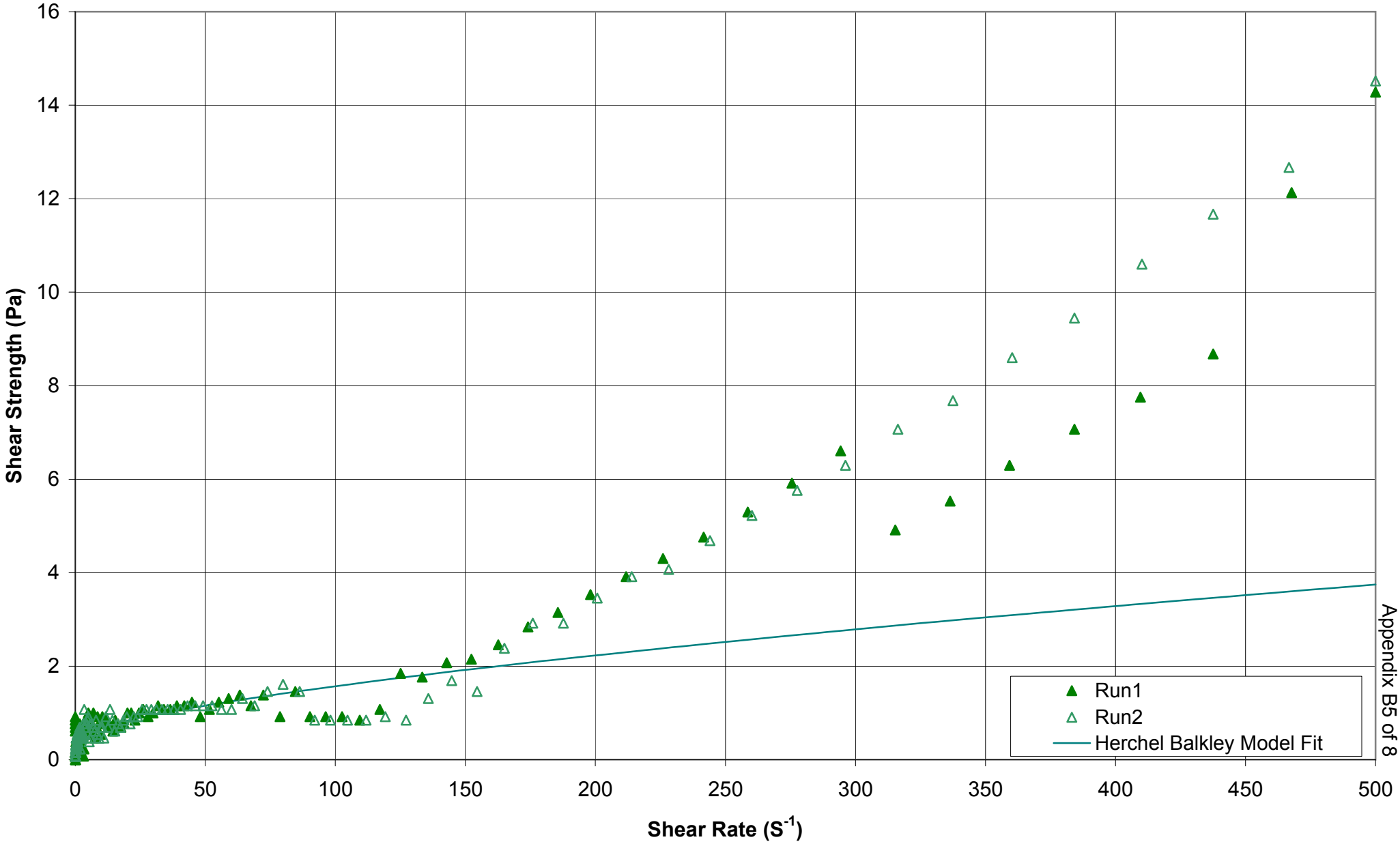
DUGALD RIVER PROJECT - FEASIBILITY STUDY
Flocculated Tailings
50.0% Solids



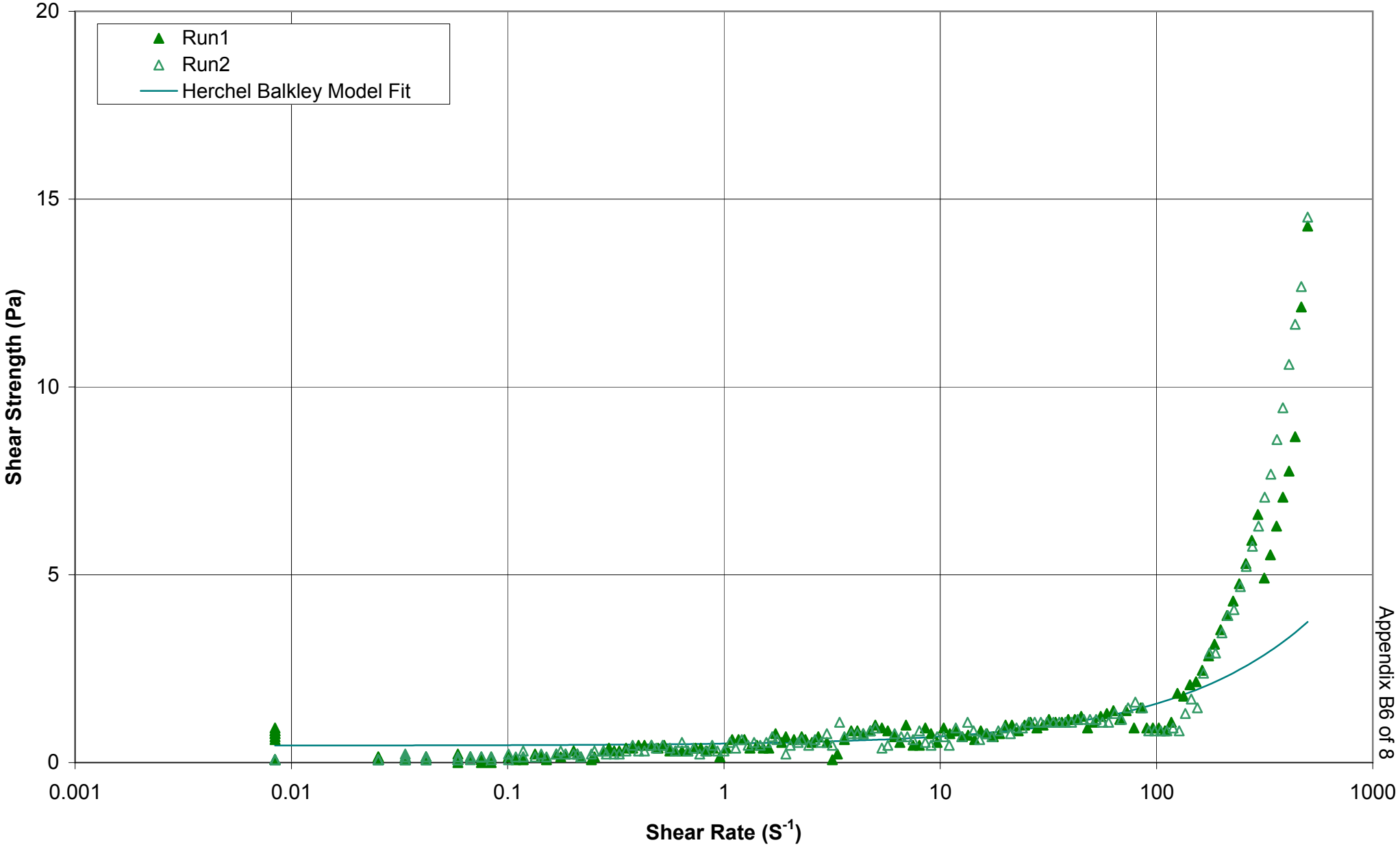
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50.0% Solids



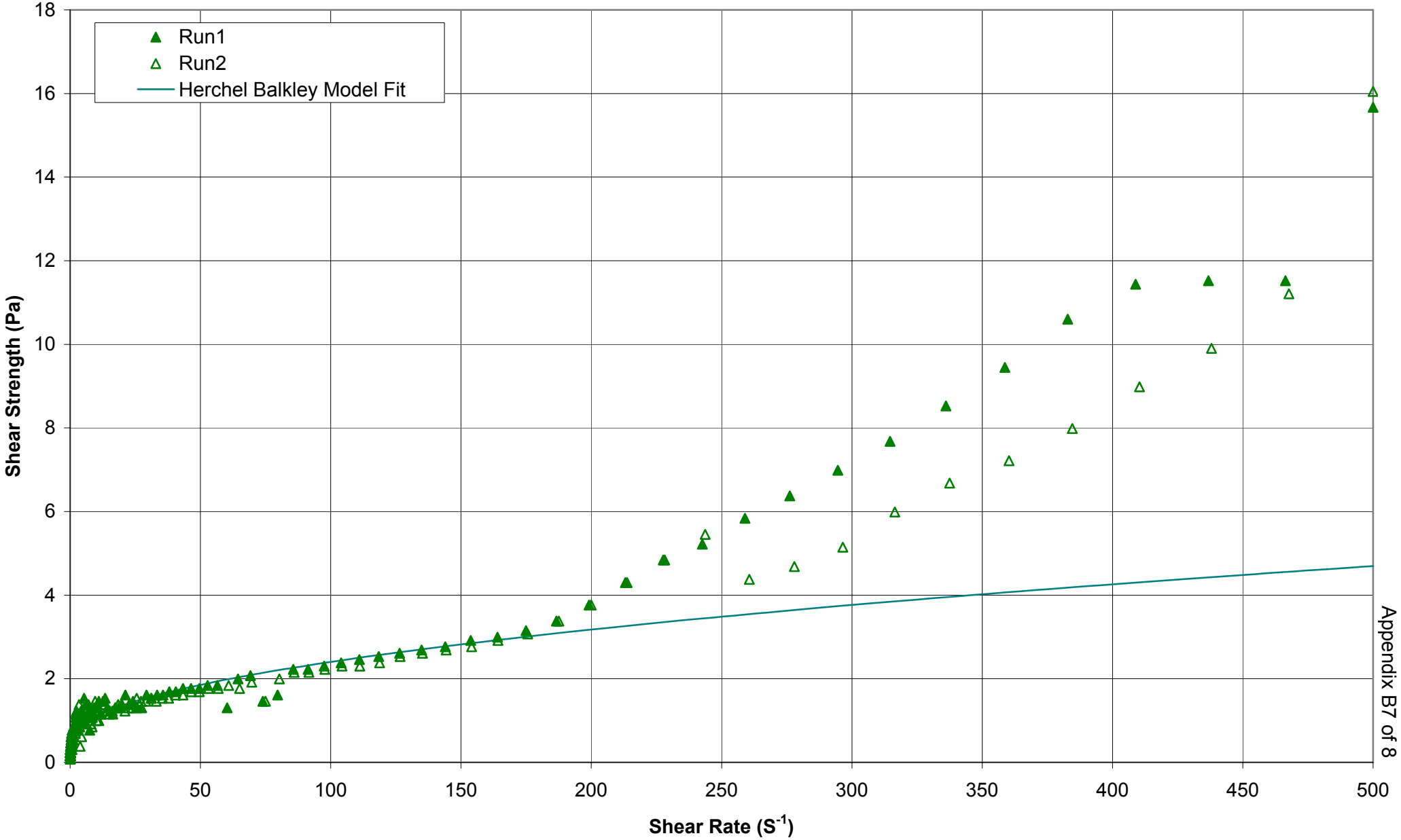
DUGALD RIVER PROJECT - FEASIBILITY STUDY
Flocculated Tailings
52.6% Solids



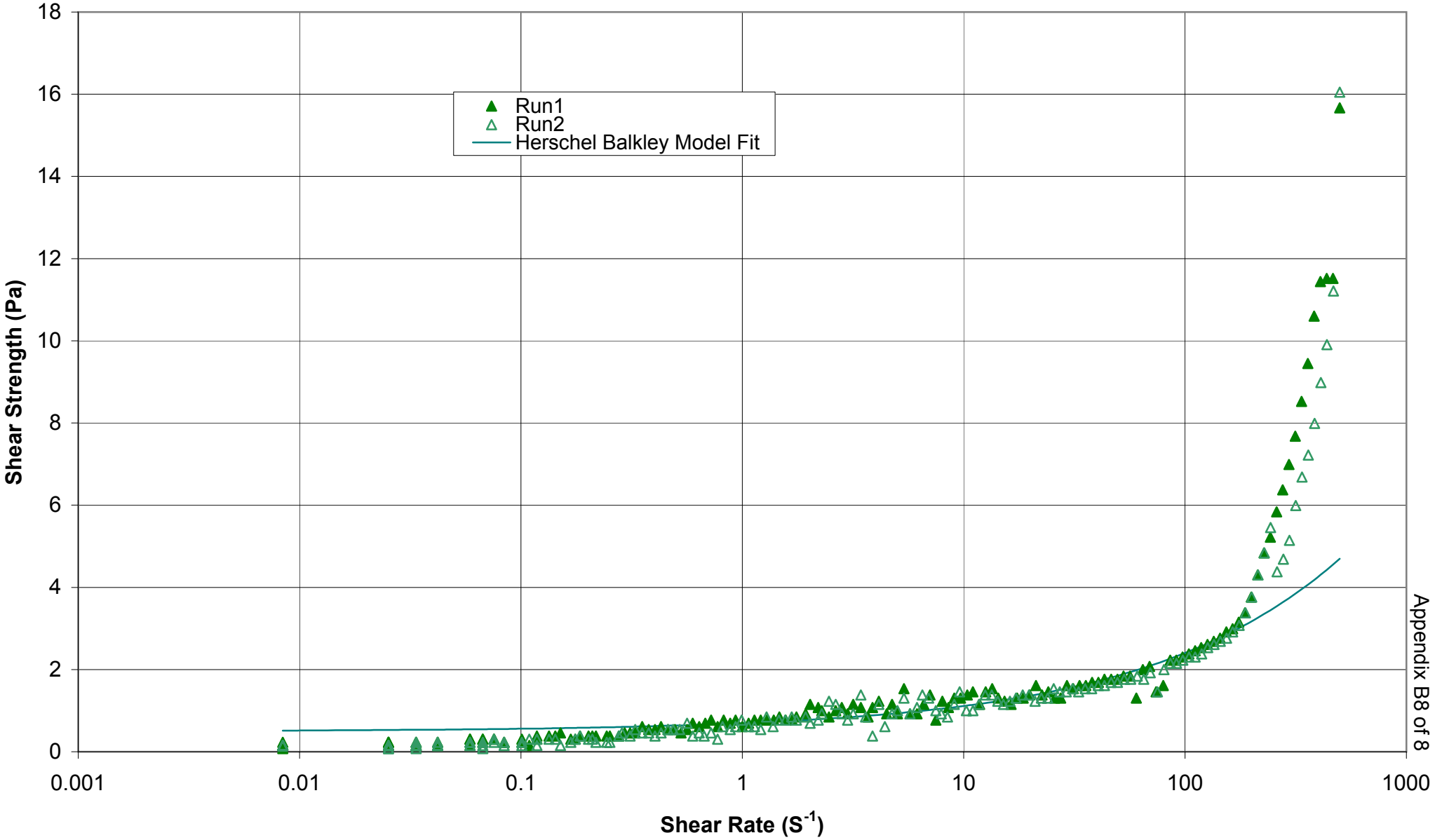
DUGALD RIVER PROJECT - FEASIBILITY STUDY
Flocculated Tailings
52.6% Solids



DUGALD RIVER PROJECT - FEASIBILITY STUDY
Flocculated Tailings
55.1% Solids



DUGALD RIVER PROJECT - FEASIBILITY STUDY
Flocculated Tailings
55.1% Solids



APPENDIX B

TAILINGS CONSOLIDATION MODELLING

This Appendix provides background information regarding the consolidation modelling conducted for the Dugald River TSF Feasibility Study. All section references refer to the relevant sections within the Main Report.

1 BACKGROUND TO COMPUTER MODEL

The traditional methods of analysing the consolidation of soil layers, as originally developed by Terzaghi, are based on the simplifying assumptions that although the permeability and compressibility of the soil may change as it consolidates, the ratio between the two, (i.e. the coefficient of consolidation, c_v), remains constant throughout the application of a load increment and that the change in height of the layer due to consolidation is small enough to be neglected. It is also assumed that the soil is consolidating only under the influence of an applied surcharge load and the self-weight of the soil is ignored.

Within tailings deposits, none of these assumptions is valid. The coefficient of consolidation can vary by more than an order of magnitude over the range of interest, the material may compress to half its original volume, and the self weight of the tailings, far from being able to be ignored, is indeed the consolidating influence.

More recently, differential equations governing non-linear finite strain (or large strain) consolidation have been developed. These equations are general in their application and are capable of handling the self-weight consolidation of low-density slurries with non-linear properties, variable deposition rates, and nominated boundary drainage conditions.

Australian Tailings Consultants has developed a computer model based on a numerical solution of the partial differential equation governing large-strain, self weight consolidation. The technique intrinsically copes with the highly non-linear behaviour of tailings deposited at low solids content and is applicable both during and after tailings deposition. The program has been calibrated against the results of tests presented in published literature, and also using laboratory column tests.

The model has been used on many mining projects over the past 18 years. On the occasions where direct comparison of prediction versus performance has been possible, the results have been satisfactory. Validation of the programs is discussed in *Murphy, S. (1997) "Consolidation of Deep Tailings Deposits – A Case Study". Proc. 1st ANZ Conference on Environmental Geotechnics, Melbourne*.

2 PROGRAM INPUTS

Consolidation modelling has been carried out for the Knapdale Valley TSF, based on the filling relationships described in **Section 8.4**.

The major inputs to the model are:

- Tailings discharge rate
- Discharge solids content

- Sedimented solids content
- Impoundment geometry
- Consolidation parameters
- Boundary conditions

The tailings discharge rate and discharge solids content is summarised in **Section 3**, whilst the sedimented solids content is discussed in **Section 7.1**.

The impoundment geometry must be known in terms of tailings level versus volume and level versus surface area. These relationships were derived from the filling relationships described in **Section 8.4** of the main report, and the beach surface development discussed in **Section 14.1**. The location within the TSF used for the analyses was adjacent to the Main Embankment, where the valley is deepest.

The tailings consolidation parameter inputs are based upon the curves from the laboratory Rowe Cell results, contained in **Appendix A**.

The boundary conditions relate to the impoundment geology and soil types. Effectively two extreme boundary conditions exist:

(i) If the soils or rock underlying the tailings deposit are less permeable than the tailings then consolidation flows will be upwards, seepage is minimal and the boundary condition is an impermeable base.

(ii) At the other extreme, if the soils or rock underlying the tailings are more permeable than the tailings then water can flow out of the base of the deposit. This boundary condition is a permeable base.

The head of water at the base of the deposit can affect the long-term density of the tailings. If the tailings are under-drained such that the drains are maintained at atmospheric pressure then consolidation will ultimately be due to total weight and a more dense deposit will be formed due to seepage forces acting on the tailings.

If the head at the base is equivalent to the head in the decant pond and the base is impermeable then consolidation will be due to buoyant self weight. However, consolidation will be less rapid than for the permeable base case. The final density profile will, however, be the same.

In this case, the expected geotechnical and hydrogeological conditions within the Knapdale valley quartzite suggests a basement permeability of the order of 1×10^{-8} m/sec. The Rowe cell test results indicate that the majority of the tailings deposited will have a permeability of the order of 1×10^{-7} m/sec, and consequently the modelling has conservatively adopted an impermeable base with upward drainage.

The modelled location within the TSF is where the decant pond will form. The adopted boundary condition reflects this, as it assumes the tailings are saturated, and that deposition is essentially sub-aqueous.

APPENDIX C

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Dugald River Zinc Project, Queensland

Geochemistry and Column Leach Testing of Tailings

Final Report - July 2009

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1.0 Introduction

Environmental Geochemistry International Pty Ltd (EGi) was commissioned by Australian Tailings Consultants Pty Ltd to investigate the geochemistry and acid forming characteristics of tailings which will be produced at the Dugald River Project being developed by OZ Minerals Australia Limited. The project will involve underground and possibly open-pit mining of a stratabound, massive lead/zinc deposit hosted within a black slate environment. Ore will be processed on site using conventional flotation technology, producing a lead/zinc/silver concentrate for shipment and a tailings that will be discharge to a tailings storage facility adjoining the plant site.

Sphalerite (ZnS) and galena (PbS) are the main primary sulphides in Dugald River ore but there is also significant pyrrhotite and pyrite which will report mainly with the tailings. The presence of pyrrhotite and pyrite are a potential concern since they are prone to oxidation processes if exposed to atmospheric conditions and could possibly result in tailings acidification in the longer term.

The testing program undertaken by EGi involved initial geochemical characterisation of the tailings solids using static test procedures, then column leach testing to assess the geochemical behaviour over time. The main objectives of the laboratory testing program were as follows:

- to quantify the acid forming characteristics of the tailings and the total capacity for acid generation using static testing procedures;
- to assess the reactivity of any carbonate mineralisation within the tailings and the extent to which such mineralogy might delay the onset of tailings acidification;
- to assess the reactivity of the tailings under controlled laboratory conditions, including the kinetics of sulphide oxidation and the time for acid generation to occur when the tailings are exposed to atmospheric conditions;
- to identify any environmentally significant metals that could mobilise from the tailings in the event that sulphide oxidation and acidification occur.

A two-staged testing program was carried out by EGi. Stage 1 involved static test procedures to determine the elemental composition and acid forming characteristics of the tailings. A preliminary report on the results from the Stage 1 characterisation program was prepared by EGi[1] in September 2008. Stage 2 involved the set-up and operation of a column leach test to assess the longer-term geochemical behaviour of the tailings under controlled atmospheric conditions.

This report presents the methodology, results and findings of the column leach testing program and also includes the initial geochemical characterisation of the ore samples.

[1] **EGi (2008)**. Dugald River Zinc Project: Geochemistry and column testing of tailings - Preliminary report. Prepared for OZ Minerals Australia Limited by Environmental Geochemistry International Pty Ltd, Sydney, September 2008.

2.0 Testing Program

2.1 Sample Preparation

Approximately 5 kg of tailings slurry was provided. A 1 litre sub-sample of the tailings liquor was initially taken for elemental analysis and measurement of pH, alkalinity and electrical conductivity. Most of the remaining excess liquor was then decanted into a separate container and the wet tailings solids were thoroughly mixed and a sub-sample of approximately 3 kg was taken for column leach testing. A second sub-sample of approximately 200 g was also taken for geochemical characterisation. This sub-sample was oven-dried at a low temperature (50 ^{o}C) prior to analysis. The excess tailings liquor and excess tailings solids were subsequently re-combined and sealed within a plastic container for possible future use.

2.2 Testing Program

The tailings samples were assayed for the following parameters:

Tailings Liquors

- pH, alkalinity and electrical conductivity (EC)
- Multi-element analysis

Tailings Solids

- Multi-element composition
- Total sulphur content
- Sulphur and carbon forms
- Maximum potential acidity (MPA)
- Acid neutralising capacity (ANC)
- Carbonate neutralising value (CNV)
- Net acid producing potential (NAPP)
- Net acid generation (NAG) capacity
- Acid buffer characteristic curve

2.3 Analytical Procedures

The analytical methods used are summarised below.

Analysis of Liquors

The pH, alkalinity and electrical conductivity of the tailings liquor were initially measured. A 100 mL sub-sample of liquor was then filtered through a 0.45 µm membrane filter and the filtrate preserved with 1 mL of high purity nitric acid prior to despatch to Australian Laboratory Services (ALS) in Sydney for multi-element analysis. The tailings liquor was analysed for a suite of 32 elements using a combination of inductively

coupled plasma mass spectrometry (ICPMS), inductively coupled plasma optical spectrometry (ICPAES), FIMS mercury analyser, chloride discrete analyser, and fluoride potentiometric titrator.

Multi-Element Analysis of Solids

The multi-element analysis of solids was carried out by Australian Laboratory Services (ALS) in Brisbane using NATA registered procedures. The solids were digested by multi-acid addition (*i.e.* hydrofluoric, nitric, perchloric and hydrochloric acids) and the digest was analysed for a suite of 28 elements using ICPAES. Mercury was also determined using an aqua regia digestion to ensure minimal volatilisation followed by analysis using ICPMS.

Total Sulphur Content

The total sulphur content of the tailings solids was determined by the Leco furnace method. The sulphur assay was carried out by Sydney Environmental & Soil Laboratory Pty Ltd under a quality assurance system certified as complying with ISO 9002.

Sulphur and Carbon Forms

Determination of sulphur and carbon forms within the tailings solids was carried out by Australian Laboratory Services (ALS) in Brisbane and included determination of the following:

- Total sulphur - Measured using a Leco sulphur analyser
- Sulphate-sulphur - The sample was leached with hot HCl to remove acid-soluble sulphates. The amount of sulphate within the leachate was then determined by ICPAES.
- Sulphide-sulphur - Calculated as the difference between Total-S and Sulphate-S values.
- Total carbon - Measured using a Leco carbon analyser
- Organic-carbon - The sample was digested with hot HCl to remove any carbonates, then rinsed with distilled/deionised water to remove any residual chloride. The residual carbon remaining in the residue (i.e. acid-insoluble carbon) was then measured by Leco.
- Inorganic-carbon - Calculated as the difference between Total-C and Organic-C values.

Maximum Potential Acidity

The maximum potential acidity (MPA) is the amount of acid that theoretically could be generated by the sulphur contained within a sample assuming that all the sulphur occurs as reactive pyrite and that there is complete oxidation of the pyrite according to the reaction:

$$FeS_2 + 15/4\ O_2 + 7/2\ H_2O \Rightarrow Fe(OH)_3 + 2\ H_2SO_4$$

The MPA of the tailings was calculated from the sulphur content as follows:

$$MPA\ (kg\ H_2SO_4/t) = \%S \times 30.6.$$

Acid Neutralising Capacity (ANC)

The acid produced by pyrite oxidation will to some extent react with other minerals contained within a sample. This inherent acid buffering is quantified in terms of the ANC which has the same units as MPA. The ANC of the tailings was determined using the Sobek Method. This involved reacting a sub-sample of the tailings with a known amount of acid at around pH 1, then back-titrating to determine residual acid. The amount of acid consumed by the tailings was subsequently calculated by difference.

Carbonate Neutralising Value

The CNV is another measure of the inherent buffering capacity within a sample. The CNV was calculated from the carbonate-C content as follows:

$$CNV\ (kg\ H_2SO_4/t) = Total\ \%\ Carbonate\text{-}C \times 81.67$$

Acid Buffer Characteristic Curve

An acid buffer curve was produced by slow titration of the tailings solids with dilute HCl acid over a period of 24 hours. The curve provides a measure of the buffering provided by more soluble carbonates within a sample, with the readily available fraction typically defined as the amount of acid that was neutralised by a sample above pH 6.

Net Acid Producing Potential

The NAPP is the amount of acid that potentially can be produced by a sample after allowance for the ANC. It is calculated by subtracting the ANC value from the MPA value. If the NAPP is negative then it is likely that the material has sufficient inherent buffer capacity to prevent acid generation. Conversely, if the NAPP is positive then the material may be acid generating.

Net Acid Generation (NAG)

The NAG test is a rapid oxidation procedure for estimating the acid forming potential of a sample. Both acid generation and acid neutralisation reactions can occur simultaneously during a NAG test, hence the end result represents a direct measurement of the net amount of acid that a sample can generate. The test involves reaction of 2.5 g of sample with 250 mL of 15% hydrogen peroxide for 16 hours. Flasks are then gently heated for two hours to decompose any remaining peroxide, and after cooling the pH of the NAG liquor is recorded. If the sample after reaction has a pH of 4.5 or less (*i.e.* NAGpH≤4.5) then it is considered to be acid forming. The actual amount of acidity generated by a sample (expressed as kg H_2SO_4/t) is subsequently determined by titration of the mixture with NaOH to and end-point of pH 7.

Sequential NAG Test

When testing high sulphur samples such as Dugald River tailings a single stage reaction if often not adequate for complete oxidation of all sulphides, and a sequential procedure must be employed (*i.e.* 2.5 g of sample is reacted several times with 250 mL aliquots of 15% hydrogen peroxide). At the end of each stage, the sample is filtered to separate the solids and NAG liquor. The NAG liquor is assayed for pH and acidity, as per a standard NAG test. The solids are recovered and the oxidation process continued using another aliquot of hydrogen peroxide. The overall NAG capacity of the sample is determined by summing the individual acid capacities from each stage.

Modified Sequential NAG Test

A further modification of the NAG test was necessary to clarify the acid forming potential of the Dugald River tailings. Such a modification is sometimes required when testing high sulphide, base metal tailings where there are several different sulphide minerals present. With the modified procedure, the tailings was initially reacted with dilute HCl acid to dissolve any carbonate mineralisation present. The solids were then thoroughly rinsed with deionised water, then reacted with hydrogen peroxide to oxidise all sulphides present. A total of five sequential reaction stages were carried out to ensure complete sulphide oxidation.

Classification of ARD Potential

The acid forming potential of a sample is commonly classified on the basis of the NAPP and NAG test results as either *Non-Acid Forming (NAF) or Potentially Acid Forming (PAF).*

The criteria used to define PAF material are a positive NAPP and a positive NAG. By definition, PAF material has a significant sulphur content, the acid generating potential of which exceeds the inherent acid neutralising capacity of the material. This means there is a risk that such a material could oxidise and generate ARD if exposed to atmospheric conditions.

The criteria used to define NAF material are a negative NAPP and a NAG of zero. By definition, the ANC of a sample classified as NAF is more than adequate to neutralise any acid that theoretically could be produced by any sulphide minerals that may be present, and hence such material would be considered unlikely to produce ARD.

An *uncertain* classification may also be assigned when there is disparity between the NAPP and NAG test results: for example, when the NAPP is positive but the NAG is zero, or when the NAPP is negative but the NAG is positive. In such situations further testwork is required to confirm the acid potential but a tentative classification may be provided based on the results that are available.

3.0 Geochemical Characteristics of Tailings

3.1 Composition of Tailings Liquor

The multi-element composition of the tailings liquor is given in Table 1. The tailings liquor was circum-neutral (pH 7.3) and moderately alkaline (53 mg $CaCO_3$/L). The major ion chemistry was dominated by sulphate (1310 mg/L), chloride (714 mg/L) and sodium (175 mg/L). There were also high concentrations of calcium (75 mg/L), magnesium (31 mg/L) and potassium (44 mg/L).

Amongst the trace elements there was some soluble manganese (1.1 mg/L), lead (0.33 mg/L) and zinc (0.25 mg/L), but the concentrations of other environmentally important elements were relatively low. They included aluminium (0.02 mg/L), cadmium (0.001 mg/L), copper (0.03 mg/L), iron (0.11 mg/L), mercury (<0.0001 mg/L), nickel (0.001 mg/L), selenium (<0.01 mg/L) and zinc (0.02-0.24 mg/L). The low concentrations of dissolved metals are consistent with solubility constraints commonly observed under pH neutral conditions.

3.2 Composition of Tailings Solids

The multi-element results for the tailings solids are given in Table 2. Geochemical Abundance Indices (GAIs) were also calculated for each element and are included in Table 2. The GAI compares the actual concentration of an element in a sample with the median soil[2] abundance for that element. The main purpose of the GAI is to provide an indication of any elemental enrichments that may be of environmental importance. The GAI for an element is calculated as follows:

$$GAI = \log_2 [C / (1.5*S)]$$

where C is the concentration of the element in the sample and S is the median soil abundance for that element. The GAI are truncated to integer increments (0 through to 6, respectively) which correspond to the following enrichment ranges:

- GAI=0 < 3 times median soil abundance
- GAI=1 3 to <6 times median soil abundance
- GAI=2 6 to <12 times median soil abundance
- GAI=3 12 to <24 times median soil abundance
- GAI=4 24 to <48 times median soil abundance
- GAI=5 48 to <96 times median soil abundance
- GAI=6 ≥ 96 times median soil abundance

As a general rule, a GAI of 3 or above is considered significant and may warrant further examination.

[2] References for median soil data were: (1) Bowen, H.J.M. (1997) Environmental Chemistry of the Elements. Academic Press, London. (2) Berkman, D.A. (1976) Field Geologists' Manual, The Australian Institute of Mining and Metallurgy, Parkville, Victoria, Australia

The assay results confirm the presence of high concentrations of sulphur (7.9%), lead (0.99%) and zinc (2.6%) within the tailings solids. The significance of sulphides such as pyrite, sphalerite and galena in relation to the acid forming potential of the tailings is discussed in Section 3.3.

In addition to the resource metals, the tailings were also significantly enriched (*i.e.* GAI≥3) with a number of non-resource elements including antimony (36 mg/kg), arsenic (476 mg/kg), bismuth (5.6 mg/kg), cadmium (54 mg/kg), mercury (0.79 mg/kg), and molybdenum (85 mg/kg). All of these elements are part of the general elemental association reported for hydrothermal sulphide ores, hence their occurrence within the tailings is not remarkable.

There was also minor enrichment (GAI = 1 or 2) relative to background soil with chromium (535 mg/kg), copper (164 mg/kg), nickel (353 mg/kg), selenium (3 mg/kg) and uranium (15 mg/kg).

Metals such as copper, cadmium, nickel and zinc are highly mobile under acidic conditions and elevated concentrations of these metals would be expected within tailings pore water if the tailings were to acidify below pH 6.5. There is also potential for mobilisation of semi-metals such as arsenic and antimony, although the geochemical behaviour of such elements are more difficult to predict as their solubilities in geological systems are usually controlled by adsorption or co-precipitation reactions involving other elements such as iron at lower pHs and calcium at higher pHs.

3.3 Acid Forming Characteristics of Tailings Solids

The acid forming characteristics of the tailings solids are given in Table 3. Overall, the results confirm that the tailing solids have a high pyritic-S content and a correspondingly high capacity for acid generation. Based on the NAPP and NAG test results the Dugald River tailings were classified as PAF.

Sulphur Speciation and Maximum Potential Acidity

Several different procedures were used to assess the acid forming potential of the tailings. The standard acid-base account method assumes that all of the sulphur within a sample occurs as pyrite and that the oxidation of pyrite results in generation of 30.6 kg H_2SO_4/t for every 1 %S present. The total sulphur content of the Dugald tailings was 7.9 %S which corresponds to a maximum potential acidity (MPA) of 241 kg H_2SO_4/t.

The assumption that all sulphur is pyritic is conservative in that some sulphur often occurs as sulphate, which is non-acid forming, or as sulphides that generate less acid than pyrite when oxidised. In the latter case, the oxidation of monosulphides such as sphalerite (ZnS) and galena (PbS) typically has little consequence for the acid potential as both sulphides (like sulphate) generate little or no free acid when oxidised. The oxidation of sphalerite by oxygen, for example, occurs without generating hydrogen ions according to the reaction:

$$ZnS + 2\,O_2 \Rightarrow Zn^{2+} + SO_4^{2-}$$

The multi-element scans on the tailings solids confirms the presence of significant zinc (2.6 %Zn) and lead (0.99 %Pb) which presumably occur primarily as sphalerite and galena, respectively. This means that the standard acid-base account method based on total sulphur content will almost certainly over-estimate the acid potential of the tailings.

An attempt to analytically determine the content of sulphate-S within the tailings was inconclusive. The method used by ALS involved reaction of the tailings with 10% v/v HCl at 115 ^{o}C to dissolve acid-soluble sulphur forms, followed by analysis of the leachate for sulphate by ICPAES. The acid leachable fraction is generally considered to be sulphate-S, but mono-sulphides can also dissolve to varying extents. As such, the method isn't specific for sulphate-S when applied to samples such as Dugald tailings containing sphalerite and galena. The method used by ALS gave an acid-soluble sulphur content of 6.9 %S. Assuming this includes sulphate-S as well as sulphur present as sphalerite and galena, then the pyritic-S content would be only 1.0 %S. Such a low result was considered to be unrealistic for a Zn/Pb flotation tailings with a total sulphur content of 7.9 %S.

A modified version of the net acid generation(NAG) test was subsequently used in an attempt to clarify the speciation of sulphur within the Dugald tailings. As described in Section 2.3, the tailings were initially reacted with dilute HCl acid to dissolve any carbonate mineralisation present. The solids were then thoroughly rinsed with deionised water, then reacted a total of five times with hydrogen peroxide to oxidise all sulphides present. With this modified procedure, the tailings reacted vigorously and the total amount of acid generated was equivalent to 140 kg H_2SO_4/t. Most of this acidity was produced during the first two stages of peroxide oxidation, with the tailings acidifying to around pH 2.5. The amount of pyrite-S that needs to be oxidised to generate 140 kg H_2SO_4/t is approximately 4.6 %S.

The estimated speciation of sulphur within the tailings is given in Table 4, based on the metals assay data and the results of the modified NAG test. It is estimated that approximately 58% of the sulphur occurs as pyrite (or pyrrhotite), 16% as sphalerite, 2% as galena, and 24% as some other non-acid generating forms (possible sulphate).

Acid Neutralisation Characteristics

Any acid produced by oxidation of pyrite or pyrrhotite will to some extent react with other minerals contained within the tailings solids. This inherent acid buffering is commonly quantified in terms of the ANC. The ANC of the Dugald tailings was 54 kg H_2SO_4/t, which is considered to be within the low to moderate range for process tailings.

Carbonate mineralisation is usually the main source of neutralisation capacity. The carbonate-C content of the tailings was determined by difference between total-C and acid insoluble-C assays. The total-C content of the tailings was relatively high at 4.65 %C, but most was acid insoluble (*i.e.* possibly graphitic shale), leaving a *carbonate-C* content of 0.58 %C. This corresponds to a carbonate neutralising value (CNV) of 47 kg H_2SO_4/t, which is only slightly less than the ANC measurement of 54 kg H_2SO_4/t, and suggests that carbonate mineralisation is responsible for most of the neutralisation capacity of the tailings.

Acid Buffer Curve

The neutralising characteristics of the tailings solids were investigated further by defining the acid buffer curve. The buffer curve was produced by slowly titrating the tailings with dilute HCl acid over a period of 24 hours. The curve provides a measure of the buffering provided by more soluble carbonates within a sample, with the readily available fraction typically defined as the amount of acid neutralised by a sample above pH 6.

The buffer curve for the tailings (see figure 1) exhibited a steady downward trend with added acid. The buffer curve was located well above the curve for the blank confirming some neutralisation taking place, but there was no plateau[3] region which typically occurs when a sample contains highly reactive carbonate. Such a plateau is illustrated for calcite in Figure 1.

The amount of acid neutralised by the tailings solids above pH 6 was equivalent to 25 kg H_2SO_4/t, which is just under half of the ANC value of 54 kg H_2SO_4/t. Therefore, although the tailings have the capacity to neutralise up to 54 kg H_2SO_4/t, some of this capacity is not readily available and may only react once the tailings have acidified. This means that the actual capacity of the ANC to delay the onset of acid conditions in the event that the tailings are exposed to atmospheric conditions is likely to be considerably less than what would normally be expected.

Net Acid Producing Potential

The tailings were estimated to have a NAPP of 86 kg H_2SO_4/t. This value was calculated from the total acid generated in the modified NAG test (140 kg H_2SO_4/t) less the ANC value (54 kg H_2SO_4/t).

An acid-base plot for the tailings is also given in Figure 2. The plot illustrates the relationship between pyritic-S content and the acid neutralising capacity. The tailings plot well below the NAPP=O line, consistent with the strongly positive NAPP result.

On the basis of the positive NAPP value, it is expected that Dugald tailings will be potentially acid forming (PAF) and will have a high capacity for acid generation if exposed to atmospheric conditions. The tailings do have some ANC, but the extent of any lag period will depend on the reactivity of the mineralogy contributing to the ANC. The results of static testing suggest that most ANC will not be reactive at circum-neutral pH and if this is the case then a relatively short lag period would be expected.

[3] Calcite and limestone are usually readily available for neutralisation and can maintain a plateau at circum-neutral pH up until almost all of the ANC is consumed. Dolomite is also usually reactive, however the reactivity may decline when there is significant iron substitution, such as with ferroan dolomite. In contrast, magnesite and siderite are usually poorly reactive at circum-neutral pH, and significant dissolution of these carbonates often only occurs under laboratory conditions when the pH drops below about 4.

4.0 Column Leach Test

4.1 Column Setup and Leaching Regime

A column leach test was set-up to assess the geochemical behaviour of the tailings over the longer term. Plate 1 shows the setup of the column leach test. The column comprised approximately 2 kg of tailings within a large Buchner Funnel measuring 260 mm in diameter and 100 mm in height.

The tailings were leached under free-draining conditions on a four-week leach cycle. During the first three weeks of each cycle the tailings were moistened by a once weekly addition of deionised water at a rate equivalent to 100 mL/kg/wk. During this period, heat lamps were positioned above the column to maintain a surface temperature around 30 to 35 ºC for approximately 12 hours each day. This ensured some drying of the tailings between water additions.

On the fourth week of each cycle the tailings were flushed with deionised water at a rate equivalent to 400 mL/kg/wk. Leachate draining from the bottom of the column was collected in a plastic container positioned beneath the funnel over the following three days. The volume of leachate collected was recorded and sub-samples were taken for analysis.

Analysis of leachate included initial measurements of pH, EC and alkalinity or acidity. A subsample was also filtered and preserved prior to despatch to Australian Laboratory Services (ALS) for multi-element analysis. Leachates were analysed by ICP-optical spectroscopy for the following elements: Ag, Al, As, B, Ba, Be, Ca, Cd, Cl, Co, Cr, Cu, F, Fe, Hg, K, Mg, Mn, Mo, Na, Ni, P, Pb, Sb, Se, Si, Sn, SO_4, Sr, Th, U and Zn.

4.2 Column Leach Test Results

The column leach test commenced ran for 52 weeks and comprised a total of 13, four-week leach cycles. The leachate assay results are summarised in Table 5 and shown graphically in a series of plots in Figure 3.

Sulphide Oxidation and Acid Generation

The results indicate two stages with respect to acid generation and acid neutralisation by the tailings under column leach conditions. The first stage extended for approximately 16 weeks and involved a period of rapid acidification of the tailings (Figure 3a). The initial flush from the tailings was alkaline (pH 6.9 and alkalinity of 42 mg $CaCO_3$/L) but within four weeks the tailings acidified to a pH of 3.9, then acidified further to a minimum of pH 3.5 after 16 weeks. The acidities of leachates collected during the first 16 weeks ranged between 118 and 154 mg $CaCO_3$/L (Figure 3c).



Plate 1: Column leach test setup

The rapid acidification of the tailings seemingly contrasts with the tailings having a moderately high ANC of 54 kg H_2SO_4/t. The absence of a lag period means the carbonates that contribute to ANC were not sufficiently reactive to fully neutralise all the acid generated by the high rate of sulphide oxidation occurring during the first few months of the column test. The shape of the tailings acid buffer characteristic curve (see Figure 1 in Section 3.3) also inferred that some of the ANC of the tailings might not be readily-available for buffering at near neutral pH.

Following Week 16, the pH of leachate from the tailings increased again, reaching pH 6.7 by Week 40 and thereafter appearing to stabilise at around pH 7. The acidity of leachate decreased accordingly, from around 150 mg/L at Week 16, down to around 20 to 25 mg/L in Weeks 24 to 36. Thereafter leachate from the tailings was considered to be alkaline, with measured values ranging from 43 and 164 mg $CaCO_3$/L.

The return to pH neutrality indicates that there was still significant ANC remaining in the tailings during the later half of the test. The major reason for the change would appear to be a slowing in the rate of sulphide oxidation to the point where the rate of acid generation did not exceed the reactivity of the ANC. The relative decrease in sulphide oxidation rate is manifest by the change in sulphate leaching (Figure 3q). During the initial stages of the test the concentration of sulphate exceeded 5000 mg/L but by Week 52 the concentration had decreased to 1640 mg/L (Figure 3q).

Figure 4 shows the carbonate/sulphate molar ratio for leachate during the column test, where carbonate leaching is indirectly estimated from the concentrations of calcium (Figure 3g) and magnesium (Figure 3l). As calcium concentrations were more ten times greater than magnesium it can be assumed that most of the buffering was provided by the dissolution of calcium minerals. The carbonate/sulphate molar ratio provides an indication of whether there is preferential leaching of sulphate relative to carbonate (ratio less than 1), or visa-versa (ratio exceeds 1). At the start of leaching the molar ratio was only 0.3, signifying a strong preferential leaching of sulphate, but the ratio increased almost linearly during the test and was greater than 0.8 after 12 months.

The change in the carbonate/sulphate molar ratio was almost entirely due to a decrease in the rate of leaching of sulphate produced by sulphide oxidation. In contrast to sulphate, there was only a small decline in the rate of leaching of calcium during the 52 weeks of testing. The concentration of calcium was at a maximum of 737 mg/L in Week 8 but from Week 20 onward the concentration typically fluctuated between 500 to 600 mg/L (Figure 3g). This pattern of calcium leaching suggests there was a relatively steady rate of acid buffering during the test.

It is worth noting that the concentrations of sulphate and calcium in leachate during the first six months of the column test markedly exceed the solubility index of gypsum, which suggests precipitation of gypsum was likely occurring within the tailings during that period. This is a common occurrence with high sulphide materials that also have a moderate to high calcium carbonate (*i.e.* some sulphate released by oxidation reacts with calcium released by in-situ acid neutralisation). By week 24 the solubility index for gypsum was very close to 1, suggesting that the leachate quality was in equilibrium with gypsum solubility, and by week

52 the solubility index was slightly negative, suggesting that the release of sulphate and calcium were probably not limited by gypsum solubility during the latter half of the test.

Intrinsic Oxidation Rate

The intrinsic oxidation rates (IORs) for the tailings during the test were estimated from the sulphate release rates. The IORs ranged from a very high rate of $7x10^{-7}$ kg O_2/m^3/sec when the tailings were first exposed to atmospheric conditions, decreasing to a more moderate rate of $1x10^{-7}$ kg O_2/m^3/sec after 52 weeks of exposure and leaching.

These IORs assume that all the sulphate in leachate was generated from sulphide oxidation and that all sulphate produced from oxidation was flushed from the tailings column. This may not necessarily be the case, given that the results of static testing (Table 4) suggest the presence of some non-sulphide sulphur (possible anhydrite or gypsum) within the original tailings. Also, as noted above, it is possible that some gypsum may have actually formed within the tailings during the initial stages of the column test. Such processes complicate the estimation of sulphide oxidation rate and can lead to both over-estimation and under-estimation of IOR. However, it is reasonable to expected that sulphate release rates observed in the latter half of the test were closely aligned to sulphide oxidation.

Residual ANC

As noted above, the re-buffering of tailings back to pH neutral indicates significant ANC still remained after 52 weeks. The combined leaching of calcium and magnesium during the 52 week test equates to an average decrease in tailings ANC of approximately 4 kg H_2SO_4/t, which is a relatively small percentage of the initial ANC of 54 kg H_2SO_4/t measured using the Sobek method. As a further check, a sub-sample of the top few centimetres of tailings from the column was taken for measurement of residual ANC after 52 weeks. The ANC of the surface tailings was 28 kg H_2SO_4/t, which is lower than expected[4] based on calcium and magnesium leaching, but still indicative of a moderately high ANC remaining in the tailings.

Residual Sulphur

The total amount of sulphate released from the tailings over the 52 week test period corresponds to a reduction in the sulphur content of the tailings of 0.69 %S. This amount is less than 10% of the initial total sulphur content of 7.9 %S.

If all of the sulphur released from the tailings was the direct result of pyrite oxidation then the amount of acid generated by that sulphur would have equated to 21 kg H_2SO_4/t, which is approximately 15% of the total acid generation potential of 140 kg H_2SO_4/t predicted using the modified NAG test (see Table 3 and discussion in Section 3.3). Notwithstanding effects of gypsum precipitation/dissolution, the results indicate a relatively

[4] Note: the sub-sample taken for measurement of residual ANC was from the upper few centimetres of the column where it might be expected that rates of sulphide oxidation, acid generation and acid neutralisation would be greatest. The release of calcium from the tailings is also influenced by the formation of gypsum within the tailings.

small percentage of sulphide oxidation (albeit the most highly reactive fraction) during the 52 weeks and hence a high acid potential still remaining within the tailings of exposure to atmospheric conditions.

A NAG test carried out on a sub-sample of near surface tailings confirmed that the tailings after 52 weeks were still PAF. The sub-sample had a NAG value of 119 kg H_2SO_4/t, which is consistent with the initial NAG value and the estimate of acid generation occurring within the test period.

Based on the rate of sulphate leaching in Week 52, it is estimated that the tailings could remain pH neutral for another 7 years (assuming an effective residual ANC of at least 30 kg H_2SO_4/t) and that following this lag stage the tailings could re-acidify and continue to generate sulphate rich leachate for at least a further 40 years.

Metals Leaching

In addition to sulphate, there were high rates of release of a number of environmentally important metals from the tailings, especially during the first 16 weeks of the test when the tailings were generating acidic leachate. They included zinc (13 to 75 mg/L), manganese (7 to 95 mg/L), lead (0.25 to 1.4 mg/L), and cadmium (0.12 to 0.55 mg/L). These concentrations are typically one or two orders-of-magnitude higher than the corresponding metal concentrations reported for the tailings liquor and thereby represent significant mobilisation from the solid phase as a consequence of sulphide oxidation and the initial acidification of the tailings. There was an initial flush of zinc during the first 12 weeks, then the concentration in leachate remained relatively steady at around 20 mg/L (Figure 3r). The concentrations of manganese (Figure 3m) and lead (Figure 3p) typically trended down with time.

The total amount of zinc leached over the 52 weeks was equivalent to 63 mg/kg. Although this signifies a comparatively high leaching rate, it represents less than 0.3% of the original zinc content of the tailings of 2.6 %Zn. As such, the leaching of zinc from Dugald tailings would be expected to continue into the long-term.

In contrast, there was only minimal leaching of iron (Figure 3j) and aluminium (Figure 3d) from the tailings. Both these metals commonly occur in acid drainage from sulphidic mine waste. In the case of Dugald tailings, it is likely that the iron released during pyrite oxidation was re-precipitated within the column as iron oxy-hydroxides, which are only sparingly soluble above pH 3.5.

There was also minimal leaching of antimony (<0.001-0.011 mg/L), arsenic (<0.001-0.005 mg/L), mercury (≤0.0001 mg/L) and molybdenum (<0.001-0.003 mg/L) even though these elements were identified as being significantly enriched within the tailings solids. As noted in Section 3.2, the solubilities of semi-metals such as arsenic and antimony are difficult to predict as they are often controlled by adsorption or co-precipitation reactions involving other elements such as iron.

Other elements that were not mobilised to any significant extent included cobalt (0.005-0.02 mg/L), nickel (<0.005-0.013 mg/L), selenium (≤0.01 mg/L) and tin (≤0.001 mg/L).

5.0 Summary

This report presents the results of geochemical testing of a sample representing tailings that will produced at the Dugald lead/zinc project in Queensland. The results of static testing indicated that the tailings were potentially acid forming, with a high sulphide content comprising mainly pyrite (or pyrrhotite) as well as some sphalerite and galena not recovered during processing. The net acid producing potential (NAPP) of the tailings was estimated to be approximately 86 kg H_2SO_4/t, which represents a high capacity for acid generation if the tailings were to be exposed to atmospheric conditions within the tailings storage facility.

The ANC of the tailings was 54 kg H_2SO_4/t, which is moderately high and would normally be expected to delay the onset of acid conditions by at least several years. However, the column test results indicate that the reactivity of some sulphides within the tailings is of such high magnitude that the rate of acid generation when tailings are first exposed to atmospheric conditions exceeds the reactivity of the carbonates contributing to the ANC. Within the first four weeks of column testing the tailings acidified to pH 3.9, and reached a minimum pH of 3.5 after 16 weeks. Thereafter, the pH of leachate from the tailings increased again, eventually stabilising at around pH 7 toward the end of the 52 week test period.

The return to pH neutrality can primarily be attributed to a slowing in the rate of sulphide oxidation to the point where the rate of evolution of acid was compatible with the reactivity of the ANC. However, given that the tailings sample tested had strongly positive NAPP and NAG values it is expected that the tailings would eventually re-acidify with long-term exposure to atmospheric conditions. Based on the rate of sulphate leaching in Week 52, it is estimated that the tailings could remain pH neutral for at least another 7 years (assuming an effective residual ANC of at least 30 kg H_2SO_4/t) and that following this lag stage the tailings would be likely to re-acidify to less than pH 4 and continue to generate leachate with elevated sulphate for a number of decades.

The main environmentally important metals that were released from the tailings during the column leach test were zinc (13 to 75 mg/L), manganese (7 to 95 mg/L), lead (0.25 to 1.4 mg/L), and cadmium (0.12 to 0.55 mg/L). These concentrations are typically one or two orders-of-magnitude higher than the corresponding metal concentrations reported for the tailings liquor and thereby represent significant mobilisation from the solid phase as a consequence of sulphide oxidation and the initial acidification of the tailings.

The results indicate that the Dugald River tailings represented by the sample provided are likely to generate some acid when initially exposed to atmospheric conditions but will recover to near pH neutral conditions within months. This behaviour has been observed with zinc tailings at other sites and it is recommended that monitoring and control plans are in place to prevent any adverse impacts from ARD generation.

It is recommended that monitoring of pH and alkalinity throughout the decant/tailings pond system is carried out on a regular basis and that the dissolved alkalinity within the decant/tailings pond is maintained at not less than 30 mg $CaCO_3$/L. This should ensure there is adequate buffering capacity within the water to mitigate any ARD inputs from beached tailings without adverse impacts on water quality. A decreasing

alkalinity concentration can provide an early warning of a pending pH change. For example, when dissolved alkalinity is low (less than 10 mg $CaCO_3$/L) there are likely to be wide variations in pH and small inputs of acid can result in a rapid decrease in pH from near neutral to less than 4. Therefore alkalinity is often a better parameter than pH for timely recognition of diminishing buffer capacity in decant/tailings pond system and can be used to trigger mitigation actions when necessary. Mitigation actions to raise dissolved alkalinity could include direct application of lime to the pond, addition of reactive limestone to ore feed or tailings discharge, or broadcast application of crushed limestone directly onto beaches exhibiting signs of sulphide oxidation and acid generation. The limestone requirement will be site specific and will need to be determined by field trials but for planning purposes rates around 3 to 5 kg $CaCO_3$/t are generally sufficient when added to ore or tailings, or 20 to 50 tonnes/hectare when applied to beaches.

Tables and Figures

Table 1: Composition of Dugald tailings liquor

Parameter	Unit	Limit of Reporting	Result
pH		0.10	7.3
Alkalinity	mg/l	1	53
EC	µS/cm	0.001	767
SO4	mg/l	1	1310
Cl	mg/l	1	714
Ca	mg/l	1	75
K	mg/l	1	44
Mg	mg/l	1	31
Na	mg/l	1	175
Ag	mg/l	0.001	0.04
Al	mg/l	0.01	0.02
As	mg/l	0.001	<0.001
B	mg/l	0.05	0.13
Ba	mg/l	0.001	0.098
Be	mg/l	0.001	<0.001
Cd	mg/l	0.0001	0.0011
Co	mg/l	0.001	0.002
Cr	mg/l	0.001	<0.001
Cu	mg/l	0.001	0.03
F	mg/l	0.1	2.4
Fe	mg/l	0.05	0.11
Hg	mg/l	0.0001	<0.0001
Mn	mg/l	0.001	1.1
Mo	mg/l	0.001	0.012
Ni	mg/l	0.001	0.001
P	mg/l	1	<1
Pb	mg/l	0.001	0.33
Sb	mg/l	0.001	0.018
Se	mg/l	0.01	<0.01
Si	mg/l	0.1	2.8
Sn	mg/l	0.001	0.001
Sr	mg/l	0.001	0.97
Th	mg/l	0.001	<0.001
U	mg/l	0.001	<0.001
Zn	mg/l	0.005	0.25

< element at or below limit of reporting.

Table 2: Composition of Dugald tailings solids

Element	Unit	Solids Composition	Median Soil Content	Geochemical Abundance Indices
Ag	mg/kg	34	0.1	6
Al	%	5.1	7.1	0
As	mg/kg	476	6	5
Ba	mg/kg	160	500	0
Be	mg/kg	3.6	6	0
Bi	mg/kg	5.6	0.2	4
Ca	%	2.1	1.5	0
Cd	mg/kg	54	0.4	6
Co	mg/kg	20	8	0
Cr	mg/kg	535	70	2
Cu	mg/kg	164	30	1
Fe	%	8.0	4.0	0
Hg	mg/kg	0.79	0.06	3
K	%	4.2	1.4	1
Mg	%	0.63	0.5	0
Mn	mg/kg	2930	1000	0
Mo	mg/kg	85	2	4
Na	%	0.27	0.50	0
Ni	mg/kg	353	50	2
P	mg/kg	1250	800	0
Pb	mg/kg	9890	35	6
S	%	7.9	0.07	6
Sb	mg/kg	36	1	4
Se	mg/kg	3.0	0.4	2
Sn	mg/kg	2.9	4	0
Sr	mg/kg	359	250	0
Th	mg/kg	7.2	9	0
U	mg/kg	15	2	2
Zn	%	2.6	0.009	6

Median soil data from:

Bowen, H.J.M. (1979) Environmental Chemistry of the Elements. Academic Press, London.

Berkman, D.A. (1976) Field Geologists' Manual, The Australian Institute of Mining and Metallurgy, Parkville, Victoria, Australia.

* Geochemical Abundance Indices (GAI)

GAI=0 represents <3 times median soil content
GAI=1 represents 3 to 6 times median soil content
GAI=2 represents 6 to 12 times median soil content
GAI=3 represents 12 to 24 times median soil content
GAI=4 represents 24 to 48 times median soil content
GAI=5 represents 48 to 96 times median soil content
GAI=6 represents more than 96 times median soil content

Table 3: Acid forming characteristics of Dugald tailings solids

Parameter	Unit	Dugald Tailings
Total Sulphur	%S	7.9
- Acid Soluble Sulphur *	%S	6.9
- Acid Insoluble Sulphur *	%S	1.0
Total Carbon	%C	4.7
- Acid Insoluble Carbon	%C	4.1
- Carbonate Carbon	%C	0.6
Carbonate Neutralising Value	kg H2SO4/t	47
Acid Neutralising Capacity	kg H2SO4/t	54
Maximum Potential Acidity based on Total-S	kg H2SO4/t	241
Total Acid Generated using modified NAG test	kg H2SO4/t	140
Net Acid Producing Potential	kg H2SO4/t	86
ARD Classification	kg H2SO4/t	Potentially Acid Forming

Footnotes:

* Note: These results may not accurately reflect sulphate and sulphide forms.
Refer to Section 3.3 for discussion and clarification of sulphur forms.

Methods:

Total Sulphur Content -- determined by Leco analyser
HCl Acid Soluble Sulphur - Sulphur leached with HCl acid
Acid Insoluble Sulphur - difference between Total-S and Acid Soluble-S
Total Carbon - determined by Leco analyser
Acid Insoluble Carbon - residual carbon after leaching with HCl acid
Carbonate Carbon - difference between Total Carbon and Acid Insoluble Carbon
Carbonate-C Neutralising Value (CNV) - calculated from the Carbonate-C value
Acid Neutralising Capacity (ANC) - determined using the Sobek method
Maximum Potential Acidity (MPA) - calculated from Total-S
Total Acid Generated (TAG) - measured using modified NAG procedure
Net Acid Producing Potential (NAPP) - calculated from the TAG and ANC

Table 4: Estimation of sulphur forms in Dugald tailings solids

Sulphur Forms	Unit	Dugald Tailings
Total Sulphur	%S	7.88
Sulphur as ZnS	(%S)	1.28
Sulphur as PbS	(%S)	0.15
Pyritic-S	(%S)	4.58
Other S (e.g. sulphate)	(%S)	1.88

Footnotes:

Sulphur as PbS - Calculated from Pb assay [0.99% Pb x 32.1 / 207.2]
Sulphur as PbS - Calculated from Zn assay [2.6 %Zn x 32.1 / 65.4]
Pyritic-S - Calculated from total acid generated in modified NAG test [140 / 30.6]
Other-S - Calculated by difference

Table 5: Results of column leach testing of Dugald tailings

Parameters		Tailings Liquor	Week													
			0	4	8	12	16	20	24	28	32	36	40	44	48	52
Volume	ml	-	320	345	353	360	364	365	366	376	380	382	376	386	390	422
pH	-	7.3	6.9	3.9	3.8	3.6	3.5	3.8	4.1	4.3	4.6	5.7	6.7	6.9	7.0	6.9
EC	µS/cm	0.77	1160	1990	1810	1840	1460	1360	1290	1280	1250	1140	1780	1960	2320	1890.00
Alkalinity	mg/l	53	42	-	-	-	-	-	-	-	-	-	43	164	118	89
Acidity	mg/l	-	-	153	153	154	118	69	24	21	22	25	-	-	-	-
Ag	mg/l	0.04		0.017	<0.001	<0.001	<0.010	0.012	<0.010	<0.005	0.006	0.013	<0.001	<0.001	<0.001	<0.001
Al	mg/l	0.02		0.03	0.03	0.06	0.07	0.04	0.01	0.01	0.02	0.02	0.02	<0.01	<0.01	0.01
As	mg/l	<0.001		0.003	0.003	0.003	0.004	0.004	<0.001	0.001	0.005	0.002	0.001	<0.001	<0.001	<0.001
B	mg/l	0.13		0.33	0.79	1.5	2.0	2.1	1.9	1.9	1.9	1.7	1.2	1.2	0.9	0.9
Ba	mg/l	0.098		0.029	0.032	0.030	0.028	0.025	0.024	0.017	0.021	0.018	0.026	0.016	0.015	0.014
Be	mg/l	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ca	mg/l	75		684	737	728	688	607	574	561	581	560	482	585	558	540
Cd	mg/l	0.0011		0.12	0.55	0.52	0.44	0.34	0.32	0.39	0.44	0.36	0.26	0.25	0.24	0.28
Cl	mg/l	714		1960	1130	2090	1340	837	378	316	205	372	33	18	8	4
Co	mg/l	0.002		0.017	0.015	0.020	0.012	0.008	0.005	0.008	0.008	0.007	0.009	0.009	0.010	0.013
Cr	mg/l	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cu	mg/l	0.03		0.02	0.04	0.19	0.09	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01
F	mg/l	2.4		2.2	2.1	2.1	2.7	2.8	2.6	2.6	4.1	3.3	2.7	3.1	2.9	2.7
Fe	mg/l	0.11		0.41	0.20	<0.50	0.71	<0.50	<0.05	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Hg	mg/l	<0.0001		<0.0001	<0.0010	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
K	mg/l	44		132	102	72	63	49	24	23	27	23	21	22	18	15
Mg	mg/l	31		86	39	24	19	17	8	11	12	12	11	17	13	12
Mn	mg/l	1.1		88	95	59	42	31	25	29	30	21	13	9	7	9
Mo	mg/l	0.012		0.003	0.003	0.003	0.002	0.001	0.003	0.001	<0.001	0.001	0.001	0.002	0.002	0.002
Na	mg/l	175		265	154	160	237	308	124	179	186	191	177	183	101	73
Ni	mg/l	0.001		0.007	0.013	0.012	0.009	<0.005	<0.005	<0.005	<0.005	<0.005	0.005	<0.005	<0.005	<0.005
P	mg/l	<1		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Pb	mg/l	0.33		1.4	1.3	0.99	1.1	0.86	0.45	0.69	1.01	0.73	0.38	0.32	0.29	0.25
Sb	mg/l	0.018		0.006	0.006	0.005	0.011	0.004	0.005	0.002	0.003	0.002	0.001	<0.001	0.001	<0.001
Se	mg/l	<0.01		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Si	mg/l	2.8		3.7	3.6	3.8	5.9	5.8	6.6	5.0	3.8	3.4	2.6	2.5	2.3	2.0
Sn	mg/l	0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SO4	mg/l	1310		5720	5500	4580	4220	3620	2220	2340	2650	2170	1780	1910	1680	1640
Sr	mg/l	0.97		2.8	2.5	2.7	2.5	2.5	1.9	2.4	3.0	2.9	2.6	3.3	3.0	2.7
Th	mg/l	<0.001		<0.001	<0.001	<0.001	0.02	<0.001	<0.001	0.004	<0.001	0.002	0.003	<0.001	<0.001	<0.001
U	mg/l	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zn	mg/l	0.25		50	75	55	28	16	13	21	22	18	15	14	17	21.8

Not Analysed

Note: < indicate that the concentration is less than the limit of detection

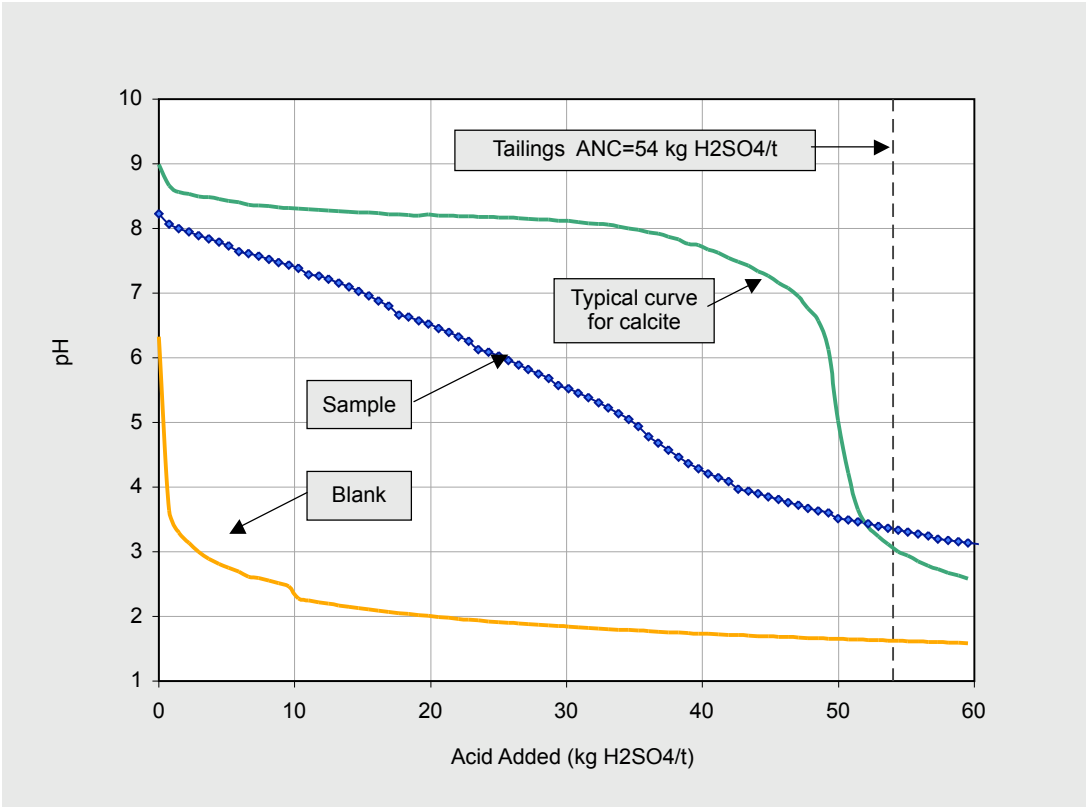


Figure 1. Acid buffer characteristic curve for Dugald tailings

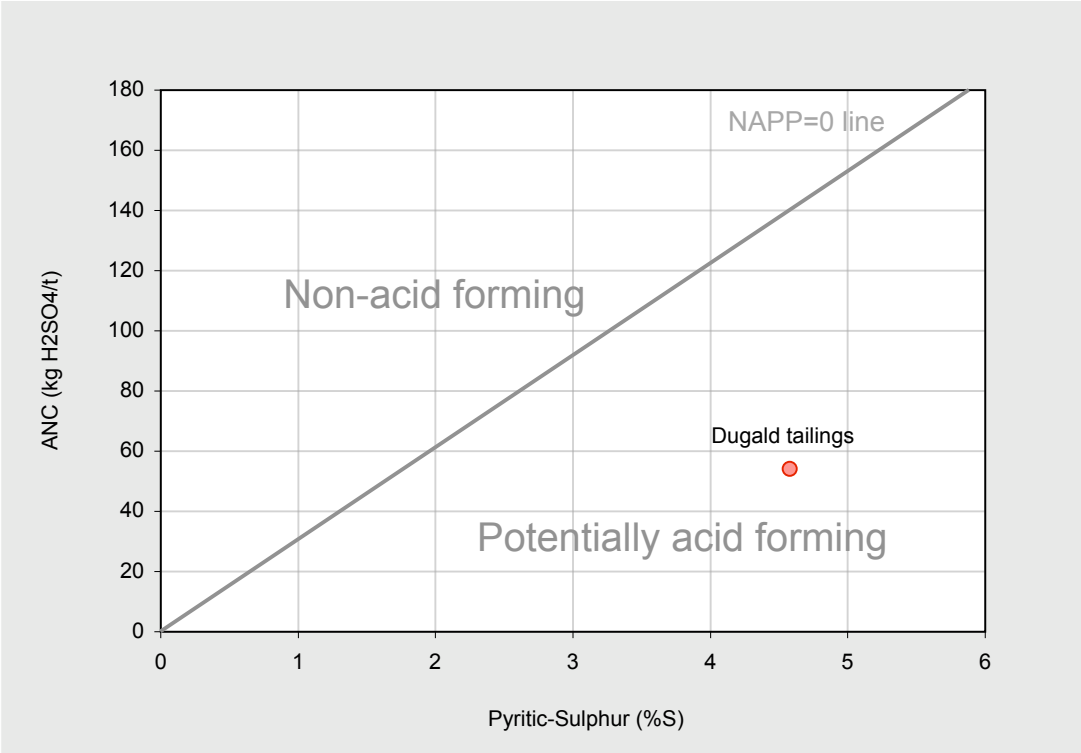


Figure 2. Acid-base account plot for Duglad tailings

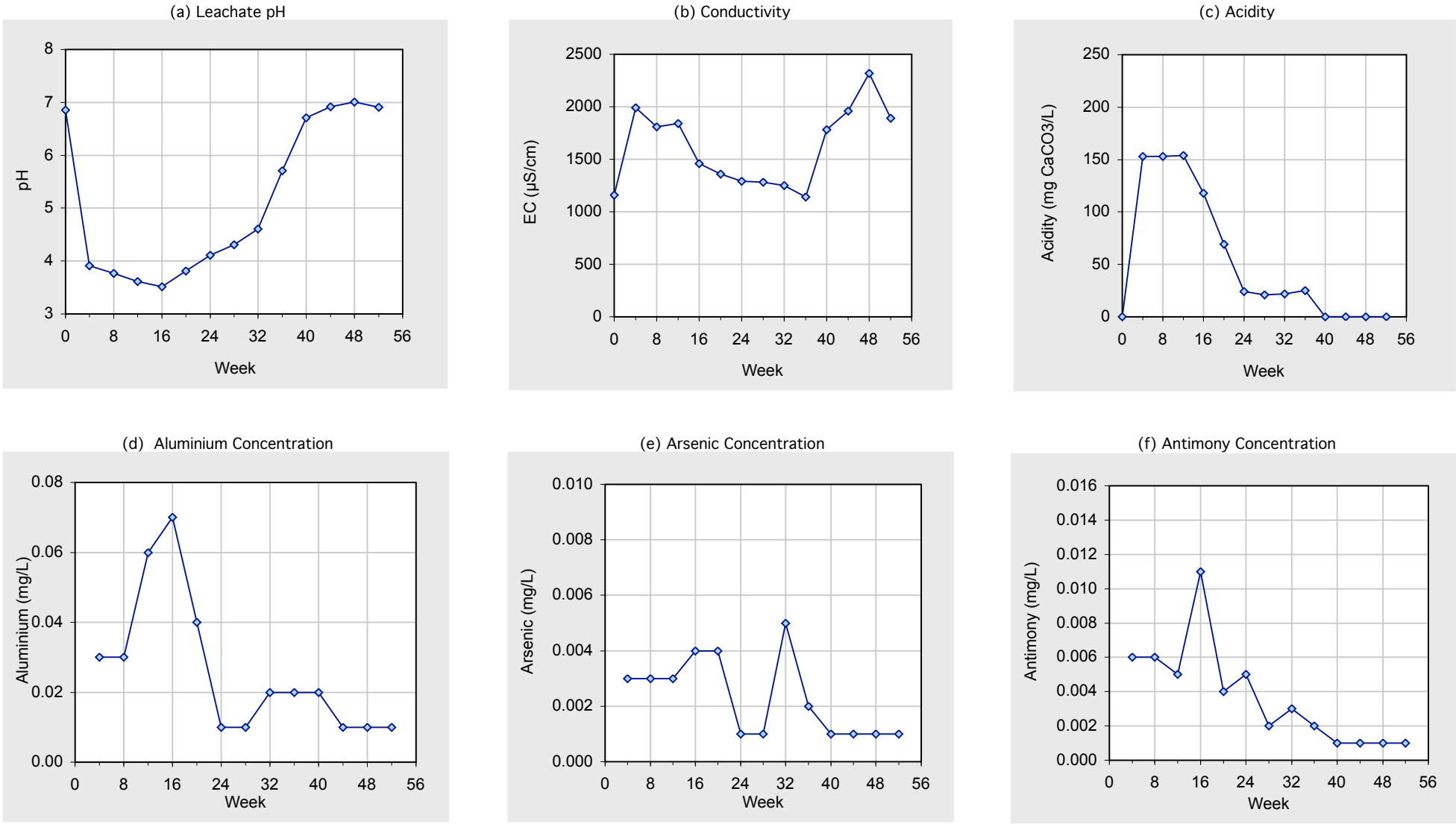
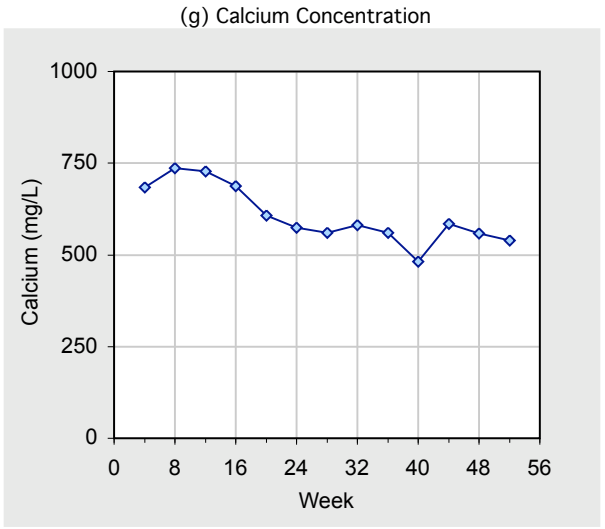
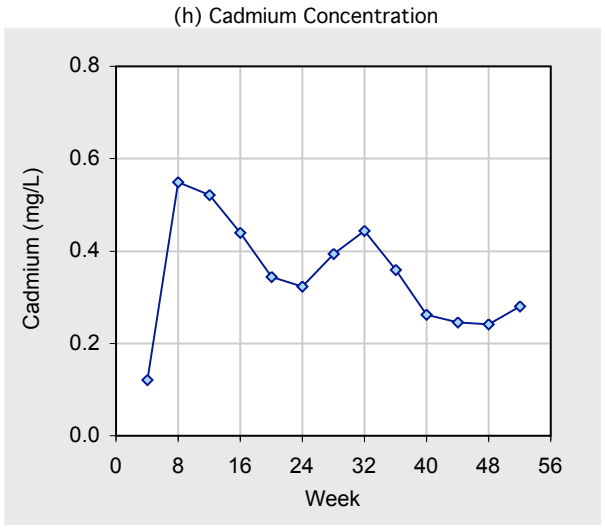
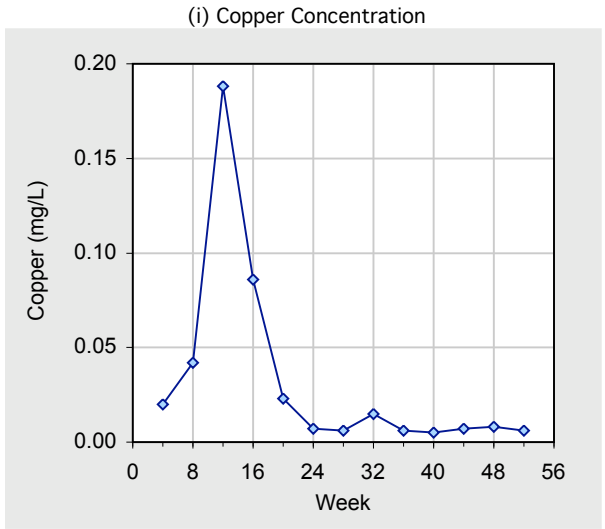
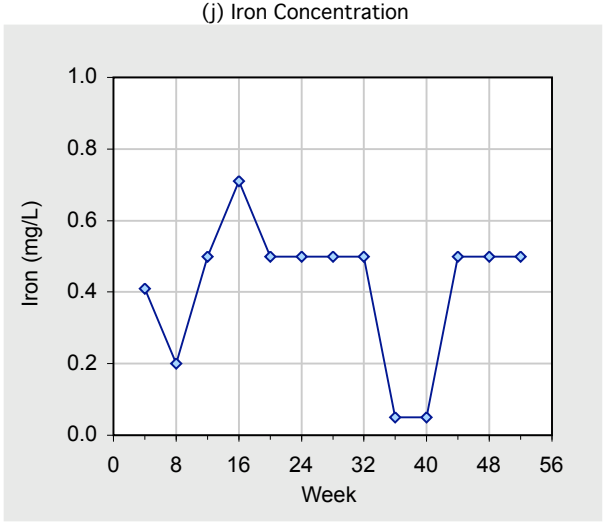


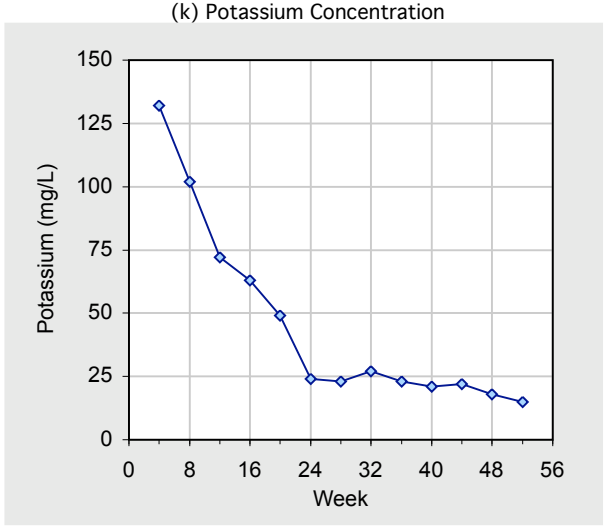
Figure 3. Leachate composition versus time plots for Dugald tailings











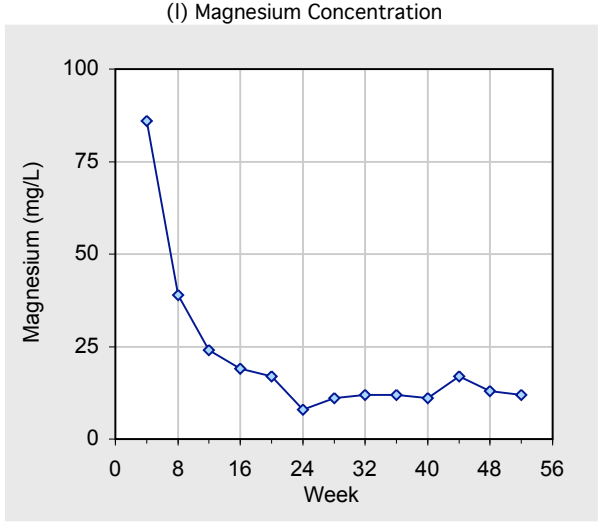
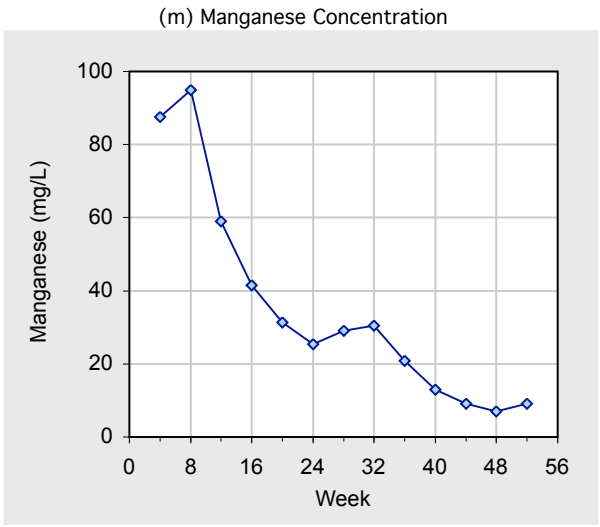
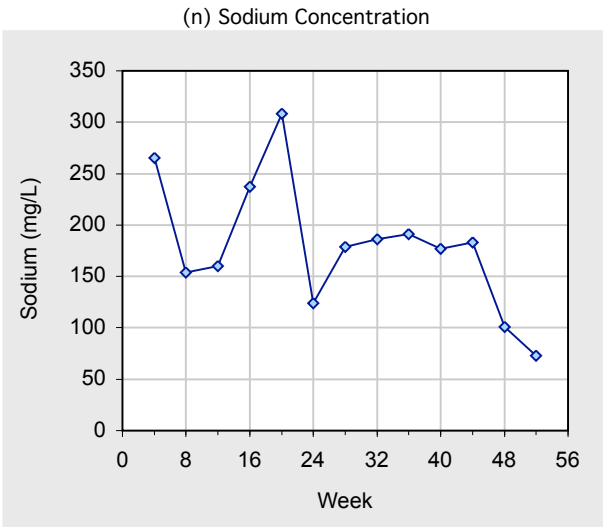
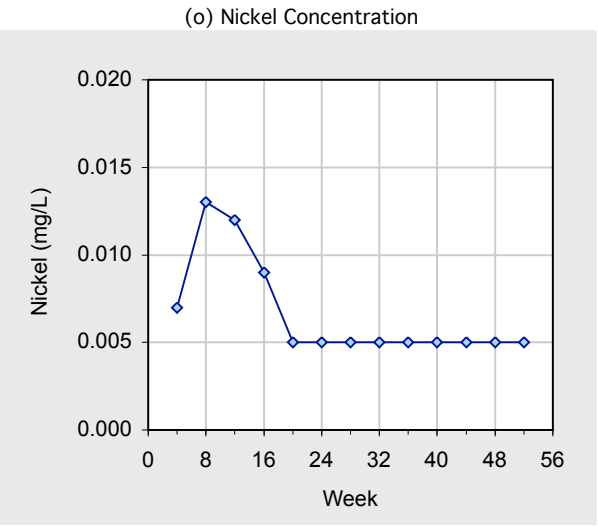
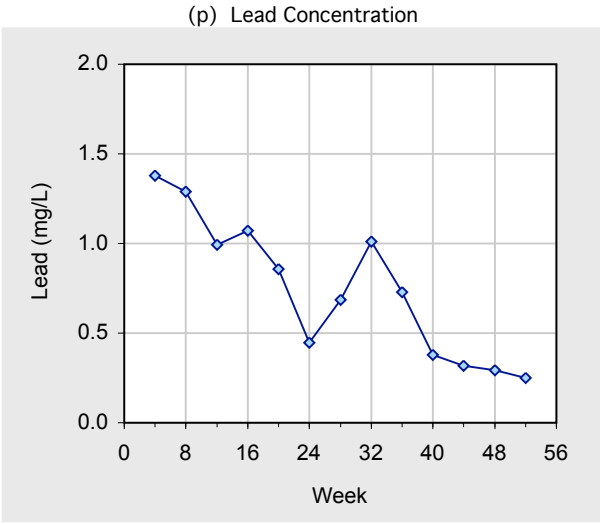


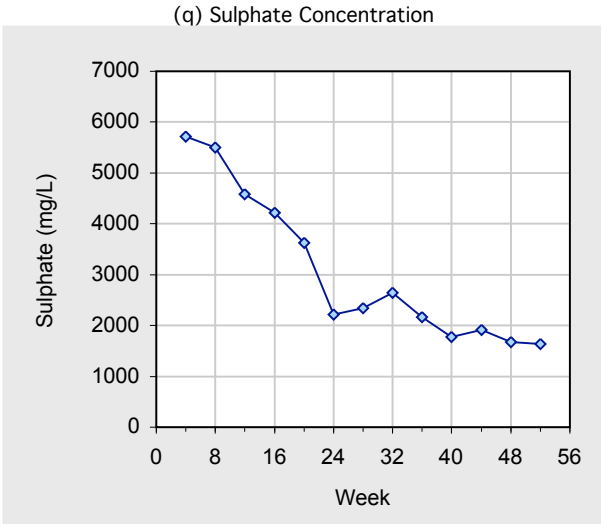
Figure 3. *Continued*











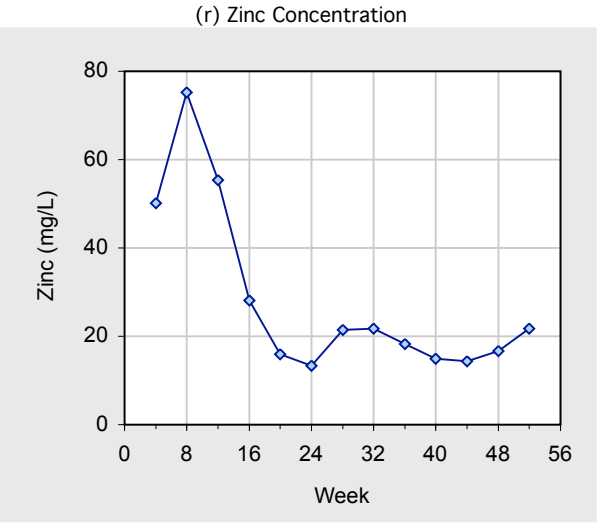


Figure 3. *Continued*

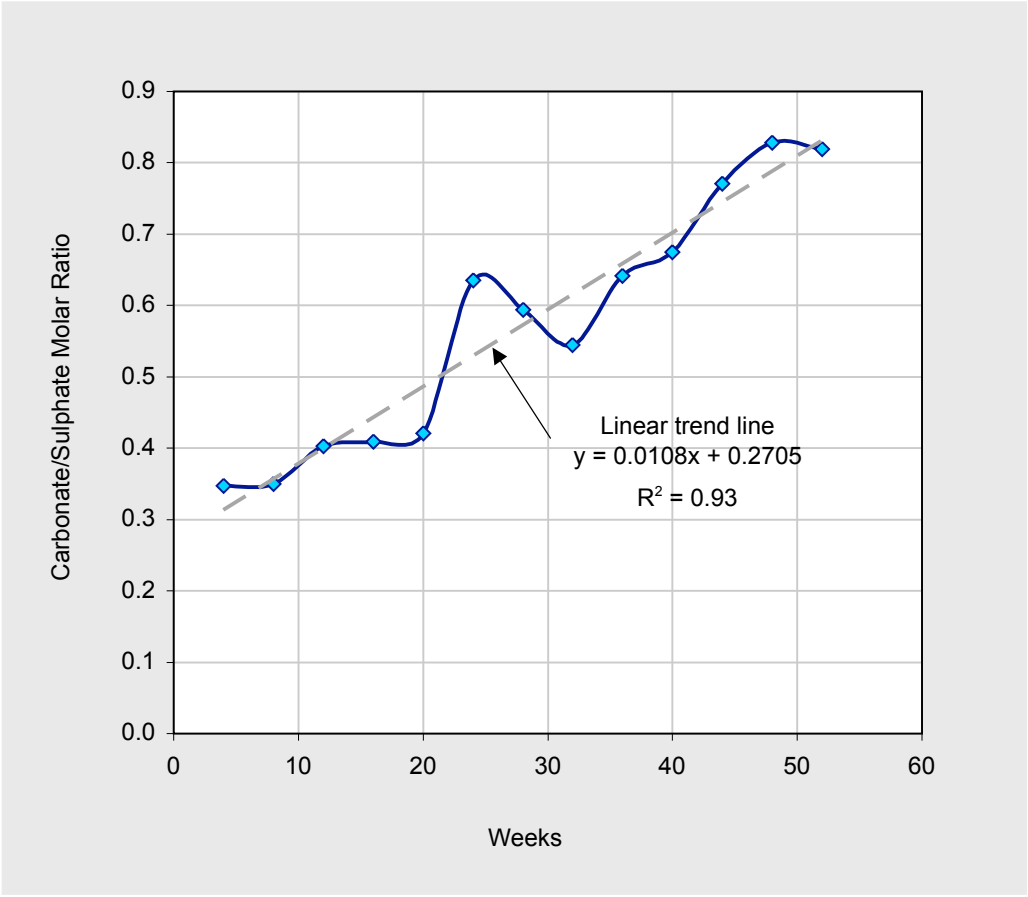
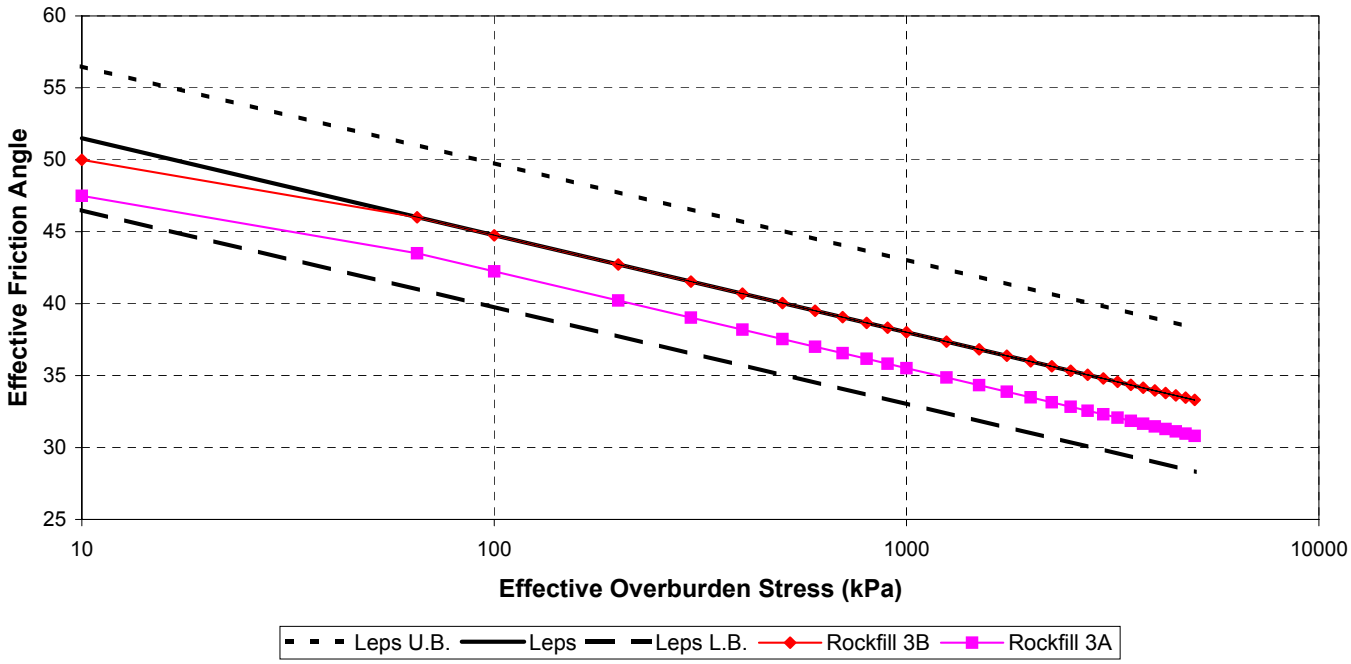
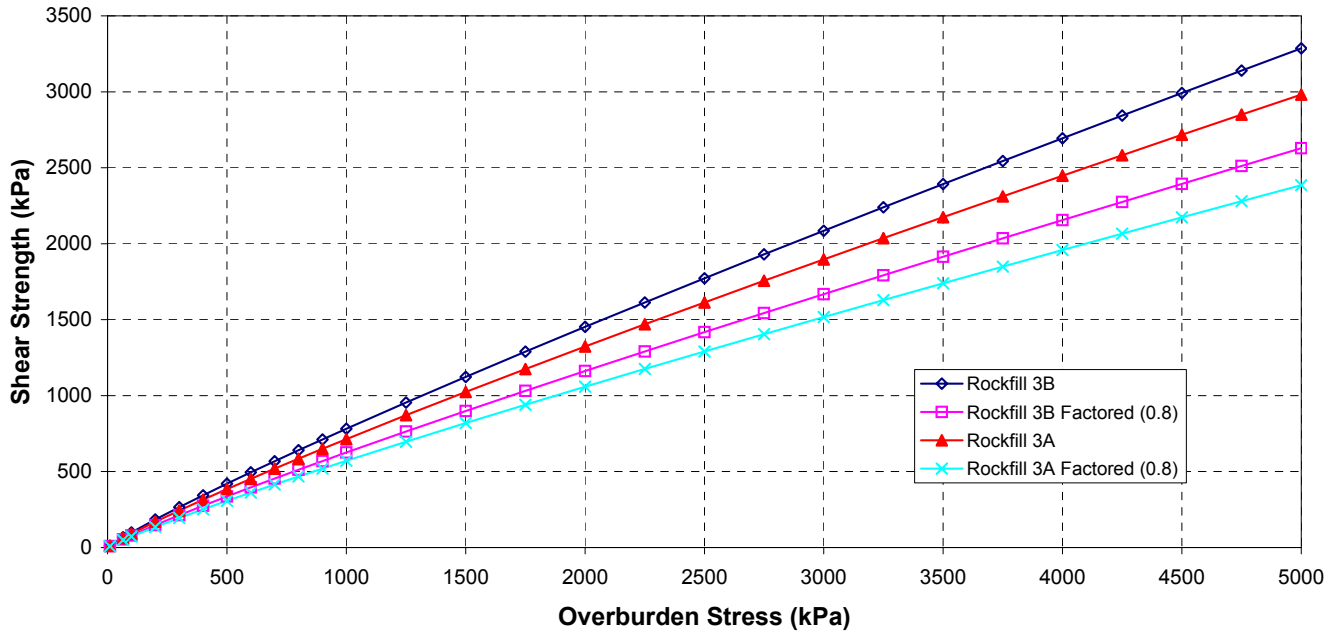


Figure 4. Carbonate to sulphate molar ratios for leachate from Dugald tailings

APPENDIX D



Reference: Leps, T.M (1970) "Review of Shearing Strength of Rockfill**",**
J. Soil Mech. Found. Div., ASCE,
Vol. 96 No. SM4, pp 1159-1170.



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DUGALD RIVER PROJECT

FEASIBILITY STUDY

KNAPDALE VALLEY TAILINGS STORAGE FACILITY

Rockfill Shear Strength

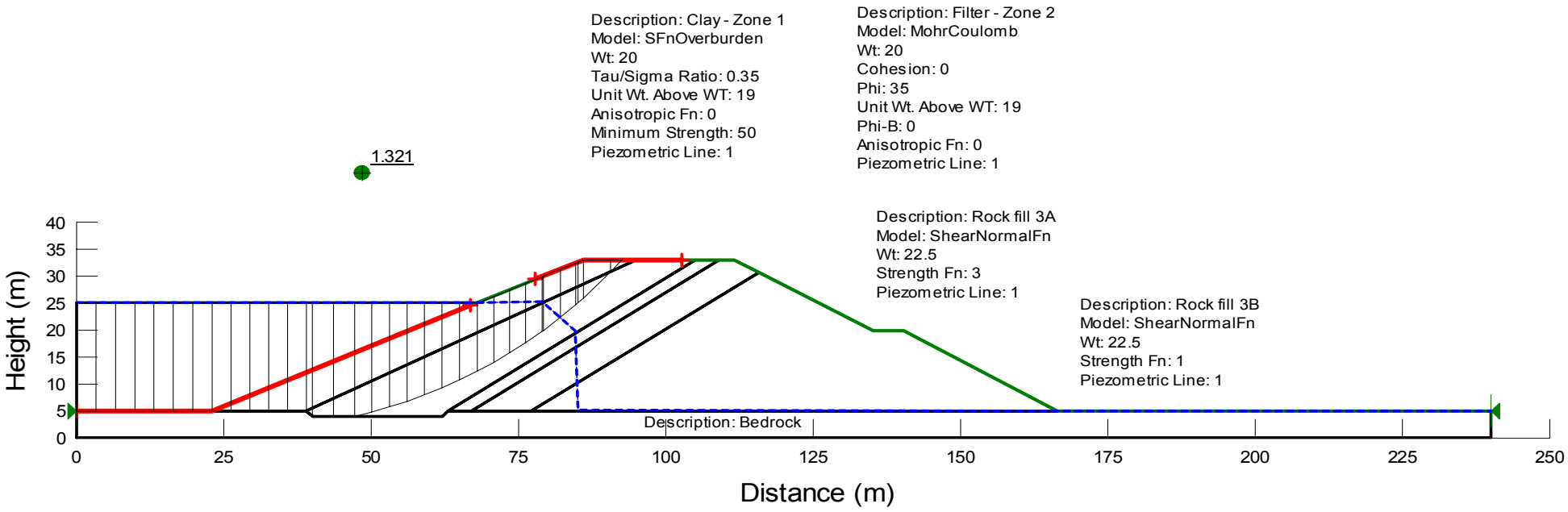
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Job No:	108003.02	**Date:**	30/06/2010

FIGURE D1

UPSTREAM SLOPE - STATIC LOADING
20m of Flood Water (DSA Pond)



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DUGALD RIVER PROJECT - FEASIBILITY STUDY

KNAPDALE VALLEY TAILINGS STORAGE FACILITY

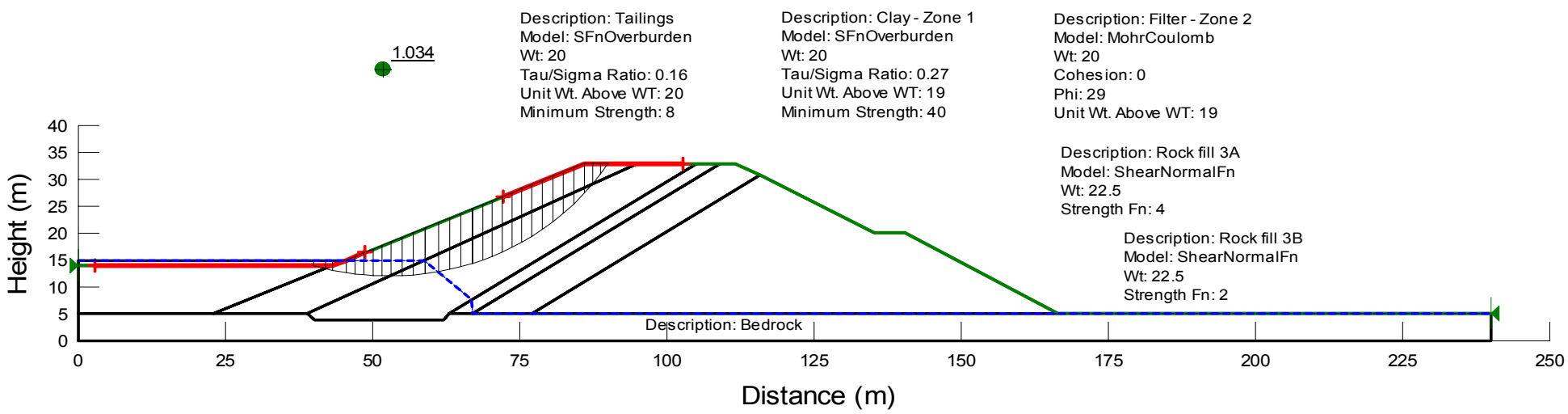
Main Embankment Stability Analyses - Clay Core Option (Stage I)

Date: 30/06/2010 **Job No:** 108003.02

FIGURE D2

J:\2008\108003 Dugald River\02 FS Update 2010\Data & Calcs\CN\APPENDIX D\Stability Figures.xls D2

UPSTREAM SLOPE - SEISMIC LOADING
(USCE Screening, OBE)
9m Tailings - 1m deep Decant Pond



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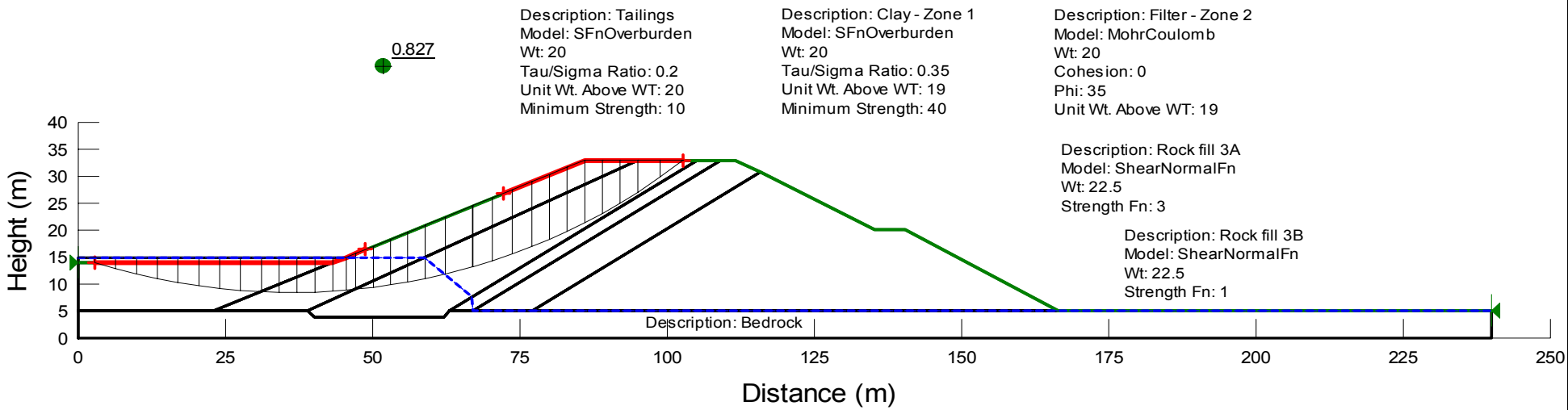
DUGALD RIVER PROJECT - FEASIBILITY STUDY

KNAPDALE VALLEY TAILINGS STORAGE FACILITY

Main Embankment Stability Analyses - Clay Core Option (Stage I)

Date:	30/06/2010	Job No:	108003.02	FIGURE D3

UPSTREAM SLOPE - SEISMIC LOADING
(MDE)
9m Tailings - 1m deep Decant Pond



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Date: 30/06/2010 **Job No:** 108003.02

FIGURE D4

UPSTREAM SLOPE - SEISMIC LOADING
(USCE Screening, OBE)
End of Construction - 5m of Flood Water

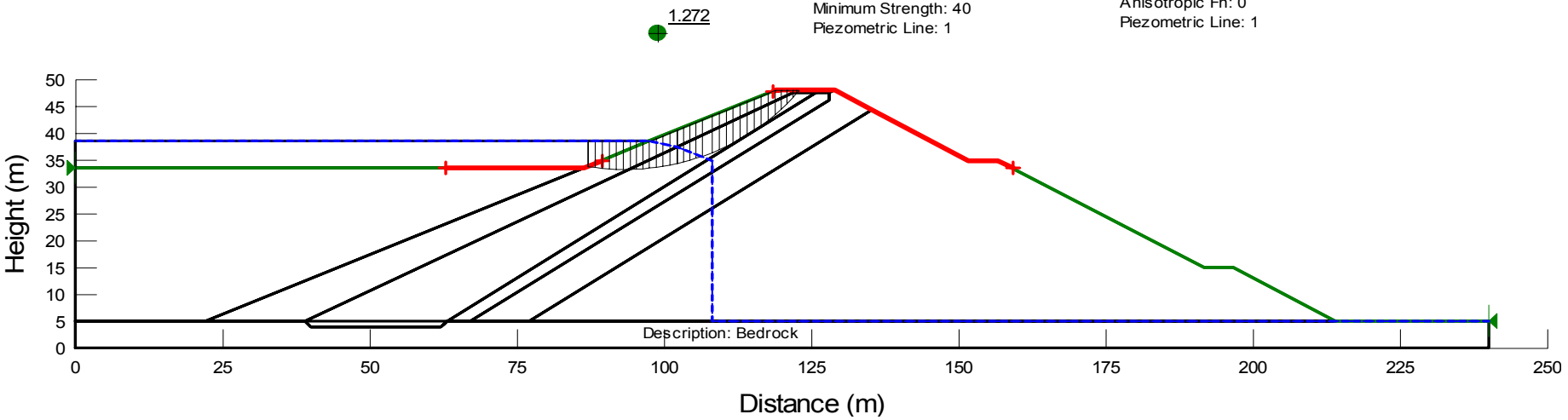
Description: Tailings
Model: SFnOverburden
Wt: 20
Tau/Sigma Ratio: 0.16
Unit Wt. Above WT: 20
Anisotropic Fn: 0
Minimum Strength: 8
Piezometric Line: 1

Description: Rock fill 3A
Model: ShearNormalFn
Wt: 22.5
Strength Fn: 4
Piezometric Line: 1

Description: Rock fill 3B
Model: ShearNormalFn
Wt: 22.5
Strength Fn: 2
Piezometric Line: 1

Description: Clay - Zone 1
Model: SFnOverburden
Wt: 20
Tau/Sigma Ratio: 0.27
Unit Wt. Above WT: 19
Anisotropic Fn: 0
Minimum Strength: 40
Piezometric Line: 1

Description: Filter - Zone 2
Model: MohrCoulomb
Wt: 20
Cohesion: 0
Phi: 29
Unit Wt. Above WT: 19
Phi-B: 0
Anisotropic Fn: 0
Piezometric Line: 1



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Main Embankment Stability Analyses - Clay Core Option (Stage III)

Date: 30/06/2010 **Job No:** 108003.02

FIGURE D5

DOWNSTREAM SLOPE - SEISMIC LOADING (MDE)
End of Stage - 1m deep Decant Pond

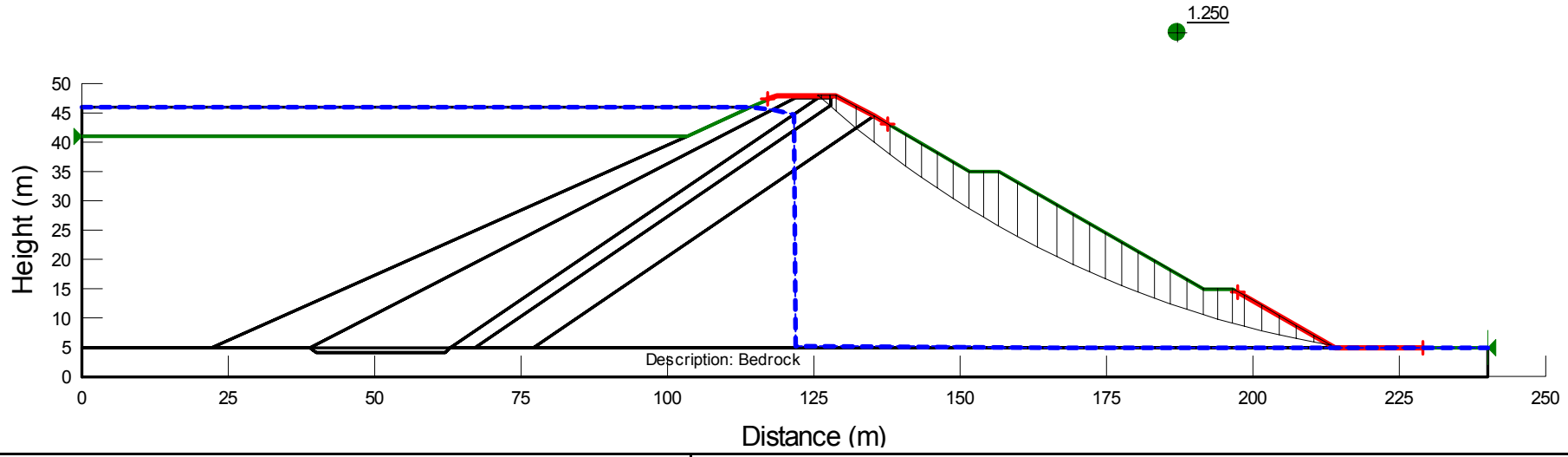
Description: Rock fill 3B
Model: ShearNormalFn
Wt: 22.5
Strength Fn: 1
Piezometric Line: 1

Description: Rock fill 3A
Model: ShearNormalFn
Wt: 22.5
Strength Fn: 3
Piezometric Line: 1

Description: Tailings
Model: SFnOverburden
Wt: 20
Tau/Sigma Ratio: 0.2
Unit Wt. Above WT: 20
Anisotropic Fn: 0
Minimum Strength: 10
Piezometric Line: 1

Description: Clay - Zone 1
Model: SFnOverburden
Wt: 20
Tau/Sigma Ratio: 0.35
Unit Wt. Above WT: 19
Anisotropic Fn: 0
Minimum Strength: 40
Piezometric Line: 1

Description: Filter - Zone 2
Model: MohrCoulomb
Wt: 20
Cohesion: 0
Phi: 35
Unit Wt. Above WT: 19
Phi-B: 0
Anisotropic Fn: 0
Piezometric Line: 1



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KNAPDALE VALLEY TAILINGS STORAGE FACILITY

Main Embankment Stability Analyses - Clay Core Option (Stage III)

Date: 30/06/2010 **Job No:** 108003.02

FIGURE D6

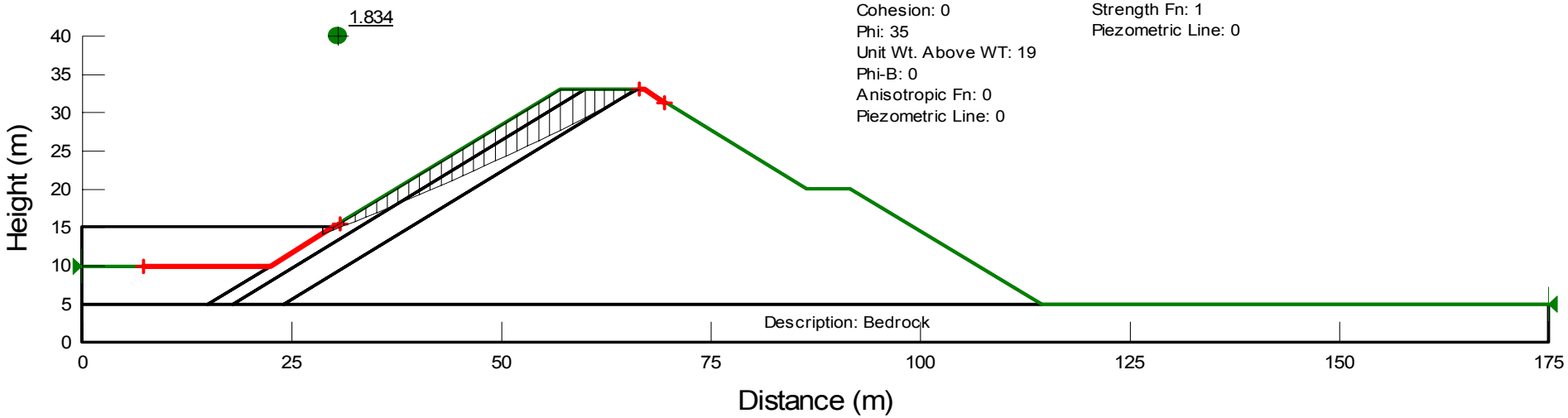
UPSTREAM SLOPE - STATIC LOADING
5m of Tailings - 5m of Flood Water

Description: Tailings
Model: SFnOverburden
Wt: 20
Tau/Sigma Ratio: 0.2
Unit Wt. Above WT: 20
Anisotropic Fn: 0
Minimum Strength: 10
Piezometric Line: 0

Description: Rock fill 3A
Model: ShearNormalFn
Wt: 22.5
Strength Fn: 3
Piezometric Line: 0

Description: Filter - Zone 2
Model: MohrCoulomb
Wt: 20
Cohesion: 0
Phi: 35
Unit Wt. Above WT: 19
Phi-B: 0
Anisotropic Fn: 0
Piezometric Line: 0

Description: Rock fill 3B
Model: ShearNormalFn
Wt: 22.5
Strength Fn: 1
Piezometric Line: 0



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Main Embankment Stability Analyses - GSS Option (Stage I)

Date: 30/06/2010 **Job No:** 108003.02

FIGURE D7

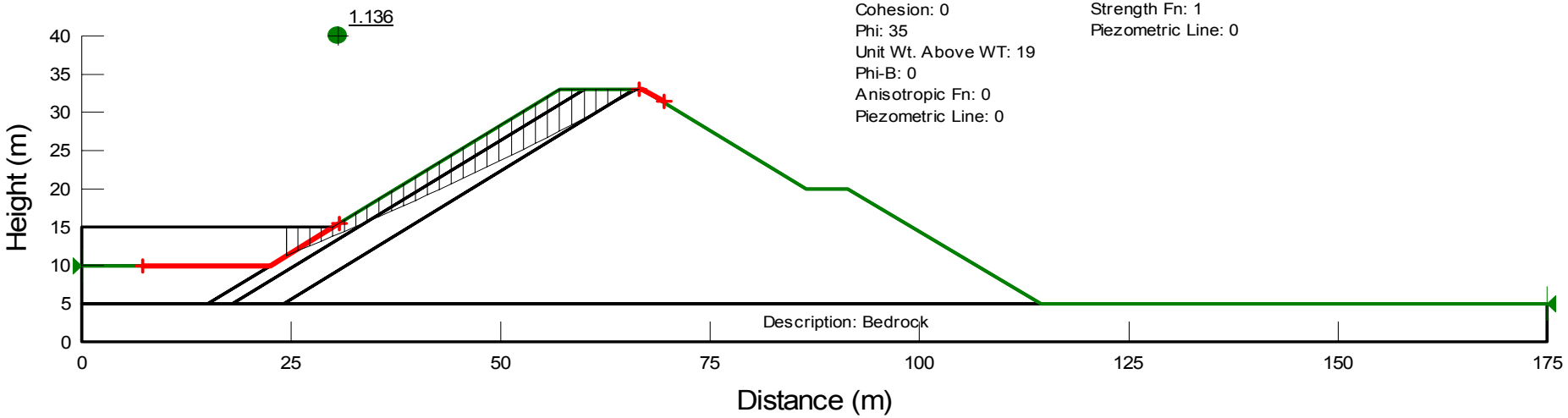
UPSTREAM SLOPE - SEISMIC LOADING
(MDE)
5m Tailings - 5m of Wet Season Flood Water

Description: Tailings
Model: SFnOverburden
Wt: 20
Tau/Sigma Ratio: 0.2
Unit Wt. Above WT: 20
Anisotropic Fn: 0
Minimum Strength: 10
Piezometric Line: 0

Description: Rock fill 3A
Model: ShearNormalFn
Wt: 22.5
Strength Fn: 3
Piezometric Line: 0

Description: Filter - Zone 2
Model: MohrCoulomb
Wt: 20
Cohesion: 0
Phi: 35
Unit Wt. Above WT: 19
Phi-B: 0
Anisotropic Fn: 0
Piezometric Line: 0

Description: Rock fill 3B
Model: ShearNormalFn
Wt: 22.5
Strength Fn: 1
Piezometric Line: 0



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FIGURE D8

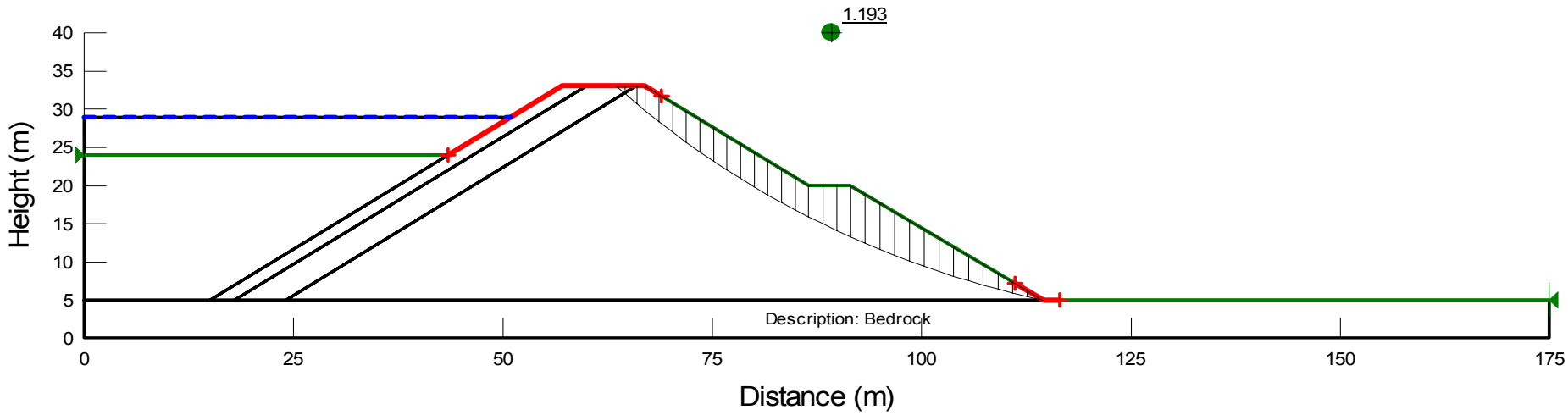
DOWNSTREAM SLOPE - SEISMIC LOADING (MDE)
End of Stage - 5m of Wet Season Flood Water

Description: Tailings
Model: SFnOverburden
Wt: 20
Tau/Sigma Ratio: 0.2
Unit Wt. Above WT: 20
Anisotropic Fn: 0
Minimum Strength: 10
Piezometric Line: 1

Description: Filter - Zone 2
Model: MohrCoulomb
Wt: 20
Cohesion: 0
Phi: 35
Unit Wt. Above WT: 19
Phi-B: 0
Anisotropic Fn: 0
Piezometric Line: 1

Description: Rock fill 3A
Model: ShearNormalFn
Wt: 22.5
Strength Fn: 3
Piezometric Line: 1

Description: Rock fill 3B
Model: ShearNormalFn
Wt: 22.5
Strength Fn: 1
Piezometric Line: 1



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Main Embankment Stability Analyses - GSS Option (Stage I)

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FIGURE D9

UPSTREAM SLOPE - SEISMIC LOADING
(USCE Screening, OBE)
End of Construction - 5m of Wet Season Flood Water

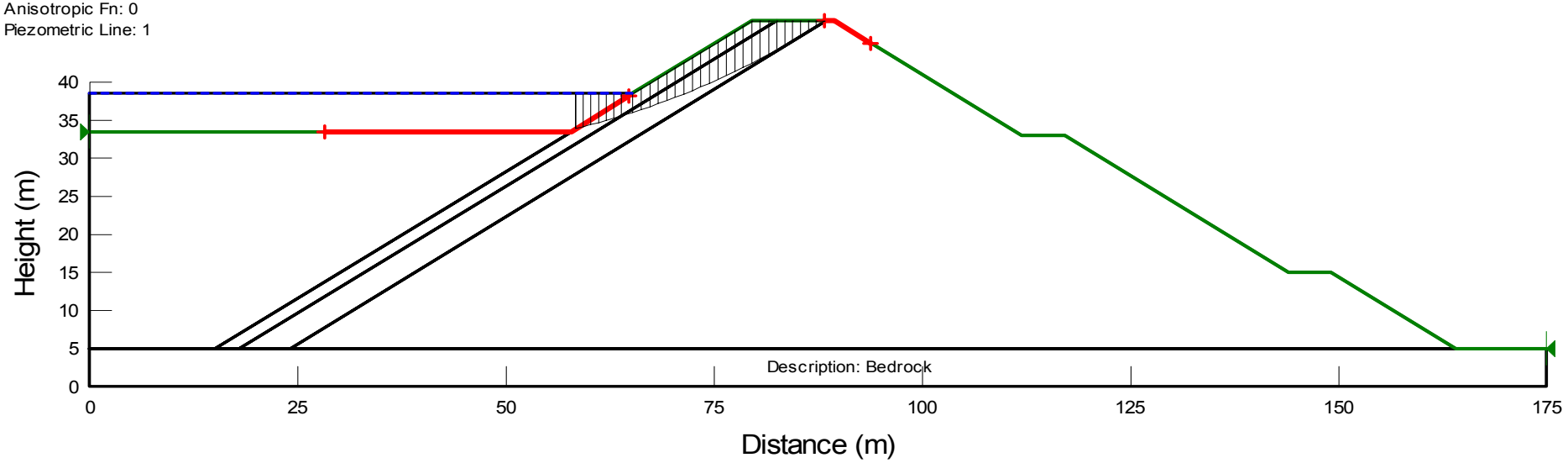
Description: Tailings
Model: SFnOverburden
Wt: 20
Tau/Sigma Ratio: 0.16
Unit Wt. Above WT: 20
Anisotropic Fn: 0
Minimum Strength: 8
Piezometric Line: 1

Description: Filter - Zone 2
Model: MohrCoulomb
Wt: 20
Cohesion: 0
Phi: 35
Unit Wt. Above WT: 19
Phi-B: 0
Anisotropic Fn: 0
Piezometric Line: 1

Description: Rock fill 3A
Model: ShearNormalFn
Wt: 22.5
Strength Fn: 4
Piezometric Line: 1

Description: Rock fill 3B
Model: ShearNormalFn
Wt: 22.5
Strength Fn: 2
Piezometric Line: 1

1.511



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KNAPDALE VALLEY TAILINGS STORAGE FACILITY

Main Embankment Stability Analyses - GSS Option (Stage III)

Date: 30/06/2010 **Job No:** 108003.02

FIGURE D10

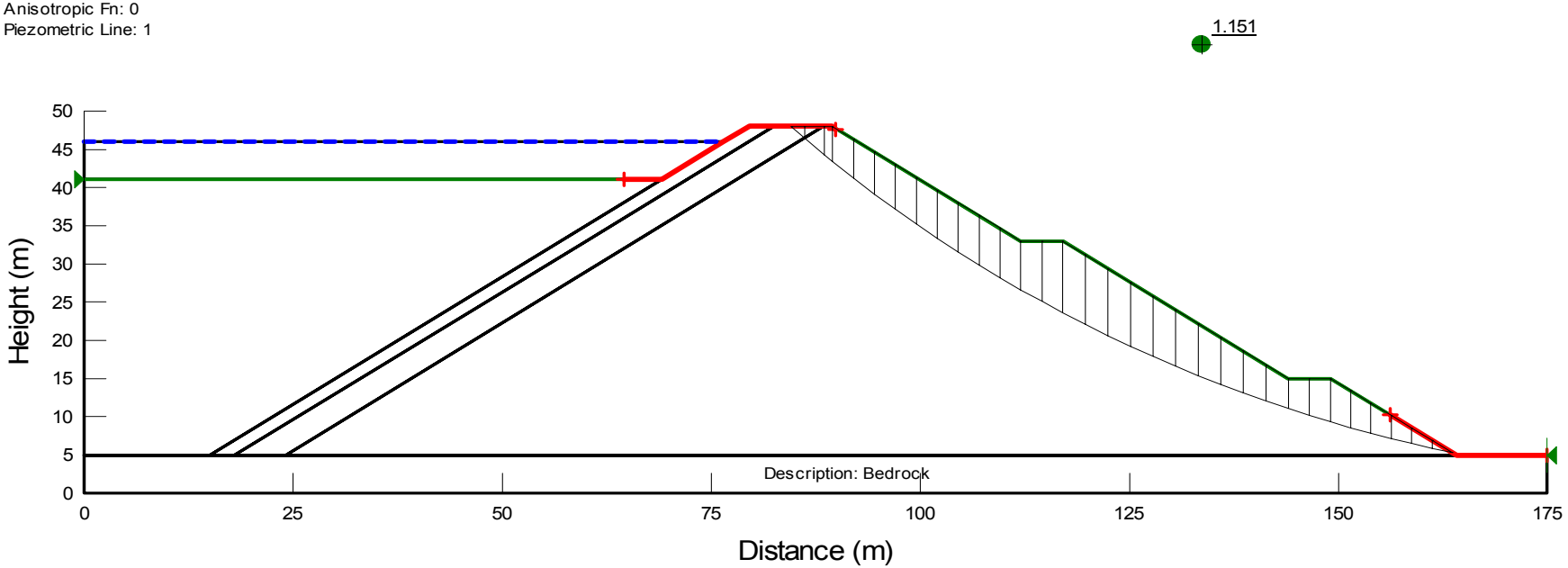
Description: Tailings
Model: SFnOverburden
Wt: 20
Tau/Sigma Ratio: 0.2
Unit Wt. Above WT: 20
Anisotropic Fn: 0
Minimum Strength: 10
Piezometric Line: 1

Description: Rock fill 3A
Model: ShearNormalFn
Wt: 22.5
Strength Fn: 3
Piezometric Line: 1

Description: Filter - Zone 2
Model: MohrCoulomb
Wt: 20
Cohesion: 0
Phi: 35
Unit Wt. Above WT: 19
Phi-B: 0
Anisotropic Fn: 0
Piezometric Line: 1

Description: Rock fill 3B
Model: ShearNormalFn
Wt: 22.5
Strength Fn: 1
Piezometric Line: 1

DOWNSTREAM SLOPE - SEISMIC LOADING (MDE)
End of Stage - 5m of Wet Season Flood Water



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FIGURE D11

APPENDIX G

DUGALD RIVER DAM
AUSTRALIA

*****

WATERPROOFING OF THE UPSTREAM FACE WITH CARPI GEOMEMBRANE SYSTEMS



Sar Cheshmeh tailings dam, Iran 2008, 1,000 m long

PRELIMINARY TECHNICAL AND ECONOMICAL PROPOSAL

Prepared August 20, 2008

FOR ATC

carpi

----------Waterproofing Specialists and Contractors----------

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1 SCOPE OF PROPOSAL

The Dugald River Tailings Storage will be constructed in Australia. Designer is ATC.
The project is a new copper mine located in north-west Queensland, Australia. It is currently at Feasibility Study level, with an excellent prospect of proceeding.
Some additional information regarding the project:

- The proposed GSS is exactly the same as the Sar Cheshmeh arrangement, except that it a new structure anchored entirely on a plinth at the toe.
- The embankment will be approx. 180m long, with a maximum height of 33m.
- The face area is only 6,200 m2
- There is a strong possibility of a second stage, making the GSS approach (as well as the lack of clay) an attractive solution.
- The embankment will need to retain up to 8m of water during wet periods, due to its location within the storage. It is hence necessary to design it as a water retaining embankment.
- Wind direction/speed data have been requested, but not yet made avaialble.
- The site is within 1 hour's drive of the town of Cloncurry, where rail and heavy road transport infrastructure exists.
- The nearest port is the city of Townsville, some 700km to the east by road/rail.

Based on Carpi verbal expression of interest in this project, ATC has requested from Carpi a price to supply and install their recommended PVC geocomposite for the above project. Being a Feasibility Study, ATC are required to submit cost estimates to an accuracy of +/- 10%.
Given that there will be a mine construction camp in place at the time the membrane will be installed, Carpi has been requested to provide the price for a REDUCED SERVICE, however also the price for the FULL SERVICE would be helpful

The technical and economical offer presented in this document is based on the information provided by ATC in the CARPI Checklist for dam info attached herewith

The preliminary solution proposed by Carpi is fully applicable to the present status of the project. The proposed solution has been already adopted by CARPI in previous projects and can be quickly adjusted to the specific requirements of DUGALD project. Therefore there will be a minimum time required to assemble the final complete detailed drawings, thus to allow almost immediate starting of the project.

Some of the systems described in this document are patented by Carpi Tech Italia S.r.l., Arona, Italy, of the CARPI Group. The preliminary solution outlined in this document is susceptible of modification/integration depending on new information that should require modifying the proposed technical solution.

2 PROJECT INFORMATION

The dam is a rockfill dam which will be used for tailing. The dam may be subjected to gradual rise. The initial stage is for a maximum height of 33 m.

Length of crest for the first phase is 180 m, no inspection gallery and upstream inclination of 1V to 1.5 H

Total area is approximately 6,200 m2 for the upstream face plus some 360 m2 at the crest (2m width x180m length). In total 6560 m2

Perimeter seal along the plinth has been calculated to be 210 m long

3 SELECTION OF THE CARPI SYSTEM FOR DUGALD RIVER DAM

3.1 GEOMEMBRANE SELECTION

CARPI, established in 1963, and today the oldest company in the world dealing with waterproofing geomembrane systems for hydraulic structures and with >1,200 projects completed worldwide, designs and installs waterproofing geomembrane systems and is not a geomembrane manufacturer. The selection of a geomembrane for each project is made by Carpi in function of the specific characteristics and requirements of the project, and is based on previous successful installations on similar structures, and on the latest developments in geosynthetics production.

3.1.1 THE RESEARCH ON GEOMEMBRANES BY THE US ARMY CORPS OF ENGINEERS

In 1994 the US Army Corps of Engineers awarded a contract to CARPI to research the subject of geomembrane systems that could be installed underwater. The Corps financed a 2-phase research project that was performed in years 1995 and 1996 by Carpi and Oceaneering, one of the largest commercial diving company in the world, under the supervision of the Corps.

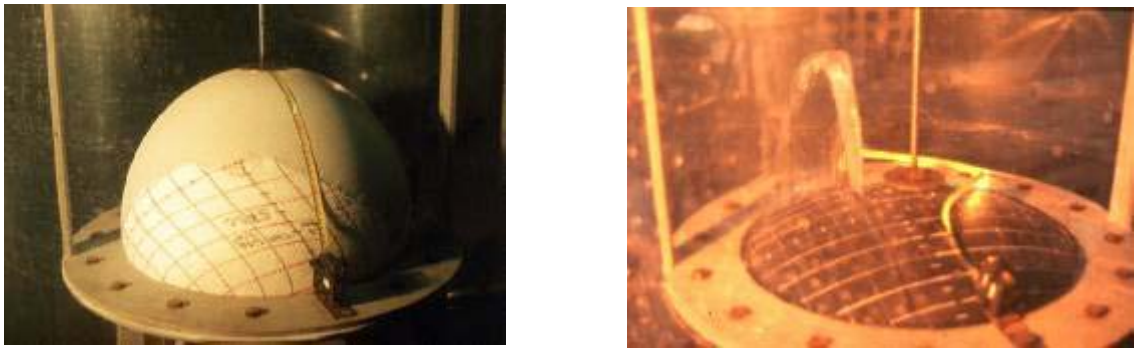
The first part of the research, carried out in 1995, focused on geomembrane liners and on developing and designing a system that could be installed underwater. According to the Corps, a reliable geomembrane liner should have, in order of decreasing importance, the following characteristics

- Very low permeability;
- High resistance to tensile stress, pressure, puncture;
- Elastic behaviour, with high-percentage elastic elongation;
- High resistance to the service environment;
- Ease of junctions;
- Satisfactory performance in previous applications;
- Repairability;
- Acceptable cost;
- Availability.

Since successful previous application was one of the requirements, the geomembrane materials considered in the research were those that had already proven to be suitable for hydraulic structures, namely PolyVynilChloride (PVC), Chlorosulphonated Polyethylene (CSPE), Polypropylene (PP), Ethylene Propylene Diene Monomer (EPDM), and High density Polyethylene (HDPE). The US Army Corps of Engineers did not consider bituminous geomembranes for the research as they were deemed not adequate. Out of these materials, 21 geomembranes of various thicknesses, with and without reinforcement, were tested under standard uni-axial tests on small specimens, and under large scale multi-axial tests. These latter tests were deemed capable of better evaluating resistance and flexibility characteristics necessary to adapt and resist irregularities of the substrate and reduce the stresses on the anchorage system. The following photos illustrate large scale multi-axial testing for puncture resistance and burst resistance of PVC and HDPE geomembranes.



Full-scale testing for puncture and burst resistance carried out by the US Army Corps of Engineers on 21 geomembranes ascertained the excellent performance of PVC compared with all other types of geomembranes. CARPI PVC geocomposite Sibelon CNT 3750 (2.5 mm PVC geomembrane + 500 g/m^2 geotextile, pictured at middle) conformed to the substrate and resisted to repeated cycles of loading-downloading at 1 MPa (100 m). The HDPE geomembrane pictured at right did not conform and ruptured at 0.15 MPa at the first loading.
(Courtesy of the US Army Corps of Engineers – Waterways Experiment Station)



Testing burst resistance. CARPI geocomposite Sibelon CNT 4600 (3 mm PVC geomembrane + 700 g/m2 geotextile, left) resisted 160 kPa, with a 271 % surface elongation. HDPE (right) failed at lower elongation, along a line indicating a zone of lower strength, and a preferential path for propagation of tear.
(Courtesy of the US Army Corps of Engineers – Waterways Experiment Station)

Table 1 in the following page (listed as Table 3 in the report by the Corps) summarises the results and evaluation after testing for puncture and burst on the 21 membranes. Maximum total available score was 35. Out of the 21 membranes tested, the PVC materials resulted to be by far the best: geomembranes/geocomposites Sibelon (listed in the table as « PVC » and « PVC-R » respectively, the first number representing the thickness of the geomembrane and the second number the mass per unit area of the geotextile) scored the best, attaining the maximum score of 35/35. HDPE score the worst, 5/35.

Table 1. Evaluation of the membrane materials in three-dimensional testing for puncture and burst - US Army Corps of Engineers.

Table 3
Multiaxial Tests Membrane Material Evaluation

Test 1 Multiaxial Puncture Test	PVC 1	PVC 1.5	PVC 2	PVC 2.5	PVC-R 1+ 200	PVC-R 1.5+ 200	PVC-R 2+ 200	PVC-R 2.5+ 500	CSPE-S 1	CSPE-S 1.2	CSPE-S 1.4	CSPE-R 0.8+ 0.4	CSPE-R 1+ 0.4	CSPE-R 1.2+ 0.4	PP 1.5	PP-R 1.5+ 300	EPDM 2	EPDM 3	HDPE 1.5	HDPE 2	HDPE 2.5
Conformability to substrate	5	5	5	4	5	5	5	5	5	5	5	4	4	4	5	5	4	4	1	1	1
Failure at protrusions (puncture)	5	3	5	5	5	4	5	5	4	4	4	3	3	3	3	3	5	5	1	1	1
Failure at depressions (burst)	3	5	5	5	4	5	5	5	3	4	4	2	2	2	2	4	5	5	n.a.	n.a.	n.a.
Elastic recovery	3	3	4	5	3	4	5	5	3	3	3	1	1	1	1	1	5	5	n.a.	n.a.	n.a.
Total Rating Test 1	16	16	19	19	17	18	20	20	15	16	16	10	10	10	11	13	19	19	2	2	2
Test 2																					
Burst Test																					
Homogeneity	4	5	5	5	5	5	5	5	4	4	4	1	1	1	2	2	4	4	1	1	1
Isotropy	4	5	5	5	5	5	5	5	4	4	4	1	1	1	4	3	4	4	1	1	1
Capability to deform	5	5	5	5	5	5	5	5	4	4	4	3	3	3	4	4	5	5	2	1	1
Total Rating Test 2	13	15	15	15	15	15	15	15	12	12	12	5	5	5	10	9	13	13	4	3	3
Total Rating Tests 1 & 2	29	31	34	34	32	33	35	35	27	28	28	15	15	15	21	22	32	32	6	5	5

n.a. = not applicable due to extreme lack of conformability to substrate
Numbers indicate membrane thickness + reinforcement identification

To complete the evaluation, other relevant characteristics of the geomembranes (imperviousness, tear resistance, dimensional stability, seamability, etc.), and other parameters considered important to select an adequate material (constructability, previous applications, durability, availability, repairability, and costs) were investigated. Again PVC geocomposite ranked first, with a score of 256 out of the maximum total available score of 260, and HDPE geomembrane ranked last, with a score of 140/260. Table 2 in the following page (listed as Table 4 in the report by the Corps) represents the results of the overall geomembranes' evaluation.

It should be noted that the research attributed a significant importance (weight = 4 in a scale from 1 to 5) to previous experience, when evaluating the various geomembranes. The geocomposites Sibelon CNT (listed in the table as « PVC-R ») resulted to be the best. The geomembranes Sibelon C, a PVC geomembrane without geotextile backing, (listed in the table as « PVC ») scored second.

The US Army Corps of Engineers waterways Experiment Station Technical Report REMR-CS-50 illustrates the first phase of the research and all results of evaluation and system design.

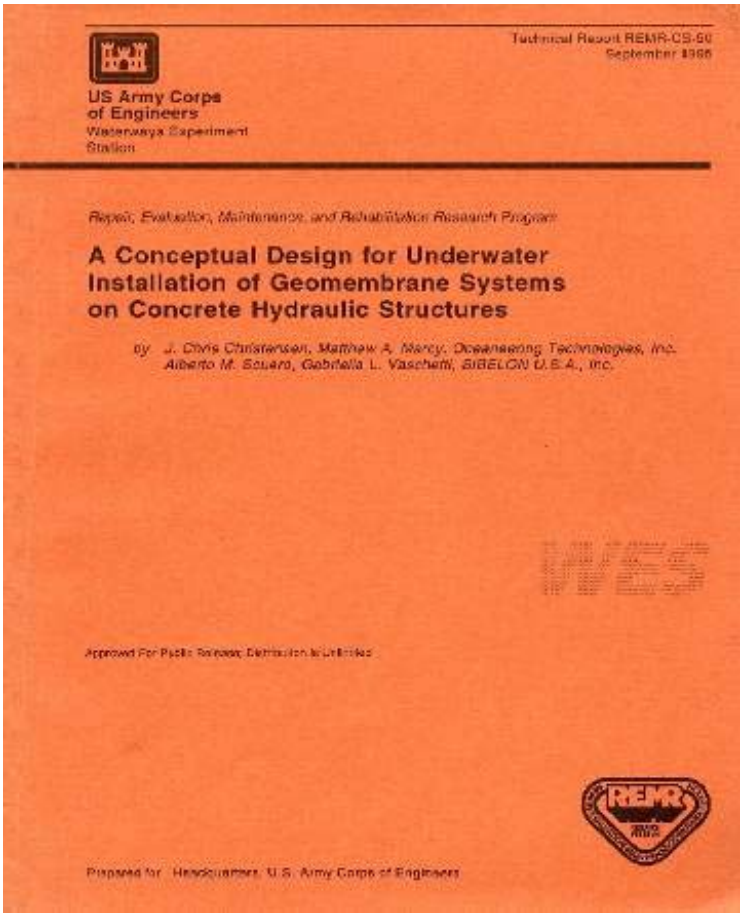


Table 2. Evaluation of the membrane materials - US Army Corps of Engineers.

Table 4
Membrane Material Evaluation for Underwater Installation

Property	Weight	PVC		PVC-R		CSPE-S		CSPE-R		PP		PP-R		EPDM		HDPE	
		Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score
PART A																	
Impermeability	5	5	25	5	25	5	25	5	25	5	25	5	25	5	25	5	25
Tensile behavior	5	4	20	5	25	5	25	5	25	3	15	5	25	4	20	2	10
Tear resistance	5	3	15	5	25	5	25	5	25	3	15	4	20	5	25	4	20
Puncture resistance	5	4	20	5	25	3	15	3	15	3	15	4	20	4	20	2	10
Flexibility	5	5	25	5	25	5	25	3	15	5	25	4	20	5	25	2	10
Specific gravity	5	5	25	5	25	5	25	5	25	1	5	1	5	5	25	1	5
Seamability	4	5	20	5	20	3	12	3	12	4	16	4	16	3	12	2	8
Dimensional stability	1	4	4	5	5	5	5	4	4	4	4	5	5	4	4	3	3
Total Score A			154		175		157		146		120		136		156		91
PART B																	
Overall constructability	4	5	20	5	20	4	16	4	16	3	12	3	12	4	16	1	4
Previous applications	4	5	20	5	20	4	16	1	4	2	8	2	8	2	8	2	8
Durability	3	5	15	5	15	5	15	5	15	5	15	5	15	5	15	5	15
Availability	2	4	8	4	8	2	4	1	2	3	6	3	6	3	6	5	10
Repairability	2	5	10	5	10	4	8	4	8	3	6	3	6	3	6	1	2
Cost	2	4	8	4	8	2	4	2	4	3	6	3	6	1	2	5	10
Total Score B			81		81		63		49		53		53		53		89
Total Score A & B			235		256		220		195		173		189		209		140
Rank			2		1		3		5		7		6		4		8

Results of extensive testing and evaluation showed PVC geocomposites as the most suitable materials

3.1.2 Bituminous or polymeric geomembranes - ICOLD data base

ICOLD, the International Commission on Large Dams, in the new Bulletin on geomembrane sealing systems for dams, formed a database on all types of geomembranes used on large dams. According to the ICOLD database, out of a total of 263 dams for which data are available, only 23 dams have been waterproofed with bituminous geomembranes, while all remaining 240 dams have adopted polymeric geomembranes. Out of the 23 bituminous liners, 20 are prefabricated geomembranes, 3 are made in-situ by impregnation.

The following table lists the findings of ICOLD.

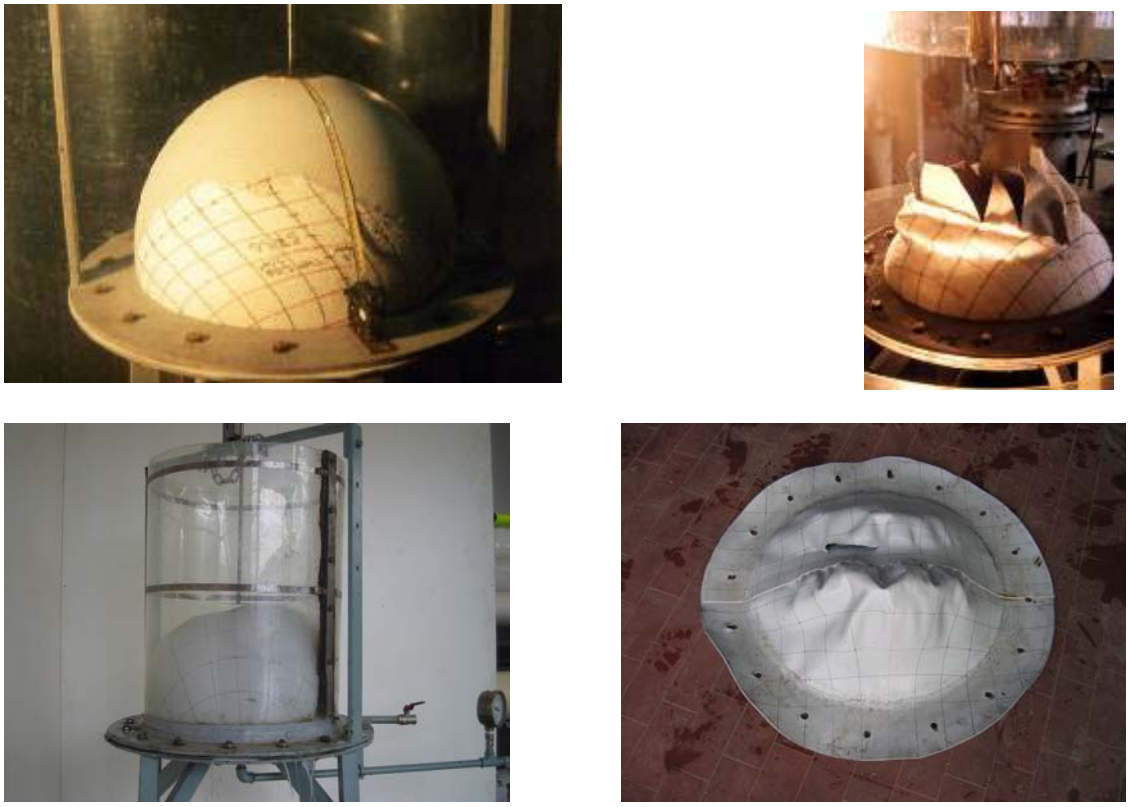
GM type	Basic material	Abbreviation	Total dams				%
			Exposed	Covered	Unknown	TOTAL	
Polymeric	Polyvinylchloride – Plasticised	PVC-P	80	73	3	156	59.32
Polymeric	Polyolefin	LLDPE*	0	29	1	30	11.41
Polymeric	Polyolefin	HDPE	3	12	1	16	6.08
Polymeric	Butyl rubber, polyisobutylene, ethylene-propylene-diene monomer	IIR, PIB, EPDM	5	4	2	11	4.18
Polymeric	Chlorosulfonated polyethylene	CSPE	3	5	1	9	3.42
Polymeric	Geotextiles impregnated with polymers	In situ membrane	2	7	0	9	3.42
Polymeric	Polyolefin	PP	3	3	0	6	2.28
Polymeric	Chlorinated polyethylene	CPE	0	3	0	3	1.14
Bituminous	Oxidized bitumen	Prefabricated GM	7	10	0	17	6.47
Bituminous	Polymeric bitumen	Polymeric bitumen	0	3	0	3	1.14
Bituminous	Oxidised bitumen	In situ membrane	3	0	0	3	1.14
Sub-total polymeric						240	91.25
Sub-total bituminous						23	8.75
Total known						263	100,0

* LLDPE includes all types of flexible PE geomembranes that have lower density than HDPE

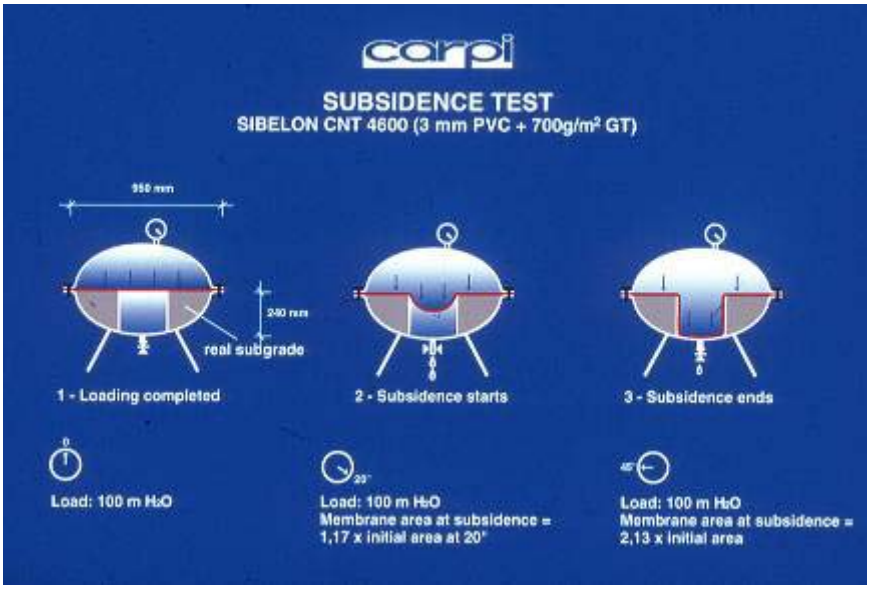
3.1.3 Which type of polymeric geomembrane

According to the ICOLD database PVC is the most commonly used geomembrane material among polymeric geomembranes, with a total of 156 dams.

PVC is the most used material because of higher performance in respect to tensile properties and flexibility, to the possibility of coupling it to a geotextile, to ease of handling and placement, to ease and reliability of seams. No other geomembrane has a performance that can match that of PVC geomembranes in this respect.



Destructive testing for resistance to burst. On top row, the PVC geocomposite (3 mm PVC geomembrane + 700 g/m^2 geotextile) resisted up to 160 kPa, with 271 % elongation. On bottom row, the same test to test burst resistance of the welds on a 3 mm thick PVC geomembrane. The PVC geomembrane resisted up to > 350% elongation, deforming less in correspondence of the weld, where the thickness is double, and bursting outside the area of the weld. This indicates that welds, which are a critical point for all geomembrane systems, in case of a PVC geomembrane are areas of HIGHER resistance.













Testing resistance to subsidence prior to final design for Bovilla dam: CARPI geocomposite SIBELON CNT 4600 (3 mm PVC geomembrane + 700 g/m2 geotextile) tested at 100 m head, 213 % elongation without failure.

The above tests provide laboratory evidence of the capability of PVC geocomposite to resist settlements, and opening of cracks and fissures.

Furthermore, PVC, and in particular high quality PVC geocomposites such as SIBELON CNT, is the only material that has a long list of successful precedents in the field

- On all types of dams
- On dams with very high water heads (198 m on embankment dams, 174 m on concrete dams, 188 m on RCC dams),
- On dams located in climates with high temperature differentials
- On dams with presence of ice >150 cm
- On dams located at high altitude (>3500 m) with high UV exposure
- Of long service life in exposed position (first installation of SIBELON CNT by CARPI on a dam was made in 1976 and still in service).

The choice has therefore been made by Carpi of proposing a PVC product for DUGALD RIVER dam.

3.1.4 PVC geocomposite

Repeated and documented experience has shown the multiples advantages of using a PVC sheet in combination with a nonwoven geotextile backing, adhered to the PVC. This is normally called a "geocomposite". The geocomposite possesses a dimensional stability which is larger than that of the PVC (the low thermal expansion coefficient gets even smaller), a larger modulus of deformation (both in one and bi-directional extension). Because the geotextile backing fails in tension (when tested in one directional extension) at about 45 % strain, much before the failure point of the PVC, the geocomposite maintains the very large failure strain typical of PVC. The use of a geocomposite is

suggested by other considerations, too:

The geotextile acts as a bedding layer between the support and the PVC liner thus allowing placing the PVC liner even on fairly rough supports. Where the geocomposite sits on protruding points the geotextile acts as a de-coupling layer and allows bi-directional, sidewise movements of the PVC sheet thus favouring a reduction of the otherwise concentrated stresses related to sharp bends of the liner over the protruding points of the bedding

- The geotextile increases friction stability in respect to sliding, facilitates the positioning of the geocomposite, and decreases the potential for stretching, due to its high friction angle on the base layer
- The geotextile provides drainage capability on the backside of the geomembrane, reducing the risk of uplift
- The geotextile eliminates the potential for wrinkling due to temperature variations.

The geotextile acts as a buffer in case of localized damages to the PVC liner. The leakage that will leave the pond from an occasional puncture or hole will be efficiently reduced by the presence of a non woven geotextile whose in-plane transmissivity is much less than the transmissivity of the fish mouths that may exist under a smooth liner, particularly if quite rigid.

The choice has therefore been made of using a PVC geocomposite for DUGALD RIVER dam.

3.2 EXPOSED OR COVERED GEOMEMBRANE

CARPI has 40+ years of activity in waterproofing of 85 large dams, of canals, of hydraulic tunnels and of reservoirs. Carpi experience and international experience has shown that geocomposites adequately formulated and designed provide satisfactory watertight behaviour. In particular for Carpi PVC geomembranes, in those areas above the maximum reservoir level, and therefore never submerged by water, and where in fact imperviousness is not even required, the predicted service life is of 50 at least years, based on high thickness material and depending on the climate. It must be noted that the thicker the geomembrane is, the longer its durability will be. In general, a geomembrane with double thickness will last four times longer. In the area permanently submerged by water, durability is in excess of 200 years.

Type of structure	Number of hydro projects as of September 2007	Quantity of geomembrane material as of September 2007 (m^2)	Cumulated years of experience (number of projects x years in operation) as of September 2007
DAMS	86	672,914	782
RESERVOIRS	22	367,471	314
CANALS	32	525,494	404
HYDRO TUNNELS	11	43,939	173
TOTAL	151	1,609,818	1,673

CARPI has adopted the exposed configuration on the greatest part of its projects. Out of 85 dams waterproofed since 1970, more than 85% have an exposed geomembrane. In all these projects, there has not been one case of geomembrane losing its waterproofing function because of deterioration due to UV rays, or to impact by ice, floating objects, rocks, vandalism etc. All of them have been performing with full efficiency since they have been installed. There are a number of examples, in

different climates and on all types of dams and other hydraulic structures, of exposed geomembranes that have been successfully performing for more than 25 years.
To Carpi knowledge all the EXPOSED INSTALLATIONS have experienced NO MAINTENANCE and NO VANDALISM

The exposed system permits:

- Elimination of the possibility of damage associated with installation of the cover layer
- Total control of the integrity of the liner along the entire upstream face of the dam,
- Quicker and easier installation,
- Easy inspection and repair, even underwater.
- Overall lower cost.

In case of concern for vandalism, a partial light cover can be installed in the area that can be accessed by vandals

Based on this experience, and on good performance of all our exposed geomembrane systems, Carpi believes that an exposed geomembrane system could provide long lasting efficient performance for the project on issue. Carpi has therefore chosen to propose an exposed geomembrane system, according to a solution patented by Carpi and already successfully applied in the field as further described, upstream face slope 1V:1.5H..

4 EXPOSED GEOMEMBRANE

Precedents of Carpi exposed geomembranes on embankment dams date back to 1979, and include 20 large fill dams, with a maximum height of 196 m. Application include rehabilitation of large fill dams with exposed geomembrane and construction of new dams with geomembrane both covered and exposed.





Rehabilitation of Winscar dam, ACRD, UK





Rehabilitation of Sa Forada dam, ACRD, Italy

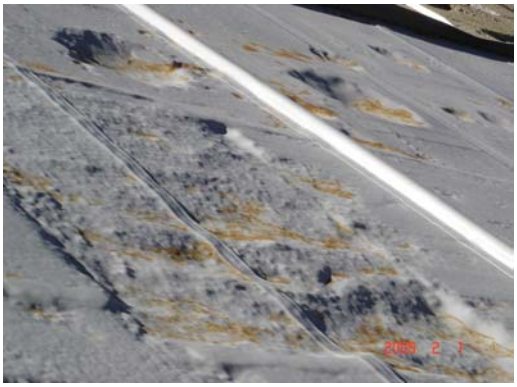




Rehabilitation of Midtbotnvatn dam, CFRD, Norway








Salt Springs CFRD. The dam was built in 1935. In 70 years of operation the dam was repaired 24 times, always unsuccessfully. Carpi exposed PVC geocomposite on upstream face was installed in the most critical part of the dam in 2004. In 2005, lining was completed in the remaining crucial section. The exposed PVC geocomposite after one year of service, when installation was resumed: the membrane adapted to the rough surface under the water head (dam is 101 m high), without any rupture. Impact by heavy floating trees does not damage the Carpi exposed geocomposite.





Karahnjukar CFRD, Iceland. Carpi exposed PVC geocomposite covers the horizontal joint between the phase 1 and phase 2 slabs, where major movement is expected. New construction





Sabrina Wood Faced Rockfill dam (WFRD), USA. Carpi exposed PVC geocomposite on upstream face





Rehabilitation of Moravka dam, Czech Republic

Carpi PVC geomembranes have been used in construction of new very high dams





The Carpi PVC geocomposite under installation at the concrete toe wall of Karahnjukar CFRD in Iceland, 198 m of head (left), and at Miel I 188 m high RCC dam in Colombia (right).

An exposed geomembrane system, quite similar to what proposed for DUGALD RIVER, was installed on new dams such as at Alento cofferdam in Italy (see paragraph on 4.4.1) and at two pilot projects in Turkey (Ministry of Irrigation) and at Toulnustouc CFRD in Canada (Hydro Quebec).





Antalya cofferdam, Ministry of Irrigation, Turkey, the PVC geocomposite has been installed on both upstream and downstream surfaces





Toulnustouc dam, Hydro Quebec, Canada

In 2004, a first full field application was made at Kohrang headpond in Iran (Ministry of Energy). During the first year of operation, recorded temperatures varied from -37 °C (February 2005, with 3 m thick snow and 0.5 m thick ice formation against the exposed geomembrane) to +35°C (July 2005). The liner behaves very satisfactorily, as expected (see photographs at paragraph 4.4.2

The same system proposed for DUGALD RIVER dam is at present under installation on the raised embankment of Sar Cheshmeh tailings dam in Iran, owned and operated by NICICO, one of the largest copper mining operation in the world, and designed by Australian Tailings Consultants and Middle East Water & Environment Joint Venture.
Sar Cheshmeh is a large existing copper mine in central Iran. The existing tailings dam comprises a 70m high embankment consisting an inclined clay core and an outer colluvial gravel shell. A design for tailings storage for the remaining mine life requires a 40m high, 1000m long downstream raise to the embankment in four stages.
The critical design case included up to 20m of water ponding against the upstream face. The location of the clay core in the raised embankment is constrained by the existing inclined core. Iran is one of the more seismically active regions in the world, and with only hydrostatic loading, the undrained shear strength of the clay was low and the resultant seismic factor of safety unacceptable.
Instead of clay, it was concluded that a cross-section consisting of a thin membrane sealing system on a rockfill embankment would be a more stable arrangement. Assessment and analysis of options is discussed. From a construction, performance and cost point of view an exposed cover was preferred, and due to its superior mechanical and durability properties, a 3mm thick PVC geocomposite represented the optimal GSS solution.
Innovations include the face anchorage system which fastens the geocomposite to a base of extruded porous concrete curbs constructed integrally with the embankment rockfill. GSS connection details with the existing core and rock abutments are discussed, as well as leak detection instrumentation. Construction of the raise is currently underway, with the first stage recently under completion as planned.

The system foresees an exposed PVC liner, anchored to the upstream face of the dam along vertical continuous anchorage lines, and watertight fastened along all peripheries, as some photos in the following chapters describe.The system includes Carpi patents

4.1 WATERPROOFING GEOCOMPOSITE

The impervious liner proposed by Carpi is a geocomposite formed by a specially designed low permeability PVC geomembrane heat-laminated during fabrication to a geotextile.

The PVC geomembrane has the purpose of providing watertightness, maintaining its imperviousness and resistance characteristics over time. The PVC geomembrane, with elongation at break > 200%, no yield, and high flexibility, will allow accommodating the tensile stresses (differential deformations, stretching, etc) and minimise the potential of fatigue phenomena.
The geotextile is a multi-function layer:

- It increases puncture resistance;
- It increases friction stability in respect to sliding, facilitates the positioning of the geocomposite, and decreases the potential for stretching, due to its high friction angle on the base layer;
- It provides drainage capability on the backside of the geomembrane, reducing the risk of uplift;
- It eliminates the potential for wrinkling due to temperature variations.

For the first phase of DUGALD RIVER dam, 33 m high, CARPI proposes the geocomposite SIBELON CNT 3750, consisting of a 2.5 mm thick PVC geomembrane coupled to a 500 g/m^2 geotextile. The geocomposite is manufactured exclusively for CARPI, with a Carpi proprietary

formulation and under ISO 9001 certification to guarantee constant and controlled quality.

The geocomposite proposed has weathering characteristics totally compatible with a very long service life. The PVC geomembrane is resistant to ultraviolet attack, to deterioration under the alkali environment of damp concrete, and to degradation from organic and bacterial growth. The PVC geomembrane has sufficient flexibility to be field welded and lapped as required in the field at temperatures ranging from -20 to +60 degrees Celsius. The geotextile is treated so that its perfect adherence to the PVC does not hamper its transmissivity and therefore its drainage capability. The geocomposite is resistant to punctures and tears during handling, installation and operation. The same type of geocomposite is used by CARPI for all installations on dams of all types.

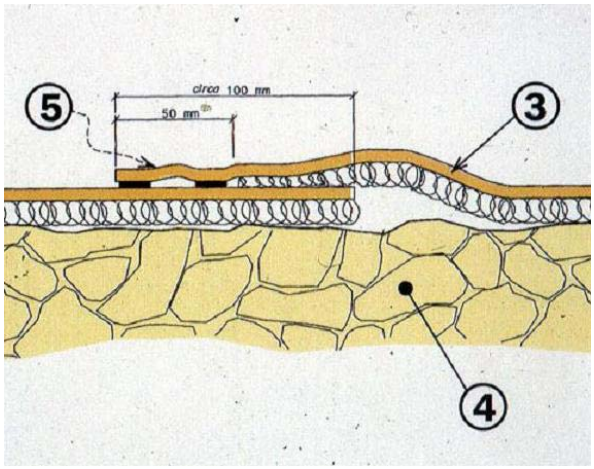
The SIBELON CNT 3750 geocomposite is supplied in standard 2.10 m wide sheets that can be prefabricated in larger panels to expedite installation if needed. The PVC sheets/panels, usually prefabricated in length equal to the length of the slope to be covered, are temporarily fastened at top by embedment in a trench created in the embankment, and hence unrolled down to the upstream toe. Each sheet has a custom made length, and is placed vertically from the dam crest. For DUGALD RIVER, Carpi has foreseen to assemble 6 m wide panels by watertight heat-welding 3 sheets of 2.1 m standard width.





Installation of standard 2.1 m wide PVC geocomposite sheets on Bovilla dam, Albania 1996, and of 6 m wide PVC geocomposite panels on Moravka dam, Czech Republic 1999.

Adjoining sheets/panels are watertight heat-welded by specialised welder working on the dam face, by automatic two-tracks welding machines wherever possible, and manually by single track welding at points that are not accessible by the automatic machine (e.g. triple points). All watertight welds are checked with ASTM 4437 standard methods or equivalent. After all welds have been successfully tested, there is one continuous waterproof liner over the entire upstream face of the dam.





Schematic welding of double track automatic heat welding machine





100 % of welds are tested by air pressure. If required, welding is also possible in presence of rain

Temporary anchorage of the geocomposite to the base layer may be necessary till when the face anchorage system is in place. The sheets/panels can be temporarily ballasted against wind suction with lines of sand bags or concrete blocks tied along longitudinal ropes placed at about 4/6 m intervals, depending on the expected maximum daily wind velocity.

4.2 BASE LAYER

The performance, survivability and service life of a geomembrane system is greatly increased if the surface on which the geocomposite sits is adequate. This means smooth, free from too coarse elements, free draining, competent. A smooth surface allows a better and more regular placement of the individual geocomposite rolls as well as a more regular operation of the welding machine. The absence of extra size elements avoids overstressed patches on the PVC and ensures a uniform stress level across the liner. A free-draining support guarantees against the insurgence of uplift pressures which may dislodge the deck. Finally, a competent support allows the geocomposite adhering to the body of the dam providing an extra safety against wave and wind forces before of increased cohesion.

Details on base layer on which the geomembrane will be placed are not at present available. In any case, the layer should be stable and not erodible by rainwater. Workers should be able to walk on the base layer without provoking any displacement. A layer of gravel material, which is the same random fill which shall be processed to remove aggregates > 50 mm, placed on a slope, would be a suitable subgrade for the installation of the geocomposite. This solution was used at Bovilla dam.





Bovilla, Albania 1996: the waterproofing PVC geocomposite has been placed over a layer of gravel stabilized

with lean concrete. The dam is a rockfill dam 91 m high. For DUGALD RIVER, Carpi proposes that the base layer is constructed according to the so-called ITA method, which constructs as transition zone a curb wall consisting of continuous porous concrete curbs made by extruding equipment. The curbs are extruded at the upstream face, as the fill is being constructed. The ITA method has the advantage of constructing a stable and fairly regular slope in short times, of providing a transition zone of constant characteristics over the entire upstream face, and if necessary of permitting to install the waterproofing liner by stages, as the construction of the dam continues.

The curbs can be placed over the 2B layer, or also directly on the fill material. Adopting the curbs option can also allow to increase the slope inclination of the upstream face to a steeper face (e.g. 1: 1.5), with reduction in volume of fill and with reduction of quantity of geomembrane. The curbs are made of porous concrete, maximum size aggregate ½“, no sand, 70 kg/m^3 of cement.

A similar base layer has been adopted for example at Sar Cheshmeh tailings dams in Iran, where a Carpi exposed geomembrane system identical to what proposed for DUGALD RIVER is presently under construction, and at Karahnjukar CFRD in Iceland, where a Carpi covered geomembrane system was installed over the >40 m high toe wall and on the curbs at the horizontal joint between Phase 1 and Phase 2 face slabs, where major movement is expected.





Execution of base layer with extruded porous concrete curbs at Sar Cheshmeh tailings dam in Iran.





Execution of base layer with extruded porous concrete curbs at Karahnjukar CFRD in Iceland.

4.3 DRAINAGE SYSTEM

The permeability of the curbs and of the geotextile forming the geocomposite is sufficient to grant an efficient drainage of the geomembrane.

4.4 FACE ANCHORAGE

There are several solutions available for linear anchorage of exposed geocomposites on new embankment dams. The most technically and financially effective configurations are the following.

4.4.1 Punctual PVC anchoring wings

Anchorage is made by punctual "wings" of a PVC geomembrane or geocomposite, embedded in the base layer during construction. The PVC geocomposite liner is anchored to the PVC wings by heat-welding. This solution has been adopted at Alento 21 m high cofferdam in Italy.





Alento cofferdam. (Italy): Delivering PVC geocomposite rolls at the crest and the cofferdam fully completed. The cofferdam, due a several years delay in construction of the main dam, was twice overtopped by floods.



4.4.2 PVC wings anchored in form of continuous strips

Anchorage is made by anchor wings of a PVC geomembrane or geocomposite, embedded in the base layer during construction, in such a way as to form continuous parallel strips of PVC. The PVC geocomposite liner is anchored to the PVC strips by heat-welding.

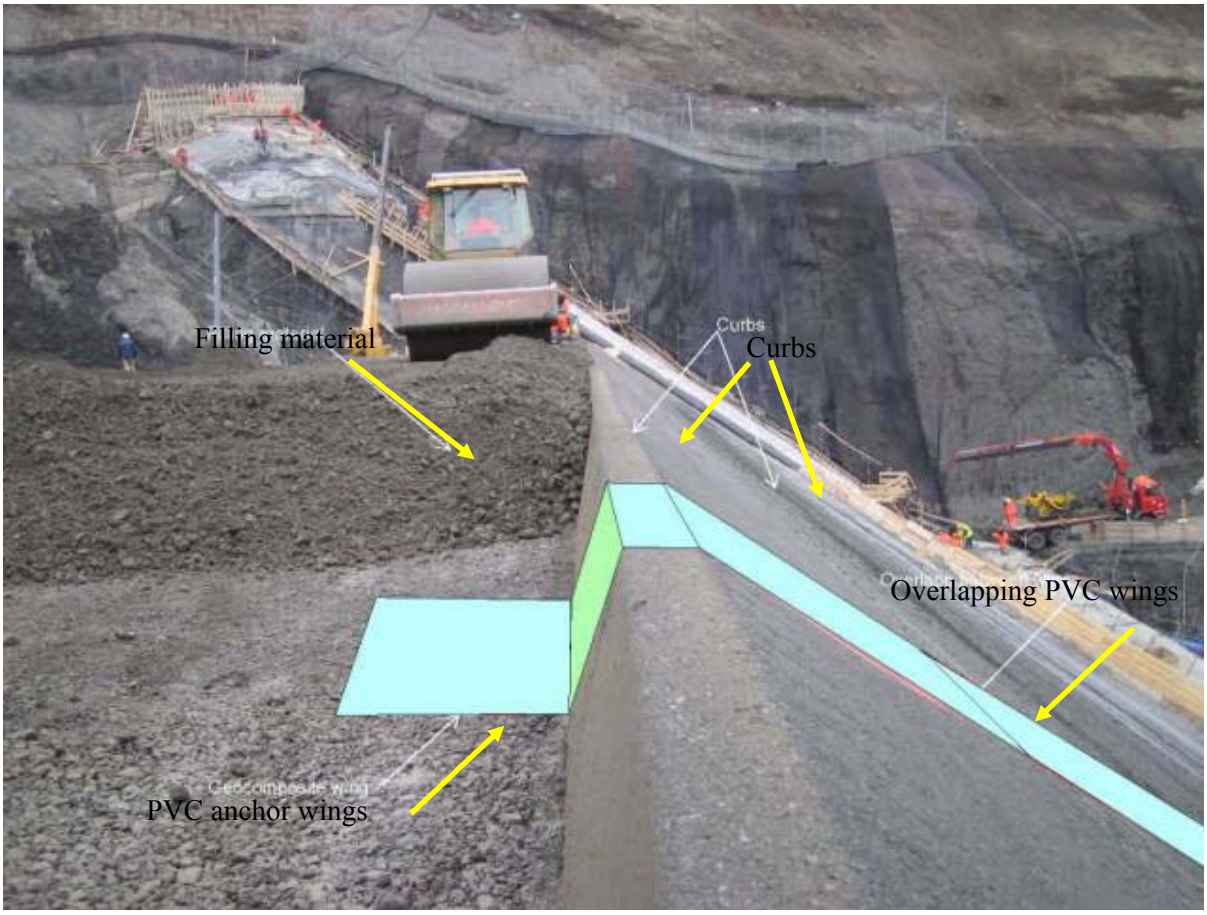





HPP Kohrang head pond reservoir, Iran. Installation of embedded anchoring PVC strips and reservoir completed.

4.4.3 PVC wings anchored in from of continuous strips in extruded curbs

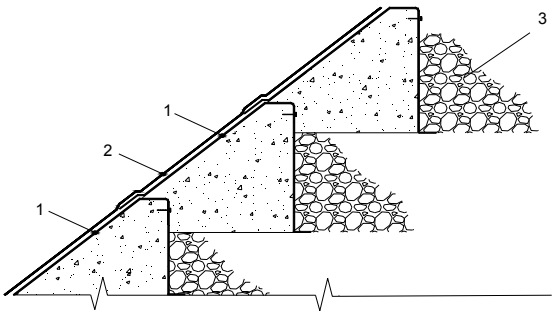
The waterproofing PVC geocomposite is anchored on the upstream face by heat-welding it to wings of PVC geocomposite that are embedded, as the dam is being built, in the extruded curbs that form the upstream facing, as shown in the following artist's impression. The PVC geocomposite wings are made with the same material of the waterproofing liner. The PVC wings, about 50 cm wide, are placed horizontally, over each line of extruded curbs, at site specific spacing. The wings are embedded in the extruded curbs, and exit at the upstream face so as to form one continuous vertical line of overlapping PVC wings, 50 cm wide and at the selected spacing. The overlapping wings are welded to each other, and as a result, the face of the dam will show continuous vertical lines of anchoring PVC geocomposite, 50 cm wide, at selected spacing, anchored into the dam by embedment. The waterproofing geocomposite is anchored by heat-welding over these PVC anchorage strips.



The PVC anchor wings are placed over the curbs, and then fastened to the dam by the ballasting action of the filling material.

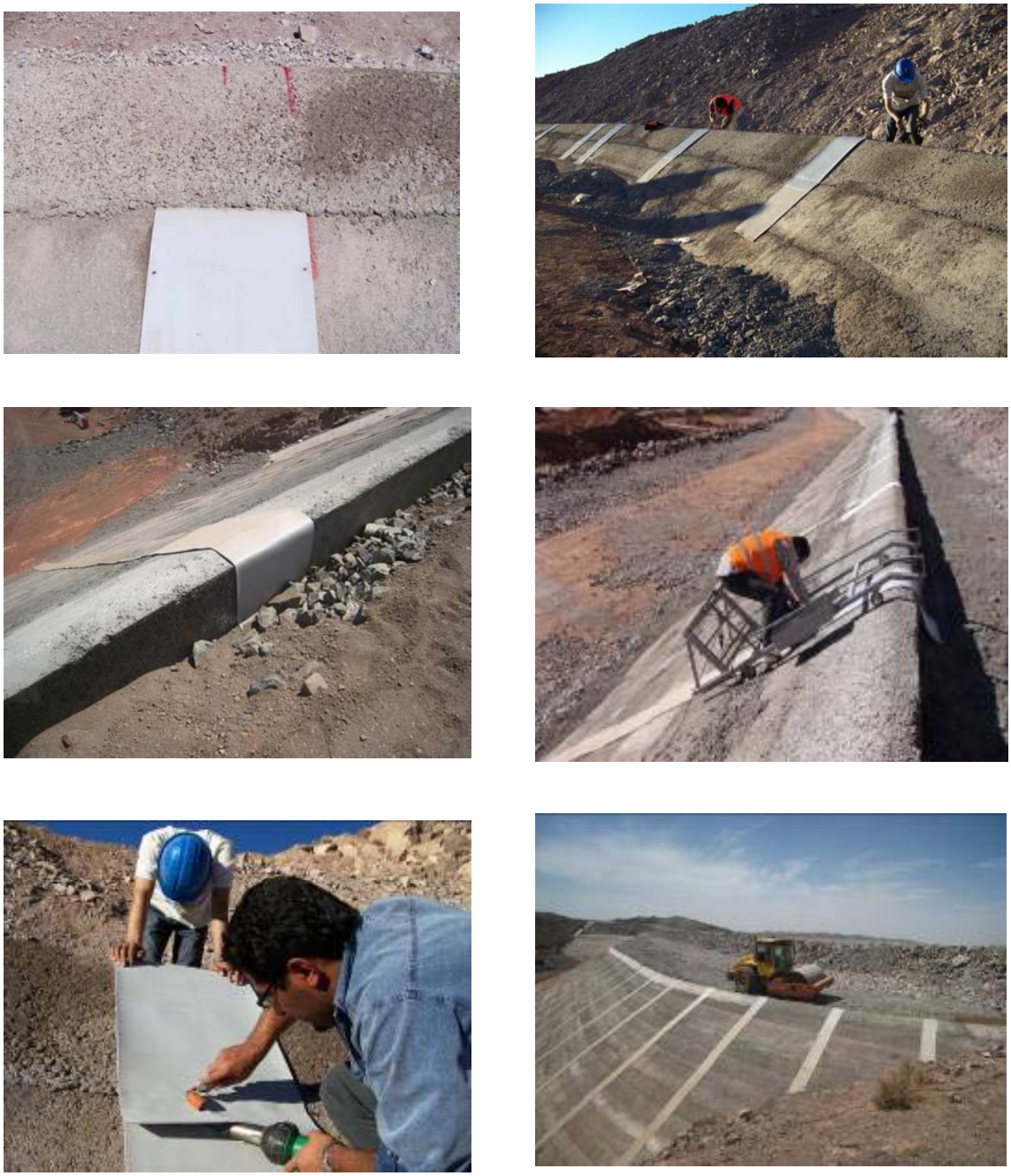
4.4.4 The face anchorage system for DUGALD RIVER dam

To fully exploit the time and costs savings that the exposed solution can provide, Carpi proposes to adopt the solution with PVC anchor wings embedded in the porous concrete curbs as they are being constructed. The wings will be placed at about 5.70 m spacing. The waterproofing PVC geocomposite will be anchored to the dam body by heat-welding it to the PVC anchor wings at 5.70 m spacing. The proposed spacing allows for a maximum wind design speed largely in excess of 100 km/h



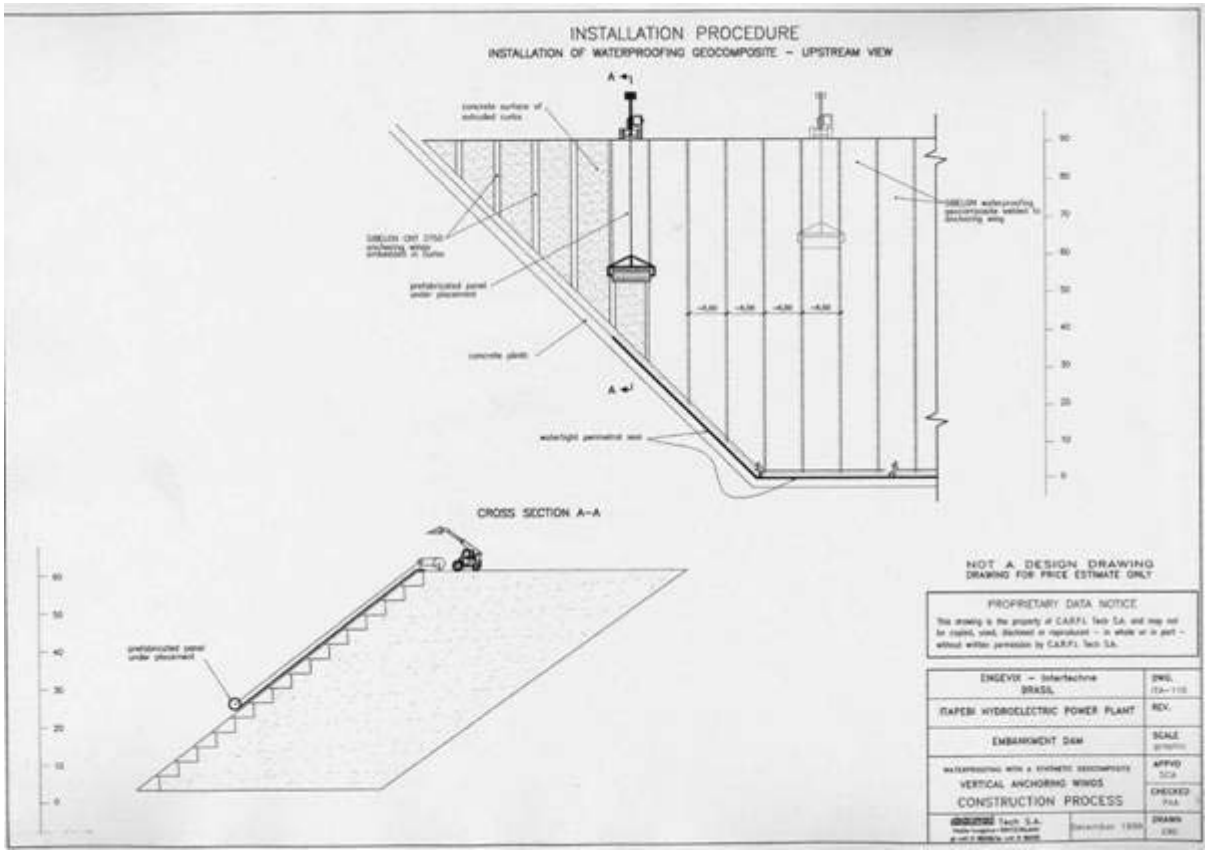
1. PVC anchor wing
2. Waterproofing PVC geocomposite
3. Transition material

The configuration proposed for DUGALD RIVER dam is totally similar to what is currently under construction in two independent steps at the 18.5 m Stage II B & C raising of Sar Cheshmeh 1 km long tailings dam in Iran, which will be followed by further Stage III and Stage IV raising, for a total of 39.5 m of heightening.



Sar Cheshmeh, Iran 2007-2008: PVC anchor wings embedded in the porous concrete curbs during construction of the raised dam (top left). Superimposed wings are welded to form a continuous vertical anchor strip (top right). Vertical strips are placed at 5.70 m spacing (bottom left). Permanent anchorage of the wings to the dam is made by compacted ballast (bottom right).

In the proposed solution, the embankment can be constructed without interruption. When it has reached the full height, then the PVC geocomposite sheets/panels are unrolled from the crest and placed so that they overlap on the PVC anchor wings, as shown in the following scheme.



Installation scheme of the exposed PVC geocomposite over the PVC anchor wings.





Sar Cheshmeh, Iran 2008: PVC sheets are positioned over the PVC anchor wings.

The PVC sheets/panels are then heat-welded over the PVC anchor wings to achieve permanent face anchorage. Adjoining PVC geocomposite sheets/panels are then watertight heat-welded, in order to construct a continuous watertight liner over the entire upstream face of the dam.





Sar Cheshmeh, Iran 2008: at left one PVC sheets being heat-welded to the PVC anchor wings to permanently anchor it to the dam body. At right the adjacent PVC sheet is overlapped on the one already anchored, to be watertight welded on it.

4.5 BOTTOM ANCHORAGE

Bottom anchorage must allow the watertight liner elongating at this crucial location. Two configurations are possible. The 'INSERT' solution embeds a PVC geomembrane strip in a longitudinal slot created in the plinth. The waterproofing geocomposite is heat-welded to the strip. In alternative, the tie-down mechanical anchorage can be adopted: the PVC geocomposite is anchored on the concrete plinth with a watertight seal made by flat batten strips compressing the PVC liner on the concrete of the plinth. To achieve watertightness, the concrete is regularised with a resin bedding mortar, rubber gaskets are placed under the entire length of the batten strips, and distribution plates between abutting batten strips.
For DUGALD RIVER dam Carpi proposes the tie-down mechanical anchorage, with an 80 x 8 mm stainless steel batten strip, anchored by chemical phials at 0.15 m spacing.





Bovilla, Albania 1996: detail of the watertight anchorage at the toe beam. At right, the fill material covering the anchorage, which has been installed over a protection geotextile and anti-friction membrane. The elongation properties of the PVC geocomposite (elongation at break exceeding 200%) allowed withstanding the differential movements at toe.

In the bottom area where the waterproofing liner will be backfilled, an 800 g/m^2 anti-puncture

geotextile will be installed over the PVC geocomposite before placement of material 1A.

The tie-down mechanical anchorage, with an 80 x 8 mm stainless steel batten strip, will be installed at any other submersible appurtenances, such as at the intake, if any.





Bumbuna rockfill dam, Sierra Leone: Carpi exposed PVC geocomposite has been installed in the area of possible opening of the joint between the concrete plinth and the asphalt concrete facing. The SIBELON CNT 3750 geocomposite and the watertight anchorage at the perimeter are identical to what proposed for DUGALD RIVER dam.

4.6 TOP ANCHORAGE

The top anchorage of the PVC geocomposite can be made of the tie down type, placed on a conventional concrete curb or at concrete parapet wall, or by embedment in a top trench. For DUGALD RIVER dam Carpi proposes anchorage by embedment in a top trench.



Bovilla, Albania 1996: the PVC geocomposite anchored by embedment in a top trench.
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5 COVERED GEOMEMBRANE OPTION

5.1 WATERPROOFING GEOCOMPOSITE

In case there is a concern for vandalism, the geomembrane can be covered.
The presence of a cover layer DOES NOT allow using thinner geomembranes as loads and stresses during placement of the cover are usually higher than those exerted by the hydrostatic head during operation. A protective layer can have detrimental aspects in the:
Risk of damage to the geomembrane while the cover layer is being laid;
Need to remove the cover layer if inspection and/or repair of the geomembrane are needed.

SIBELON CNT 3750, as for the exposed option, is proposed also for the covered option. The only difference will be a reduced UV resistance, but long enough to allow placement of cover layer without

that the properties of the material are affected.

5.2 BASE LAYER AND DRAINAGE

The base layer will be the same as for the exposed solution. A transition geotextile is not needed due to the presence of the 500 g/m^2 geotextile laminated to the PVC geomembrane.

5.3 FACE ANCHORAGE

In the covered system, anchorage is provided by the ballasting action of a cover layer placed over the geocomposite. The cover layer also provides total protection to the geocomposite against environment aggression, be it impact damage after impounding, wind suction, ultra violet radiation, fatigue damage from repeated lifting by wind and waves, uplift pressures, wilful damage, animal passage, impact damage after impounding.

As water can infiltrate through the cover layer and through its joints, drainage must be provided under the cover, so that the pressure of water trapped between the cover and the waterproofing geocomposite, especially on drawdown, does not lift the cover. The interface and the friction between the various layers shall be checked for both dry and wet conditions.

Different materials and configurations are possible for the cover layer:

5.3.1 Random fill and Riprap

This is a multi-layered configuration made by a transition anti-puncturing layer placed over the geomembrane, and by the riprap. The transition layer generally involves the use of one relatively thick geosynthetic + smaller size aggregates (sand or gravel), or just one thick and robust layer of geosynthetic materials, such as a very thick geotextile or a rubber mattress. Design must address the stability of the multi-layered configuration based on the slope and operation of the reservoir, to avoid that the action of waves and fluctuating water level can displace the various layers. Placement can be very expensive and time consuming due to material supply and selection, and to precautions to be taken during placement, to avoid damaging the geomembrane.

5.3.2 Concrete slabs and concrete blocks

These are articulated configurations: the main purpose of constructing the slope protection as an articulated pavement is to make it flexible enough to adjust to the expected embankment settlement without severe cracking. The concrete cover can be made of cast-in -place concrete slabs or made up of precast concrete units placed side by side. Cast-in-place concrete generally entails lower risk of damage to the geomembrane, as precast slabs induce higher concentrated stresses on points of contact with geomembrane. The thickness of the slabs may vary between 0.30 m and 0.08 m.





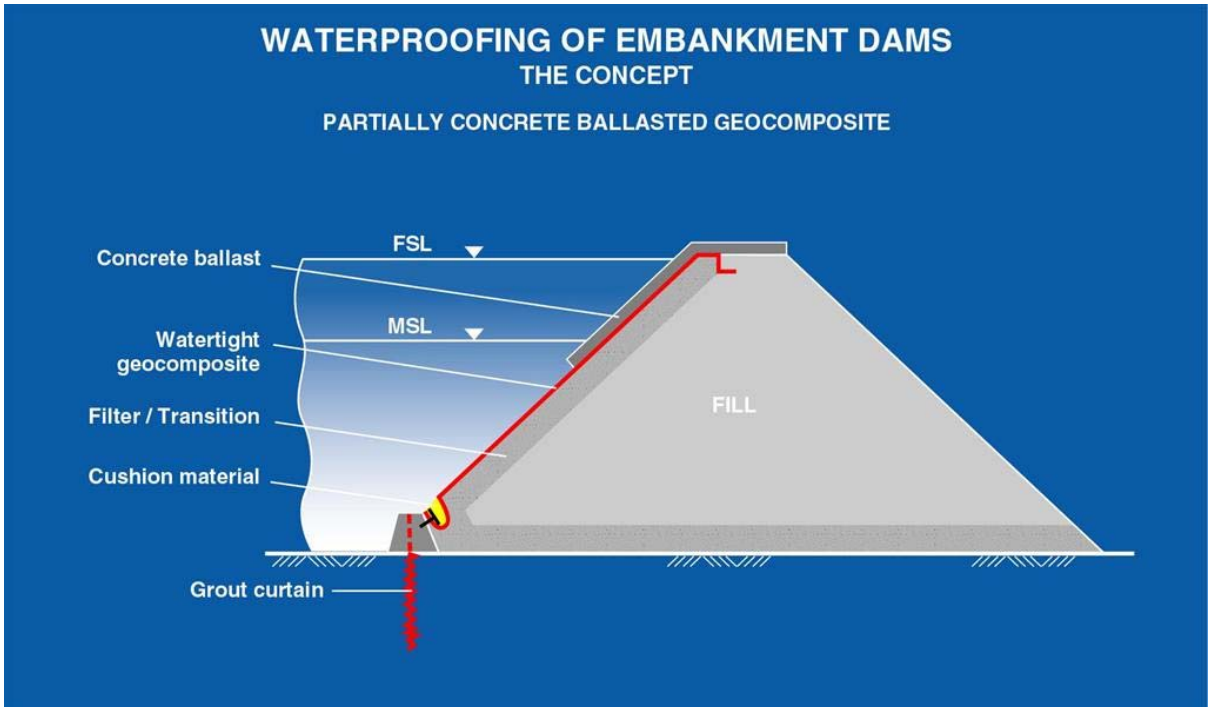





Rouchain dam, the existing damaged bituminous geomembrane has been substituted over the whole upstream face with a Carpi PVC geocomposite covered by a reinforced concrete layer. The most difficult part of the

design has been the connection of the deformable upstream face with the rigid concrete tower. Since 1994 performance is excellent

It is also possible to anchor at crest a light concrete layer, thus to limit the cover only to the fluctuation zone

















Herbes Blanches dam and reservoir, (Reunion Island, France). The PVC geocomposite has been covered on the slopes by a reinforced concrete layer anchored to the crest for a limited length of the slope. A similar concept will be used at Dumanoir dam and reservoir (2008, Guadaloupe, France, 420,000 m2 of PVC geocomposite and other geosynthetics, in 5 layers) and at Les Arcs (2008, Savoie, France, 350,000 m2 of PVC geocomposite and other geosynthetics, in 5 layers)





Jibiya dam, Nigeria. The PVC geocomposite has been covered by an unreinforced concrete layer, made in slabs, 8 cm thick, cast in situ (by Sembenelli)





Cixerri dam, Italy. Installation of prefabricated concrete over PVC geocomposite (by Sembenelli)

The PVC geocomposite can also be covered by aggressive layers without being damaged





Dyonisen canal, Austria

5.3.3 Composite systems

These systems, which have various configurations including generally a synthetic material associated to a traditional filling material, are generally thinner and lighter. They can be mats and tubes filled with lean concrete, lean sand asphalt or clay granules; fabric mattresses, laid in place when empty, joined together and then pumped full of concrete; geocells, geogrid reinforced geomats that are then filled with shotcrete. Their advantages are a generally moderate initial cost and for some of them a fairly good flexibility, disadvantages a somehow higher susceptibility to ageing and damage and for some of them little flexibility.

5.3.4 Proposal for DUGALD RIVER dam

For the cover layer at the DUGALD RIVER dam, Carpi proposes: a single layer of low paste concrete placed on an anti-puncturing geotextile, as adopted at Bovilla. The type and size of aggregate can be modified depending on the specific requirements of the project, as the only key elements are the layers immediately above and below the geocomposite, which shall provide anti-puncturing properties. The concrete slabs will have open articulated joints to allow drainage, as adopted at Bovilla.

An 800 g/m^2 geotextile will be installed over the PVC geocomposite before casting of the concrete cover slabs. The geotextile will act as an anti-puncture layer protecting the PVC geocomposite during casting of concrete, and as light reinforcement for the concrete cover itself.




Bovilla, Albania 1996: the concrete slabs during casting over the anti-puncture geotextile.

5.4 BOTTOM AND TOP ANCHORAGE

As for the exposed option.

6 SCHEDULE

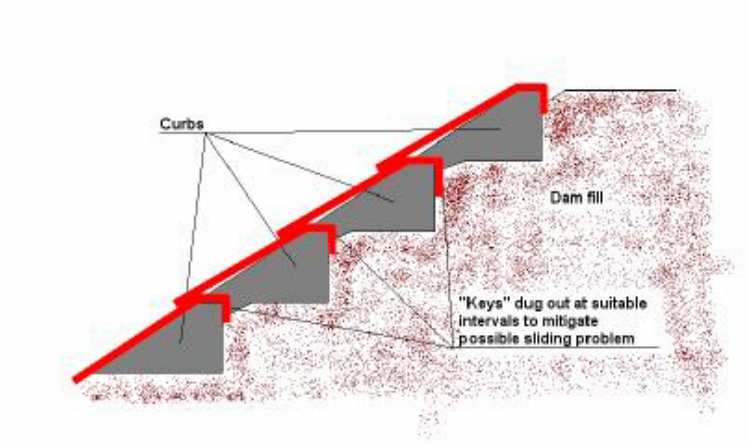
Installation executed in 1 campaign. Carpi has considered 1 full day of bad weather per month (10 hours per person per month), during which it will be impossible to work. Additional days of bad weather or delays due to interruption/disturbance by any other activity not strictly related to waterproofing works and for which Carpi is not responsible, entails an automatic extension of the completion date, without penalties to Carpi. Additional costs incurred by Carpi due to interruption/disturbance will be reimbursed by the Client according to daily rates.

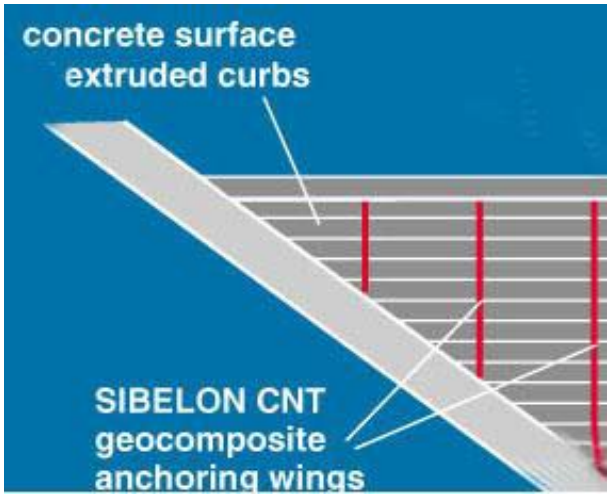
6.1 GENERAL SCHEDULE

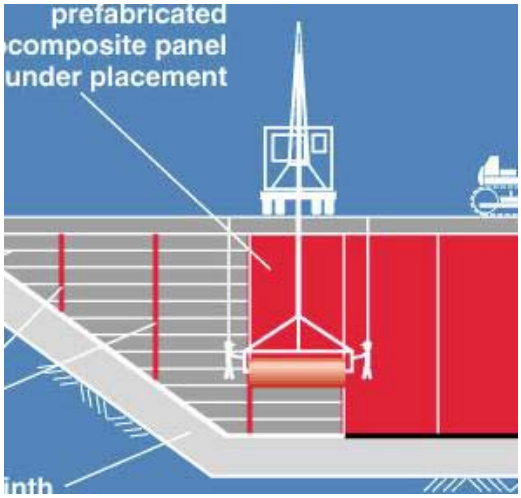
Final detailed drawings: 1 month.
Manufacture and delivery of materials: within 3 months after approval of design.
- Shipment of materials and equipment: 3 months
- Placement of geomembrane: 3 weeks (6,560 m2).

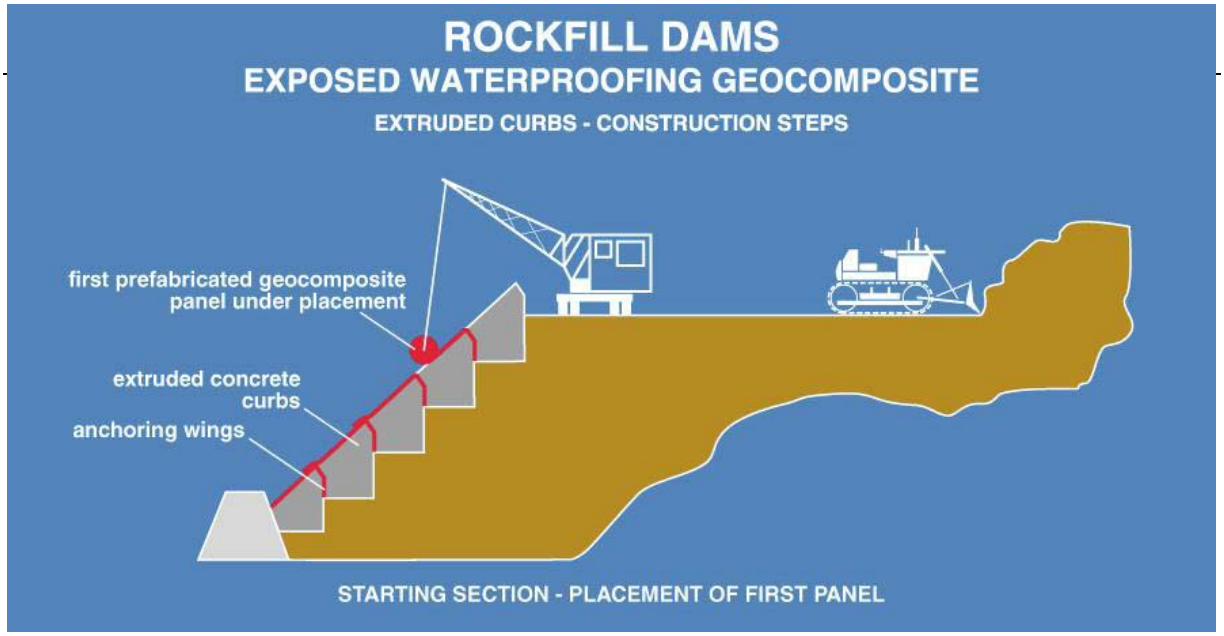
The total time required by Carpi to perform the installation of the waterproofing system is based on daytime shift only.

The placement of the exposed geomembrane system can occur concurrent with the fill placement therefore the installation is NOT EXTENDING the total dam construction time









The sketches show the main installation steps, including how the PVC geocomposite can be insalled while placement of the fill continue in other arts of the dam body

Carpi has assumed that installation will be made in weather conditions that:
- Allow safe handling of rolls, with maximum wind velocity in the days when geomembrane rolls will be placed not superior to 25 km/h maximum
- Allow welding of the geocomposite system, with minimum and maximum air temperature in the welding period between +5° and +30 ° C, and no rain.

Factories for production of geomembrane, of fastening system and of the other items are normally closed every year for scheduled maintenance/inventory between Dec 20 through Jan 10 and between Aug 5 and 25.
Those days are excluded from the manufacturing time.

6.2 CONSTRAINTS FOR INSTALLATION

The installation of the waterproofing system on the face of the dam shall be executed with no interference to Carpi activities by other parties in the section where geocomposite installation is ongoing. Activities carried out by the Main Contractors, by his sub-contractors if any, and by Carpi, shall therefore be coordinated to avoid such interference. The crest of the dam shall be fully accessible by Carpi personnel at least in the section where geocomposite installation is ongoing. No other construction activity shall be conducted on the crest, on the face, and on foundation, where Carpi is performing its installation work. Subsequently, no work will be done overhead and below of Carpi activities and there will be no interference with Carpi activities on the upstream face of the dam under installation. Any activities on the foundation, face or crest of the dam shall be at least a 10 m radius horizontally from Carpi activities and equipment, to minimize disturbance and/or risks to Carpi personnel.
If these constraints are met this means the geocomposite system can be installed in parallel with other construction works that should be going on in other parts of the dam.

7 PRICES

7.1 KEY ASSUMPTIONS FOR COSTING

To calculate the prices, Carpi has made the following assumptions:

1. Total waterproofed surface approximately 6,560 m^2..
2. Existing substrate compatible with installation of the proposed geomembrane system (sound stable surface, free from sharp roughness, irregularity and/or obstacles). Preparation made by

Main Contractor according to Carpi specifications

3. During waterproofing works the area is kept dry and there is no water other than rain on the upstream face and in all areas where access is needed
4. Carpi continuous access to the reservoir and to the working area without interruption/ disturbance by any other activity not strictly related to waterproofing works. Delayed civil works by the Main Contractor for surface preparation and/or lack of services as stated in chapter 7.3.2 "What is NOT included in CARPI's price and which shall be provided by the Main Contractor/Client FREE OF CHARGE to CARPI", are considered interruption/disturbance
5. Storage area at site, within 1.5 km from the dam, access by 30 t truck
6. Protected and secured storage area for small materials and tools, free of charge, within 500 m from the dam
7. The installation will occur in the dry in 1 phase, without any interference by other works or activities
8. Carpi will have unlimited unrestricted and priority access to dam section where it is installing the geocomposite. Carpi will take into account in the organisation of its works the simultaneous execution of other works according to a programme of works to be agreed by the Parties and based on the content of chapter 6.2 "Constraints for installation"
9. Carpi full and unrestricted use of the temporary/final crest of the dam. The Main Contractor is responsible to provide full access to Carpi to the areas of installation of the waterproofing system for all the duration of waterproofing works
10. Installation of the exposed geomembrane will be performed by Carpi from rope stairs secured to the dam
11. Prices and payments are in Euro + VAT
12. Prices are for contract awarded directly to Carpi, without any fees/ mark up by a General Main Contractor (usually 30 to 100 %)
13. Works executed by Carpi approved crew
14. Carpi shall not register as a company in Australia
15. The Client shall secure visa and working permits for Carpi foreign staff and management
16. Contract is FIDIC type, unit prices by executed quantities
17. Language of contract and communication is English.

7.2 WARRANTY

Carpi will provide a warranty of 10 years on materials and 2 years on installation. The 10 years warranty, which is covered by insurance for a value up to 5,000,000 Euro, is not a functional warranty, it is the maximum amount and time that insurance companies accept to issue on materials. The functional warranty is practically granted by the works executed by Carpi with exposed geomembranes all around the world, which provide evidence of functionality in normal operating conditions longer than 30 years.

7.3 PRICES (IN EUROS)

7.3.1 What is included in CARPI's price

The above price is a turn-key price. It includes

1) Preliminary inspection and meeting with the Client (up to 1 meeting before awarding of the contract)
2) Final detailed drawings of the Geomembrane Sealing System
3) Royalties on Carpi patents as applicable
4) Submit an affidavit that materials meet all specifications
5) Prior to start installation, one inspection of the site to asses if all requirements are met
6) Supply of all the materials that concur to form the new waterproofing system (waterproofing geocomposite and geomembrane for the facing and for the embedded anchor wings, stainless steel

batten strips and geomembrane material for the perimeter seals, anchors, gaskets, bedding resin, etc).
7) Internal QC certificate for geomembrane material by manufacturer
8) Standard QC certificates for the other materials, as provided by sub-suppliers
9) Provide small equipment and tools needed for installation
10) Provide periodical technical assistance to the Main Contractor when he installs the PVC anchor wings on the curbs. Carpi price includes a training period of 2 weeks during which a Carpi technician instructs the Main Contractor's crew on how to cut and anchor the wings. Extra assistance by a Carpi expatriate technician if needed will be charged
11) Provide all labour required for installation of the geomembrane system (daytime shift only, 10 hours / day, 26 days/month). Carpi plans to use expatriate technicians/welders familiar with the Carpi system, and local workers. The labour rates include all salary, social charges, insurance, fringe benefits, holidays, travelling expenses, etc.
12) Perform installation according to the Carpi Quality Control Plan (QCP) which will be part of the contract. Carpi QC inspector permanently resident on site
13) Provide project management. Carpi site agent permanently resident on site during installation of geomembrane system
14) Costs for phone charges from office trailer
15) Relevant quality control certificates and internal quality control
16) Provide written warranty of 10 years on materials and 2 years on installation of the geocomposite and accessories. Warranty is based on receipt of full and timely payments
17) As-built documentation
18) Standard Contractor Insurance.

Carpi has assumed that the following facts shall apply:
- Carpi shall not register as a company in Australia
- Carpi shall obtain, through the Client, and without restrictions, working permits for Carpi foreign staff.

7.3.2 What is NOT included in CARPI's price and which shall be provided by the Main Contractor/Client FREE OF CHARGE to CARPI

1) Construct the body of the dam, the plinth and the cutoff according to the design and planning agreed
2) Perform grouting curtain as required
3) Water management to keep the upstream face dry for the entire duration of the works
4) Remove of all debris and cleaning and compaction of the surface
5) All kinds of earth and civil works, such as but not limited to placement of base layer according to technical specifications provided by Carpi, regularisation of offsets where needed, placement of cover material at bottom and placement of cover layer as required / applicable (including anti-puncture geotextile), etc.
6) Pay custom duties and other relevant costs, related to importation in Australia of all the permanent materials for the waterproofing system, and for temporary importation of installation equipment and tools
7) Transport of all materials equipment and tools from main port in Australia to job site, at the point of use
8) Survey crew for correct positioning of PVC anchor strips
9) Placement of the PVC anchor wings on the curbs
10) Provide protected and secured storage area at site, where permanent materials will be stored
11) Download and place in storage and secured area (200 m2) all materials and equipment delivered to site
12) Provide one locked and secured 20 m2 room for storage of small metal parts, resin and tools, at

site, within 500 m from the works
13) Provide a clean stable area to allow prewelding and re-rolling of rolls. Depending on weather conditions the area could be covered
14) Lifting equipment and personnel to unload and store at the time of delivery permanent materials, equipment and tools from the containers/trucks in the storage area
15) Handling and transport of the needed materials from the storage yard to the installation area, according to what requested daily by Carpi
16) 1 mobile crane with operator, minimum lifting capacity 4 tons, for the total duration of waterproofing works at site
17) Provide local labour (estimated up to 6 local workers) to help Carpi in simple installation operations and for transporting all needed materials on the face of the dam where it will be required
18) Electricity: 380 V and 220 Volts, 50 Hz, 15 KVA total, at 1 main switchboard located near the works and cables which reach the entire working area
19) Lighting if required
20) Provide food and lodging for Carpi site management and Quality Control (1 per room, total 2 rooms), expatriate technicians (2 per room, total 3 rooms) at camp site. Camp site located within 15 minutes from the site. 3 hot meals per day. Same conditions apply for Carpi technical management visiting occasionally the site
21) Provide transport for Carpi personnel from/to international airport to the site and within the site
22) Local transport for CARPI's expatriate personnel (3 cars permanently available 24 h/day to Carpi with a limit of about 50 km/day average (e.g.: 70 days x 50 km/day = 3500 km) for the entire stay of the Carpi expatriate crews in Australia). Minimum requirements for cars: 4x4, >1,600 cc, 5 seats, not older than 3 years, < 50,000 km, in good working conditions
23) Office trailer (20 m2) and stock container (16 weeks)
24) Provide 2 telephone lines and internet connection, for the entire duration of the works. Cost of telephone calls will be at charge of CARPI
25) Use of change room and lavatories for Carpi crew at the job site
26) Provide permanent assistance for solving electrical problems related to CARPI equipment and tools
27) First aid and sanitary assistance
28) Surveillance on job site
29) Provide containers and disposal for approx. 4,000 kg of waste materials (PVC geocomposite and steel parts). Carpi will place waste in the containers, waste disposal shall be made by Main Contractor at no cost for Carpi
30) Provide and pay for Third Party Quality Control, which is at Client discretion
31) All kind of local taxes concerning installation activities (i.e.: sale tax, income tax, residence permit, etc)
32) Pay cost for testing of geomembrane properties if required, at independent laboratory, approved by Carpi
33) Any type of bond, which is at Client discretion.

The costs that have not been included in our price usually represent a small percentage of the total amount.

Our estimate has included costs for the difficulty in working in an inclined area.

10 CONCLUDING REMARKS

The proposed solution will provide permanent waterproofing of DUGALD RIVER dam. While we thank you for the inquiry, we hope that the above provides a preliminary set of information and look forward to co-operate with ATC for the development of a perfect design and installation of a CARPI geomembrane system at DUGALD RIVER dam.

Very sincerely yours,

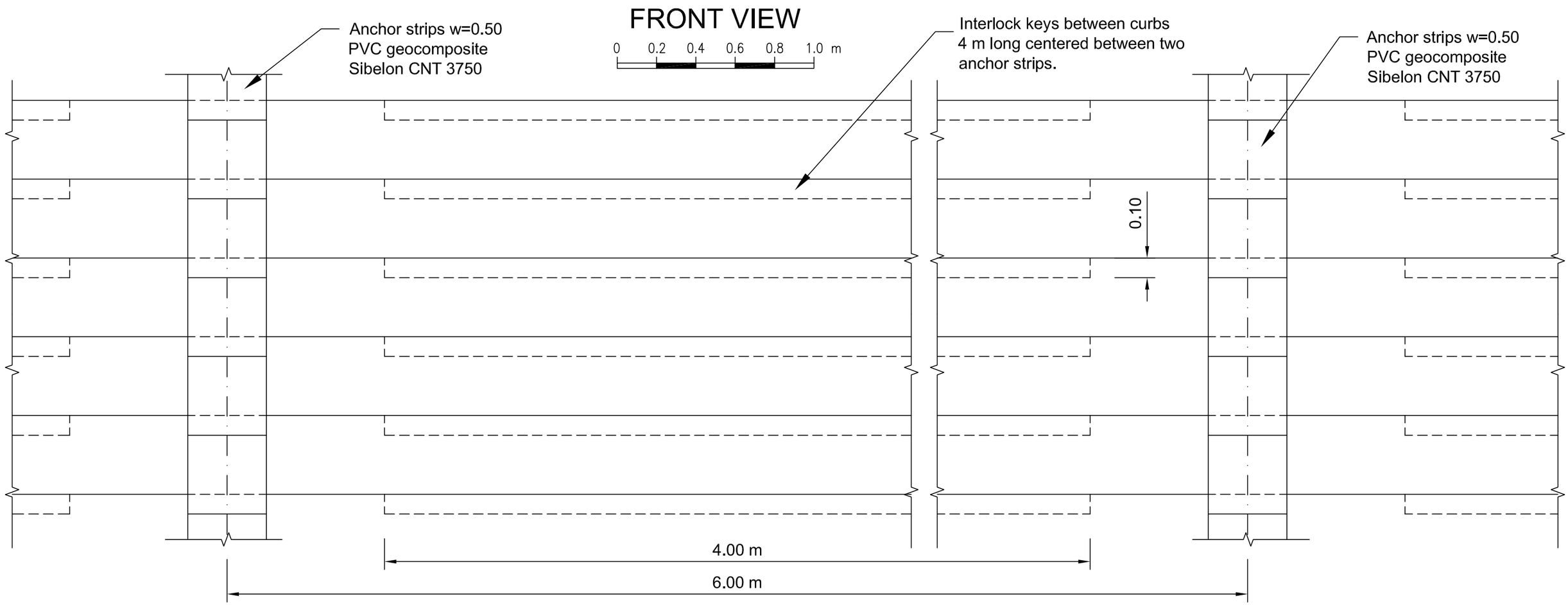


CARPI TECH BV. Amsterdam, Chiasso Branch

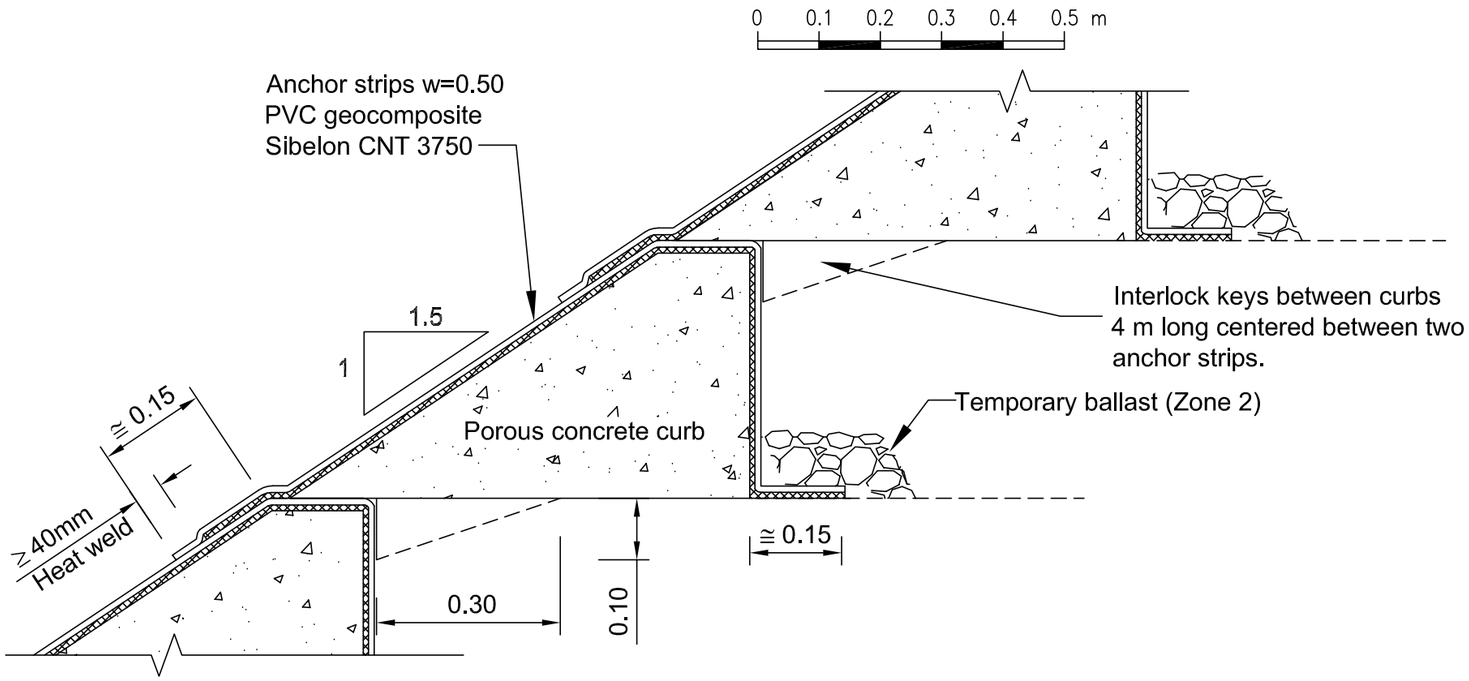
Alberto M. Scuero
Director

DRAWINGS

FRONT VIEW



TYPICAL SECTION ON ANCHOR STRIPS



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OZ MINERALS LIMITED	DWG. Carpi–1
DUGALD RIVER PROJECT FEASIBILITY STUDY	REV. 0
KNAPDALE VALLEY TSF – STAGES I – III	SCALE graphic
WATERPROOFING WITH A SYNTHETIC GEOCOMPOSITE CONSTRUCTION & INSTALLATION PHASES OF WATERPROOFING GEOCOMPOSITE LINER FACE ANCHORAGE DETAILS	APPVD SCA CHECKED PAA
carpi Tech S.A. Chiasso–SWITZERLAND ph ++41 91 6954000/fax ++41 91 6954009 — August 2008	DRAWN CRC

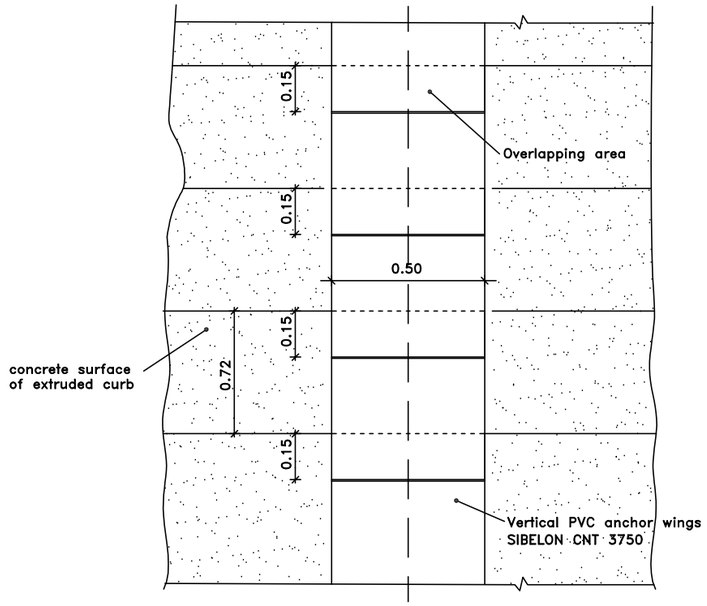
J:\2008\1108003 Dugald River\01 TSF Feasibility Study\Drawings & Figures\CARPI GSS DWGS\Carpi 1.dwg, 10/10/2008 2:18:00 PM

INSTALLATION PHASES OF GEOCOMPOSITE SHEETS

0 1 m

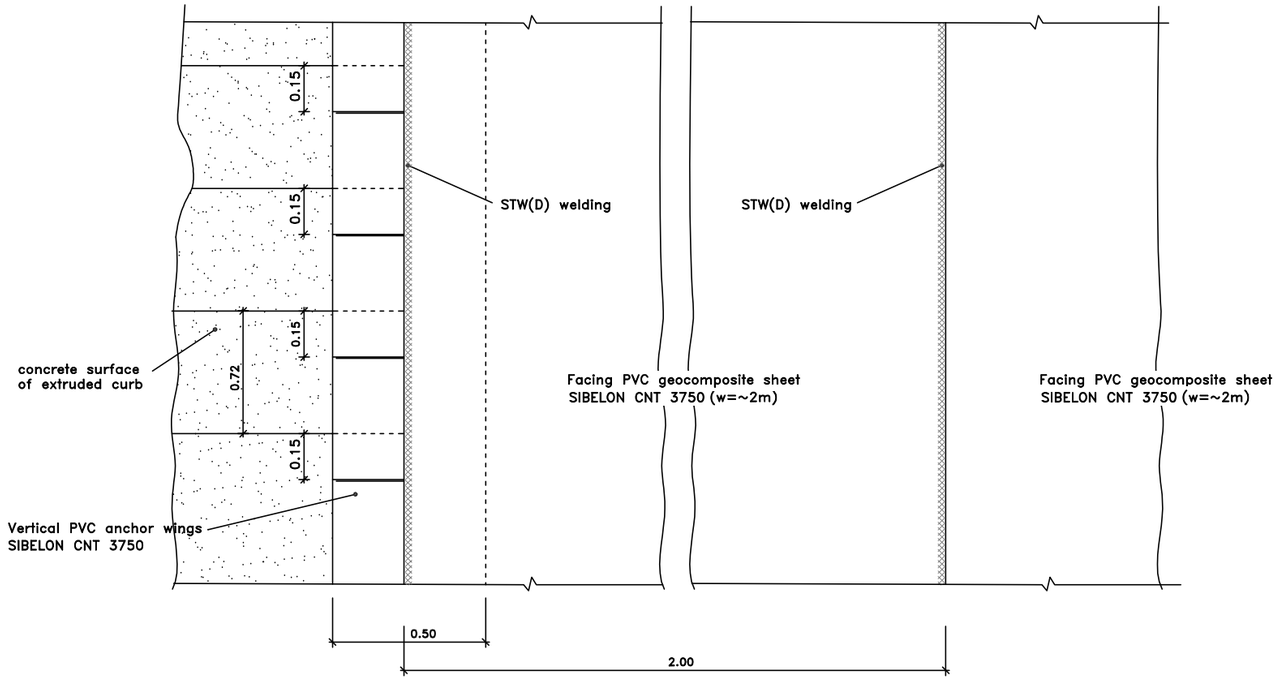
PHASE 1

Placement of PVC anchor wings embedded into concrete curbs



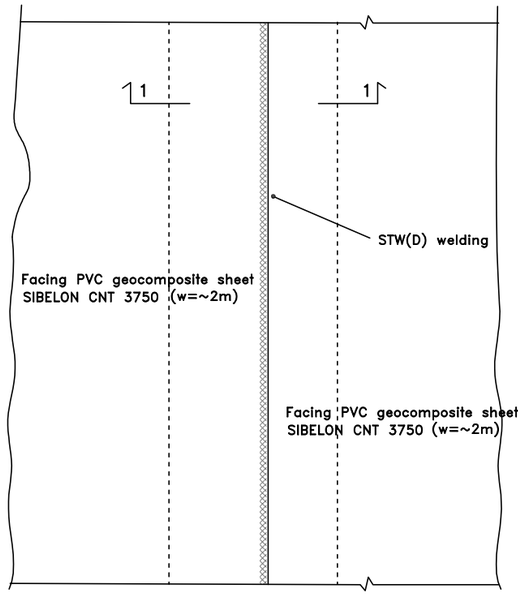
PHASE 2

Placement and welding of facing PVC geocomposite sheets

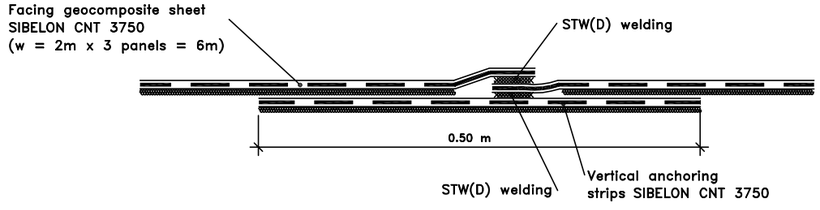


PHASE 3

Placing a new geocomposite sheet



DETAIL 1–1

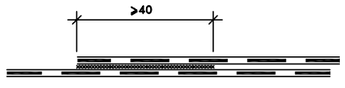


LEGEND

STW(D) – Single track weld (STW) executed on dam face (D)
Mechanical point stressing test

STW(D)

TYPICAL SINGLE TRACK MACHINE OR MANUAL WELD
Mechanical point stressing test



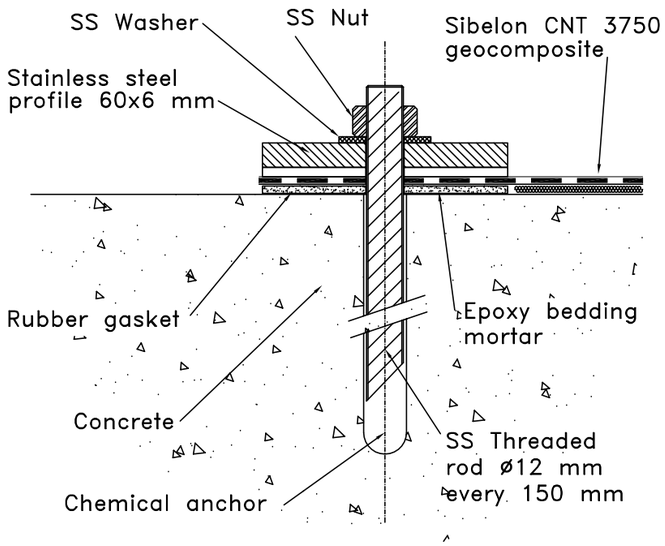
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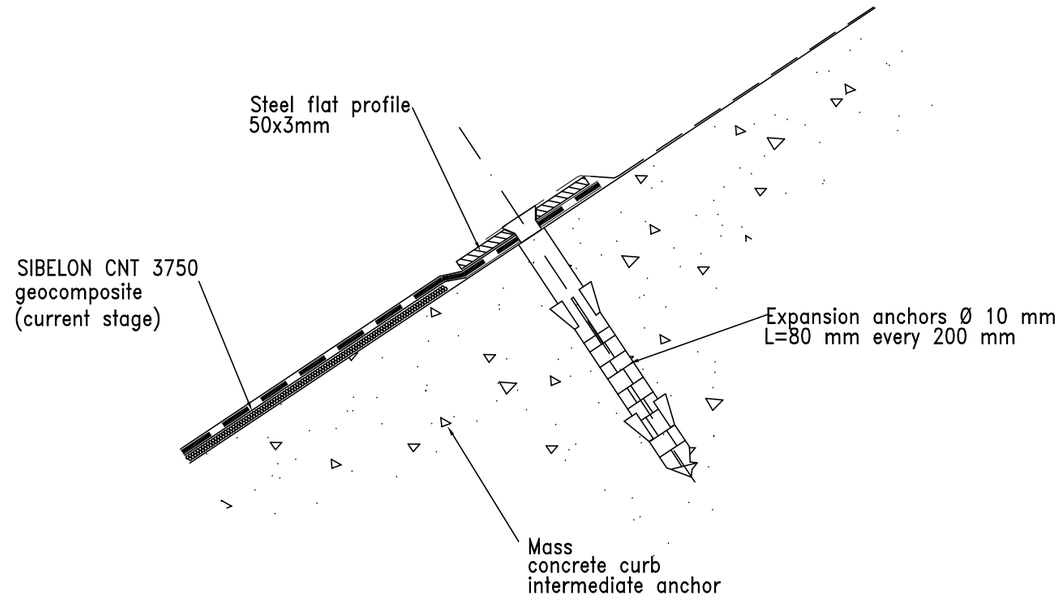
OZ MINERALS LIMITED	DWG. Carpi–2
DUGALD RIVER PROJECT FEASIBILITY STUDY	REV. 0
KNAPDALE VALLEY TSF – STAGES I – III	SCALE graphic
WATERPROOFING WITH A SYNTHETIC GEOCOMPOSITE CONSTRUCTION & INSTALLATION PHASES OF WATERPROOFING GEOCOMPOSITE LINER INSTALLATION OF GEOCOMPOSITE SHEETS	APPVD SCA CHECKED PAA
carpi Tech S.A. Chiasso–SWITZERLAND ph ++41 91 6954000/fax ++41 91 6954009 / August 2008	DRAWN CRC

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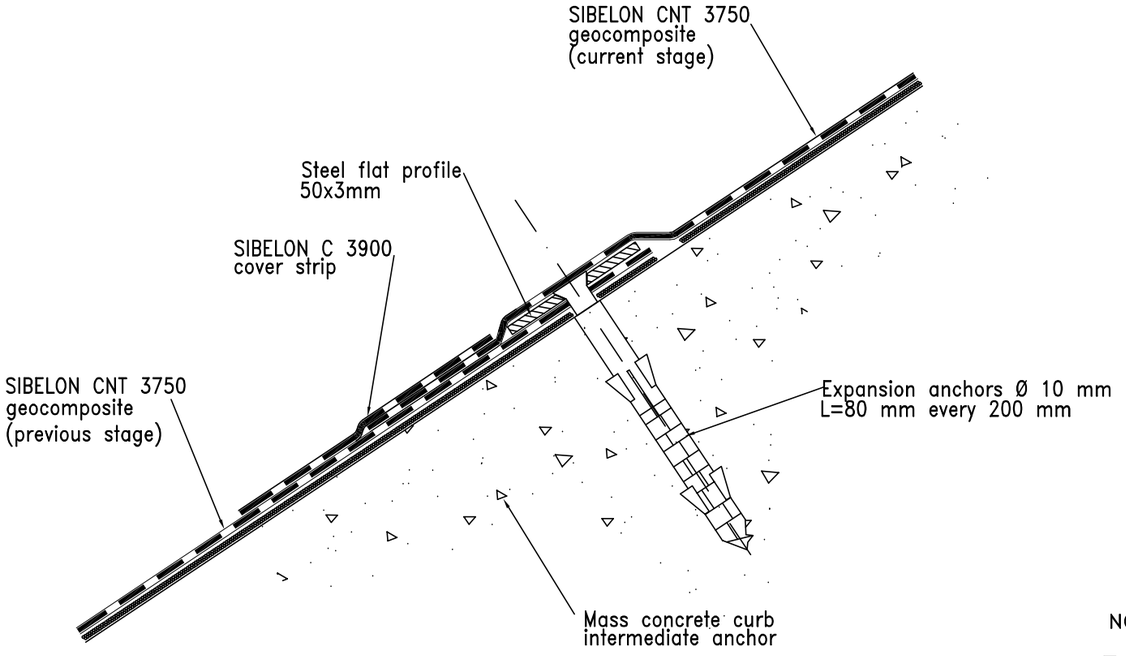
DETAIL "1"
(Lower perimeter plinth anchorage – Stage I)



DETAIL "2"
(Upper perimeter curb anchorage Stages I and II)



DETAIL "3"
(Lower perimeter curb anchorage – Stages II and III)



NOTE:

– All metalwork is made of stainless steel AISI 304 unless otherwise specified

0 20 40 60 80 100mm

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OZ MINERALS LIMITED	DWG. Carpi–3
DUGALD RIVER PROJECT FEASIBILITY STUDY	REV. 0
KNAPDALE VALLEY TSF – STAGES I – III	SCALE graphic
WATERPROOFING WITH A SYNTHETIC GEOCOMPOSITE CONSTRUCTION & INSTALLATION PHASES OF WATERPROOFING GEOCOMPOSITE LINER MECHANICAL ANCHORAGE DETAILS	APPVD SCA
	CHECKED PAA
carpi Tech S.A. Chiasso–SWITZERLAND ph ++41 91 6954000/fax ++41 91 6954009 / August 2008	DRAWN CRC

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APPENDIX H

GEOMEMBRANE SEALING SYSTEM – SELECTION PROCESS

This Appendix provides a summary of the rationale used in the selection of the adopted geomembrane sealing system (GSS) for the upstream face of the Dugald River TSF Main Embankment.

1 BACKGROUND

Research by ATC into GSS applications for embankment dams came about in 2004 as a result of a critical design issue with a large tailings dam raise project at the Sar Cheshmeh mine in central Iran. The existing inclined clay core embankment could not be raised using clay due to seismic instability.

A detailed study of water retaining elements other than clay was conducted, including asphaltic cores, bituminous and various polymeric membranes. It was concluded that a cross-section consisting of a thin geomembrane sealing system on a rockfill embankment would be the most stable, economic arrangement.

2 ASSESSMENT OF GEOMEMBRANE OPTIONS

2.1 Overview

In order to establish the criteria for the final selection of an upstream sealing system, a detailed study of the published literature was conducted. Preference was given to publications by independent bodies such the International Commission on Large Dams (ICOLD) **[Refs. H1 & H2]** and various international societies and research institutions **[Refs. H3 & H4]**, in order to obtain a balanced viewpoint on the many different products and necessary design criteria.

A number of GSS options were identified, with the main alternatives being polymeric (CSPE, HDPE, LLDPE and PVC) and bituminous. The properties of each were analysed in detail with respect to the following identified design criteria:

- Hydraulic Properties
- Mechanical Properties
- Durability Properties
- Practical Requirements (cost, ease of installation, cover requirements)
- Precedence

As a result of the study, it became clear from a construction, performance and cost point of view, that an exposed cover would be preferred. It was then concluded that a PVC geocomposite represented the only GSS solution which would meet the necessary requirements for Sar Cheshmeh.

The preferred geocomposite consists of a 2.5mm to 3mm thick PVC geomembrane thermally coupled to a 500 g/m^2 non-woven polypropylene geotextile.

The most commonly considered alternative to PVC is the HDPE geomembrane. Exposed HDPE geomembranes were found to have no application in large tailings and water retaining structures, whilst a covered HDPE system was found to unviable from a construction and economic point of view.

2.2 Mechanical and Durability Issues

HDPE Geomembrane

HDPE is a relatively stiff, inflexible material, with a high modulus of elasticity. It possesses a yield point at about 10% elongation strain (in one directional extension) and becomes strain-softening thereon.

This necessitates careful attention being paid to the support layer, in order to eliminate aggressive surfaces. Nevertheless, the possibility that the embankment may undergo appreciable (especially if localised) settlements in the early years of its operation implies the risk of failures in tension.

Once a failure has initiated, the fracture's end becomes a point of stress concentration. The stress level here is so high, in comparison with the stress-strain potential of the material, that the fracture propagates further across the HDPE sheet and may produce dramatic, far reaching failures of the membrane.

The wrinkles and folds that inevitably develop in an exposed HDPE membrane during operation (due to its high thermal dilation coefficient) can also produce stress concentrations, which can provide numerous preferential channels through which unacceptable quantities of water can flow through the liner into the dam body.

Anchorage of an exposed HDPE membrane also presents a major issue. The smooth HDPE geomembrane does not provide enough friction against the support layer, hence all the anchoring forces need to be provided by the anchors themselves. This once again can result in stress concentrations and failure of the membrane.

PVC Geocomposite

The failure strain of PVC normally exceeds 250% and for some products, 300%. In addition, and contrary to HDPE, PVC has a strain-hardening behaviour and responds to a high stress with nearly proportional deformation which stops fracture propagation.

With respect to resistance to deformations, the maximum tri-dimensional deformation that a PVC geocomposite can resist without rupture is an order of magnitude greater than that of an HDPE geomembrane.

The chemical resistance of a PVC geomembrane in contact with water from the tailings was found to present no issues. Unlike HDPE, the chemical formulation of a PVC geomembrane can be designed to specifically cater for the chemical composition of the tailings or liquids proposed to be stored.

The demanding temperature changes and the potential for localised settlements favour the choice of PVC. PVC has a much lower coefficient of thermal expansion (<0.1% / 40°C) than HDPE, resulting in much higher dimensional stability of the geomembrane.

Documented experience demonstrates the advantages of using a geocomposite. The geocomposite possesses a dimensional stability which is larger than that of the PVC (the low thermal expansion coefficient gets even smaller) and a larger modulus (both in one and bi-directional extension). Because the geotextile backing fails in tension much before the failure point of the PVC, the geocomposite maintains the very large failure strain typical of PVC.

The use of geocomposite is also recommended for the following reasons:

- the geotextile acts as a de-coupling layer between the support and the PVC geomembrane, thus allowing the geomembrane to be placed even on fairly rough subgrades.

- The geotextile acts as a planar drain, collecting any leakage crossing the geomembrane and avoids the build up of uplift pressures.

With the exposed PVC geocomposite, face anchorage can be provided in continuous vertical lines. The type of anchorage ultimately adopted for Sar Cheshmeh, with the geomembrane anchor strips sandwiched between two lifts of curbs, cannot be achieved with a stiff HDPE membrane. This type of arrangement would require many extrusion welds, and it is well documented that with HDPE these seams can detach over time, rendering the liner no longer watertight.

With respect to the life of a PVC geocomposite in an exposed installation, ICOLD **[Ref. H2]** found that.. "..some exposed PVC geomembranes in dams are currently approaching 30 years of service, with no replacement required. It is expected that PVC geomembranes produced now, with better understanding of the problems, improved quality of the ingredients, more sophisticated plant and quality control, increased thickness, the life should easily exceed 100 years".

2.3 Precedence

Of all the design criteria identified in the study, the issue of precedence was considered to be one of the most critical, as it is directly linked to the remaining four design criteria listed in **Section 2.1**. A clear historical and relevant precedence with regard to the following issues was considered essential for the adopted GSS:

(i) the type of GSS, together with the type of installation (exposed or covered), and the type of fastening system (seams and anchorage),

(ii) the manufacturer of the membrane, including the raw materials and additives,

(iii) the previous experience of the installation contractor in regard to similar projects.

Geomembrane and Installation Type

ICOLD **[Ref. H2]** documents the installation of 250 geomembranes in dam applications world-wide. Of these the majority, 143 dams (60.5% of the total) have been fitted with PVC geomembranes, over half of which were left exposed. For the purposes of comparison, the next most common solution was LLDPE, which makes up 11.8% of the total. None of these 28 installations are exposed.

Of the 39 exposed GSS installations on large earth and rockfill embankments, 22 were PVC geomembranes. Just two examples of HDPE installations are documented in **[Ref. H2]**.

PVC Geomembrane - Manufacturer and Materials

ATC conducted a detailed examination of PVC materials and installers for dam applications around the world. It was found that the supply and installation market for this type of product is dominated by Carpi Tech SA, who has patented an innovative anchorage method for the attachment of the membrane to the dam face. ICOLD make the point in **[Ref. H2]** that in the case of exposed installations, the choice of geomembrane is limited, due to the constraints of durability, anchoring

and constructability. Whilst PVC has proved to be by the far the most frequently used option, careful selection in regard to the manufacture of the membrane is crucial. Previous successful experience of the same geomembrane and same manufacturer are hence extremely important.

With regard to the membrane itself, it was found that the SIBELON PVC geocomposite (developed by Carpi and manufactured exclusively for Carpi Tech by Flag SPA) dominates the market, as it has been developed specifically for dam applications in exposed environments. Its manufacture and materials are specifically formulated to impart to the geomembrane the tensile, UV stability and weathering properties necessary to survive such conditions in the long term.

IREQ, the Research Institute of the Canadian Hydro Quebec, one of the largest dam owners in the world, conducted extensive testing in 1995 on the stability and weathering resistance of eight different types of geomembranes **[Ref. H3]**. They devised accelerated ageing tests and concluded that with the SIBELON PVC.. ".. little influence is noticed, and this must be due to the fact that membranes have been treated during manufacturing to prevent UV deterioration, and that treatment has been effective."

The IREQ conclusion, upon examination of all test results, was that the SIBELON PVC is the most adequate type of revetment to waterproof the upstream face of concrete dams.

PVC Geomembrane Sealing System – Installation Contractor

The Dugald River preliminary Technical and Economic Proposal submitted by Carpi, is presented in **Appendix G** of the Main Report. Their submission details the history of the company as a researcher and installer of waterproofing geomembranes, as well as a description of the GSS system proposed for the Dugald River Main Embankment.

The Carpi resume demonstrates experience in waterproofing all types of dams and hydraulic structures in very different climates, ranging from harsh environments at high elevation with frequent freeze-thaw cycles, to hot and humid tropical climates, and dry and sunny desert climates.

The Carpi GSS system has been installed in exposed environments on well over 100 dams and reservoirs over the past 35 years. This amounts to a total of just under one million m^2 of geomembrane, with a cumulative time in operation of over 1,000 years.

Carpi Tech also provide a 10 year warranty on both the installed geomembrane and the fastening system.

3 SAR CHESHMEH TAILINGS STORAGE EMBANKMENT RAISING

3.1 Overview

Due to its superior mechanical and durability properties and its clear, demonstrable precedence in exposed dam applications, a PVC geocomposite supplied and installed by Carpi was selected as the optimal GSS solution for Sar Cheshmeh.

The GSS installation was further streamlined by specifying the so-called Ita method of support layer construction. This involves porous concrete extruded curbs of low cement content installed on the upstream face. The curbs provide containment for the embankment fill, whilst providing a solid supporting layer for the placement, anchoring and drainage of the GSS.

It was considered that the extruded curbs would provide a very quick and effective means of installing a GSS, particularly when used in conjunction with a patented face anchorage system. This anchorage system, developed and patented by Carpi, involves embedding closely spaced strips of the same geomembrane material in the curb support layer. The strips are positioned to form continuous vertical lines, to which the sealing geomembrane is thermally welded.

Perimeter anchorage of the PVC geocomposite was of the mechanical tie-down type on the abutments and crests of the raise, and via burial in trenches on existing embankments.

Anchorage to the abutments was via stainless steel batten strips bolted to reinforced concrete plinths. At the crests of each intermediate stage, the geocomposite was anchored with tie-down fastening to extruded mass concrete curbs. For the final stage, the geocomposite will be anchored via embedment beneath a mass concrete anchor beam.

3.2 Installation and Review

Installation of the first stage, incorporating a 12m raise and approximately 21,000m^2 of geocomposite, has recently been successfully completed.

From the perspective of the designer and the owner, the selected GSS has resulted in an efficient and economic waterproofing solution for the first stage of the tailings storage raise.

The extruded curbs have proven to be an effective construction method, whilst the anchor strip installation was a simple, routine process. Together, this greatly eased the installation of the PVC geocomposite, as the photos in Pages 6 and 7 of this appendix demonstrate.

The installation was extremely fast, with the entire system installed in one month. Nevertheless, a greater speed would have been easily achieved if necessary.

As Carpi provide a 10 year warranty on materials and a 2 year warranty on installation, the quality and efficiency of workmanship displayed by the Carpi installation team exceeded all expectations given the difficult working conditions inherent to Iran.

References

H1 ICOLD Bulletin 78 (1991), “Watertight Geomembranes for Dams, State of the Art”, International Committee On Large Dams.

H2 ICOLD Bulletin (2005 - approved but as yet unpublished) “Geomembrane Sealing Systems for Dams – Design Principles and Return of Experience”, International Committee On Large Dams.

H3 IREQ (1998), “Study of Waterproofing Revetments for the Upstream Face of Concrete Dams”, ICOLD European Working Group for Geomembranes and Geosynthetics as Facing Materials, Research Institute of Hydro-Quebec.

H4 U.S. Army Engineer Waterways Experiment Station (1995), "A Conceptual Design for Underwater Installation of Geomembrane Systems on Concrete Hydraulic Structures", Technical Report REMR-CS-50, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Sar Cheshmeh GSS Installation Photos



Curb Construction



Anchor Strip Installation



Anchor Strip Installation



Completion of Curb and Anchor Strip Installation



Commencing Geocomposite Installation



Welding Geocomposite to Anchor Strip



Tie-Down Crest Anchorage



Tie-Down Plinth Anchorage

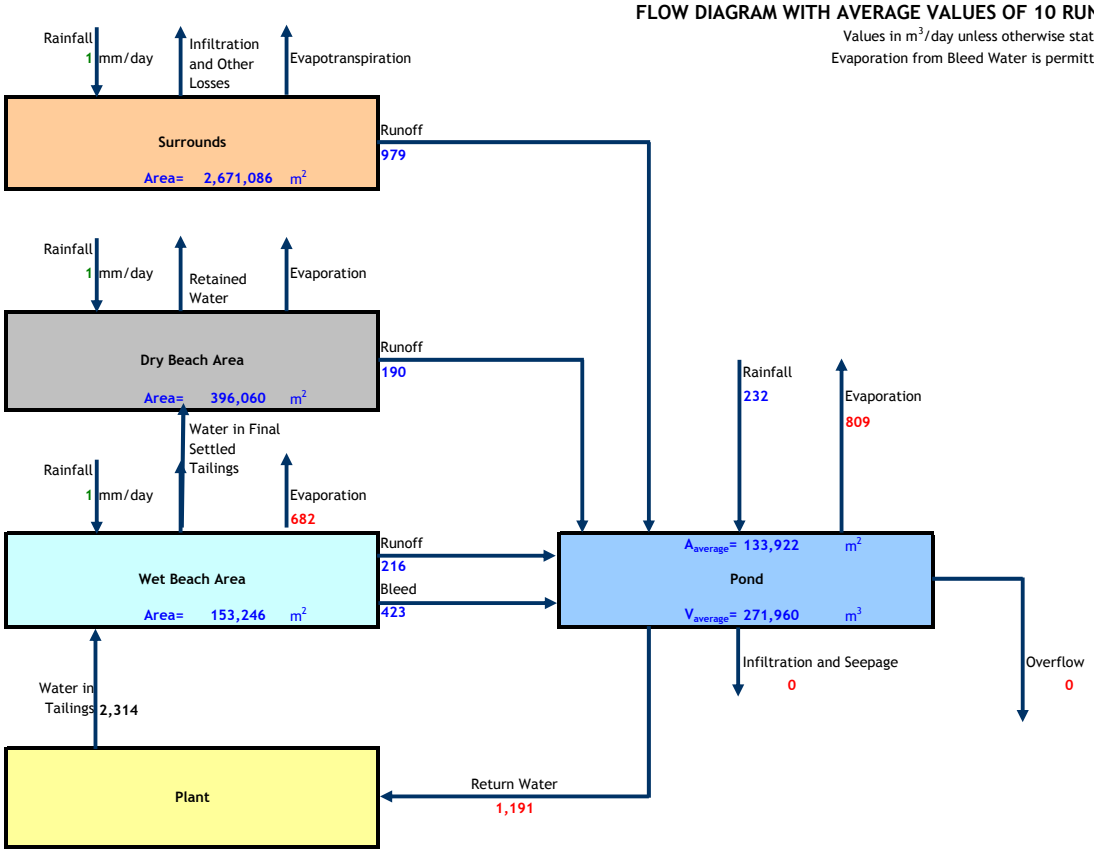


Completed Installation – Stage IIB Saddle Dam

APPENDIX I

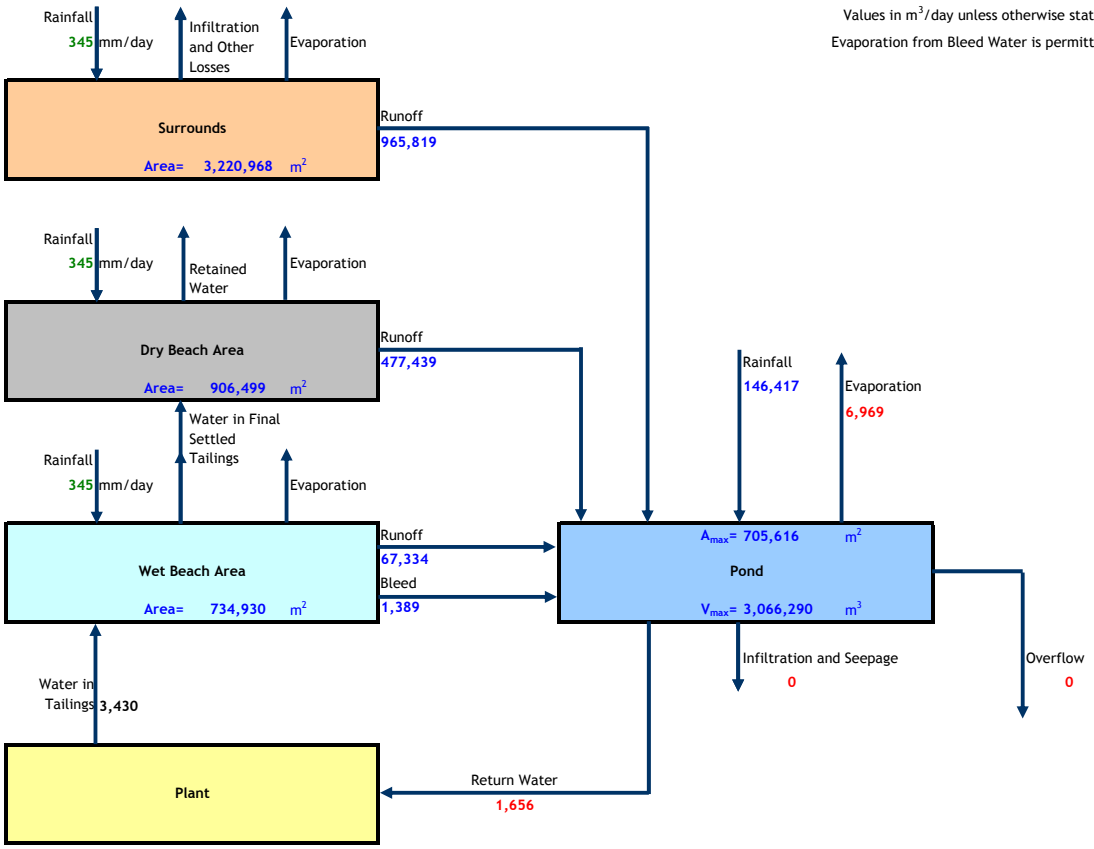
FLOW DIAGRAM WITH AVERAGE VALUES OF 10 RUNS

Values in m^3/day unless otherwise stated
Evaporation from Bleed Water is permitted



FLOW DIAGRAM WITH MAXIMUM VALUES OF 10 RUNS

Values in m^3/day unless otherwise stated
Evaporation from Bleed Water is permitted



MMG DUGALD RIVER

DUGALD RIVER PROJECT

FEASIBILITY STUDY

KNAPDALE VALLEY TAILINGS STORAGE FACILITY

Daily Water Balance Flow Diagram

Job No:	108003.02	**Date:**	30/06/2010

FIGURE I1

ATC Williams
GROUNDED IN DESIGN

ATC Williams Pty Ltd
222 Beach Road (P.O. Box 5286)
Mordialloc Vic 3195 AUSTRALIA
T +61 3 8587 0900 F +61 3 8587 0901
melb@atcwilliams.com.au www.atcwilliams.com.au

RUN	Case	Input Data		Basic information													Inputs to the Pond						Outputs from the Pond			Volume Calculations		
		Rainfall	Evap	Tailings Production	Water Content in the Tailings	Water Retained in the Initial Settled Talings	Water Retained in the Final Settled Talings	Total Catchment Area	Total Beach Area	Active Wet Beach Area	Passive Wet Beach Area	Dry Beach Area	Opening Pond Area	Catchment Surround Area	Unit Runoff-Tailings	Unit Runoff-Catchment	Runoff from Catchment Surround	Runoff from Dry Beach Area	Runoff from Wet Beach Area	Rainfall to Pond Area	Theoretical Bleed Water	Actual Bleed Water (incl. Evap)	Evaporation from active Wet Beach	Evaporation from Pond	Return Water	Opening Pond Volume	Closing Pond Volume	Average Pond Volume
		(mm)	(mm)	(ton/day)	(m3/day)	(m3/day)	(m3/day)	(m2)	(m2)	(m2)	(m2)	(m2)	(m2)	(m2)	(mm)	(mm)	(m3/day)	(m3/day)	(m3/day)	(m3/day)	(m3/day)	(m3/day)	(m3/day)	(m3/day)	(m3/day)	(m3)	(m3)	(m3)
1	Minimum	0	5	360	346	181	120	3,350,000	129,032	15,568	0	0	0	2,422,234	0.00	0.00	0	0	0	0	165	10	62	0	0	0	0	0
	Maximum	345	12	3,569	3,430	1,794	1,190	3,350,000	927,766	154,514	104,087	898,727	663,125	3,220,968	333.70	332.70	839,859	136,249	52,278	146,417	1,636	1,018	1,533	4,987	1,656	2,508,457	2,508,457	2,506,468
	Average	2	8	2,409	2,314	1,210	803	3,350,000	678,906	104,268	46,825	380,166	156,014	2,671,094	0.60	0.44	1,174	227	213	284	1,104	420	684	966	1,282	346,254	346,326	346,290
2	Minimum	0	5	360	346	181	120	3,350,000	129,032	15,568	4,907	0	0	2,422,234	0.00	0.00	0	0	0	0	165	10	62	0	0	0	0	0
	Maximum	121	12	3,569	3,430	1,794	1,190	3,350,000	927,766	154,514	120,781	900,966	484,705	3,220,968	104.50	94.03	239,642	53,498	19,390	38,176	1,636	1,018	1,533	3,375	1,656	1,133,359	1,133,359	1,131,868
	Average	1	8	2,409	2,314	1,210	803	3,350,000	678,906	104,268	52,608	451,006	71,024	2,671,094	0.35	0.23	594	164	174	109	1,104	420	684	430	1,019	97,454	97,467	97,460
3	Minimum	0	0	360	346	181	120	3,350,000	129,032	15,568	0	0	0	2,422,190	0.00	0.00	0	0	0	0	165	0	22	0	0	0	0	0
	Maximum	242	19	3,569	3,430	1,794	1,190	3,350,000	927,810	154,514	580,416	849,106	705,616	3,220,968	231.50	219.51	543,918	131,678	50,848	84,006	1,636	1,290	2,052	6,969	1,656	3,066,290	3,066,290	3,063,115
	Average	1	8	2,408	2,314	1,210	803	3,350,000	678,933	104,259	53,608	332,100	191,063	2,671,067	0.67	0.51	1,309	204	268	346	1,104	430	677	1,127	1,312	406,436	406,554	406,495
4	Minimum	0	1	360	346	181	120	3,350,000	129,032	15,568	0	0	0	2,422,234	0.00	0.00	0	0	0	0	165	0	35	0	0	0	0	0
	Maximum	139	19	3,569	3,430	1,794	1,190	3,350,000	927,766	154,514	450,844	904,797	622,974	3,220,968	121.28	111.70	317,338	73,749	26,982	43,784	1,636	1,129	1,556	4,692	1,656	1,792,555	1,792,555	1,791,358
	Average	1	8	2,409	2,314	1,210	803	3,350,000	678,906	104,268	54,252	396,279	124,159	2,671,094	0.45	0.32	839	150	226	221	1,104	425	681	721	1,141	219,286	219,286	219,286
5	Minimum	0	5	360	346	181	120	3,350,000	129,032	15,568	0	0	0	2,422,234	0.00	0.00	0	0	0	0	165	10	62	0	0	0	0	0
	Maximum	345	12	3,569	3,430	1,794	1,190	3,350,000	927,766	154,514	100,083	906,499	616,396	3,220,968	333.70	332.70	823,330	410,294	49,259	133,594	1,636	1,018	1,533	4,635	1,656	2,562,405	2,562,405	2,560,503
	Average	2	8	2,408	2,314	1,210	803	3,350,000	678,933	104,259	42,520	379,268	168,299	2,671,067	0.57	0.42	1,143	226	221	296	1,104	420	684	1,052	1,255	434,760	434,760	434,760
6	Minimum	0	3	360	346	181	120	3,350,000	129,032	15,568	0	0	0	2,422,234	0.00	0.00	0	0	0	0	165	0	32	0	0	0	0	0
	Maximum	161	19	3,569	3,430	1,794	1,190	3,350,000	927,766	154,514	104,087	904,330	451,073	3,220,968	150.30	149.30	400,314	192,843	25,611	51,313	1,636	1,018	1,533	3,058	1,656	1,351,890	1,351,890	1,350,665
	Average	1	8	2,409	2,314	1,210	803	3,350,000	678,906	104,268	47,491	415,728	113,458	2,671,094	0.46	0.33	891	173	199	176	1,104	420	684	700	1,160	177,340	177,340	177,340
7	Minimum	0	5	360	346	181	120	3,350,000	129,032	15,568	0	0	0	2,422,234	0.00	0.00	0	0	0	0	165	10	62	0	0	0	0	0
	Maximum	345	12	3,569	3,430	1,794	1,190	3,350,000	927,766	154,514	102,760	901,710	531,725	3,220,968	333.70	332.70	965,819	59,546	67,334	115,204	1,636	1,018	1,533	4,343	1,656	2,553,608	2,553,608	2,552,568
	Average	1	8	2,409	2,314	1,210	803	3,350,000	678,906	104,268	45,938	403,951	131,978	2,671,094	0.50	0.36	979	155	213	230	1,104	420	684	827	1,171	258,382	258,382	258,382
8	Minimum	0	5	360	346	181	120	3,350,000	129,032	15,568	0	0	0	2,422,234	0.00	0.00	0	0	0	0	165	10	62	0	0	0	0	0
	Maximum	121	12	3,569	3,430	1,794	1,190	3,350,000	927,766	154,514	114,035	898,670	472,472	3,220,968	104.50	97.80	252,035	82,928	18,826	38,045	1,636	1,018	1,533	3,305	1,656	1,374,983	1,374,983	1,373,685
	Average	1	8	2,409	2,314	1,210	803	3,350,000	678,906	104,268	51,461	431,695	91,568	2,671,094	0.42	0.28	736	192	187	156	1,104	420	684	553	1,088	141,660	141,712	141,686
9	Minimum	0	1	360	346	181	120	3,350,000	129,032	15,568	0	0	0	2,422,234	0.00	0.00	0	0	0	0	165	0	25	0	0	0	0	0
	Maximum	161	19	3,569	3,430	1,794	1,190	3,350,000	927,766	154,514	322,031	899,968	518,087	3,220,968	150.30	149.30	450,395	477,439	29,259	32,666	1,636	1,092	1,566	3,874	1,656	1,853,274	1,853,274	1,852,766
	Average	1	8	2,408	2,314	1,210	803	3,350,000	678,933	104,259	45,781	393,504	140,205	2,671,067	0.52	0.38	1,024	221	210	231	1,104	420	685	830	1,216	306,950	307,010	306,980
10	Minimum	0	1	360	346	181	120	3,350,000	129,032	15,568	0	0	0	2,422,234	0.00	0.00	0	0	0	0	165	0	20	0	0	0	0	0
	Maximum	181	17	3,569	3,430	1,794	1,190	3,350,000	927,766	154,514	351,348	735,987	656,165	3,220,968	174.70	173.70	443,118	75,216	41,626	47,446	1,636	1,389	1,928	5,985	1,656	2,188,222	2,188,222	2,185,739
	Average	1	8	2,409	2,314	1,210	803	3,350,000	678,906	104,268	49,320	376,906	151,454	2,671,094	0.58	0.42	1,101	189	244	268	1,104	434	673	890	1,269	330,878	330,955	330,917
MIN	Minimum	0	0	360	346	181	120	3,350,000	129,032	15,568	0	0	0	2,422,190	0.00	0.00	0	0	0	0	165	0	20	0	0	0	0	0
	Maximum	0	5	360	346	181	120	3,350,000	129,032	15,568	4,907	0	0	2,422,234	0.00	0.00	0	0	0	0	165	10	62	0	0	0	0	0
	Average	0	3	360	346	181	120	3,350,000	129,032	15,568	491	0	0	2,422,230	0.00	0.00	0	0	0	0	165	5	45	0	0	0	0	0
MAX	Minimum	121	12	3,569	3,430	1,794	1,190	3,350,000	927,766	154,514	100,083	735,987	451,073	3,220,968	104.50	94.03	239,642	53,498	18,826	32,666	1,636	1,018	1,533	3,058	1,656	1,133,359	1,133,359	1,131,868
	Maximum	345	19	3,569	3,430	1,794	1,190	3,350,000	927,810	154,514	580,416	906,499	705,616	3,220,968	333.70	332.70	965,819	477,439	67,334	146,417	1,636	1,389	2,052	6,969	1,656	3,066,290	3,066,290	3,063,115
	Average	216	15	3,569	3,430	1,794	1,190	3,350,000	927,770	154,514	235,047	880,076	572,234	3,220,968	203.82	199.34	527,577	169,344	38,141	73,065	1,636	1,101	1,630	4,522	1,656	2,038,504	2,038,504	2,036,874
AVE	Minimum	1	8	2,408	2,314	1,210	803	3,350,000	678,906	104,259	42,520	332,100	71,024	2,671,067	0.35	0.23	594	150	174	109	1,104	420	673	430	1,019	97,454	97,467	97,460
	Maximum	2	8	2,409	2,314	1,210	803	3,350,000	678,933	104,268	54,252	451,006	191,063	2,671,094	0.67	0.51	1,309	227	268	346	1,104	434	685	1,127	1,312	434,760	434,760	434,760
	Average	1	8	2,409	2,314	1,210	803	3,350,000	678,914	104,265	48,980	396,060	133,922	2,671,086	0.51	0.37	979	190	216	232	1,104	423	682	809	1,191	271,940	271,979	271,960

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DUGALD RIVER PROJECT

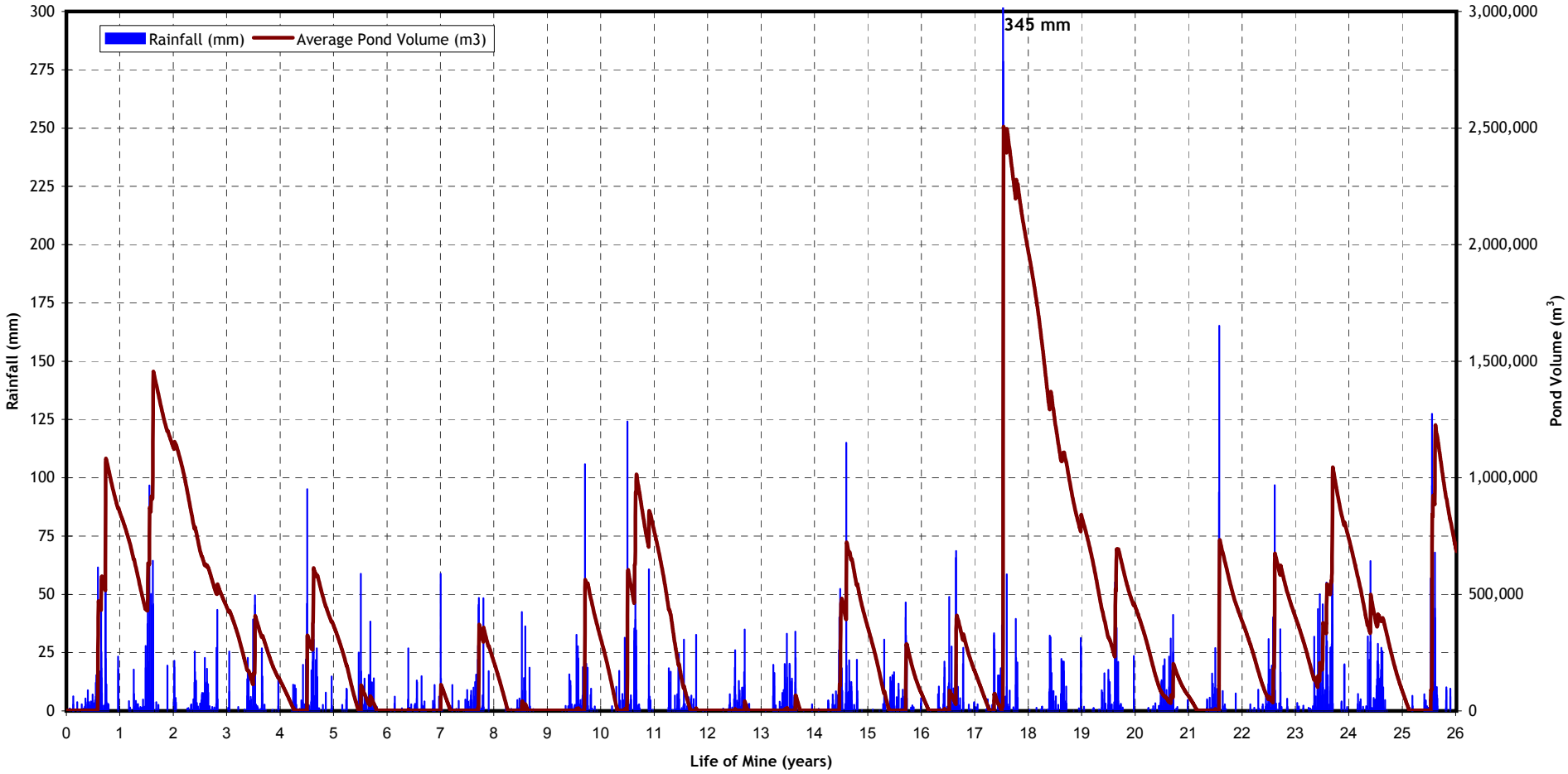
FEASIBILITY STUDY

KNAPDALE VALLEY TAILINGS STORAGE FACILITY

Life of Mine Daily Water Balance Outcome Table

Date: 30/06/2010 | Job No: 108003.02 | **FIGURE I2**

Rainfall and Average Pond Volume
Run 1 (1893-1918) = 26 Year Period with 1% Chance of Exceedence



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KNAPDALE VALLEY TAILINGS STORAGE FACILITY

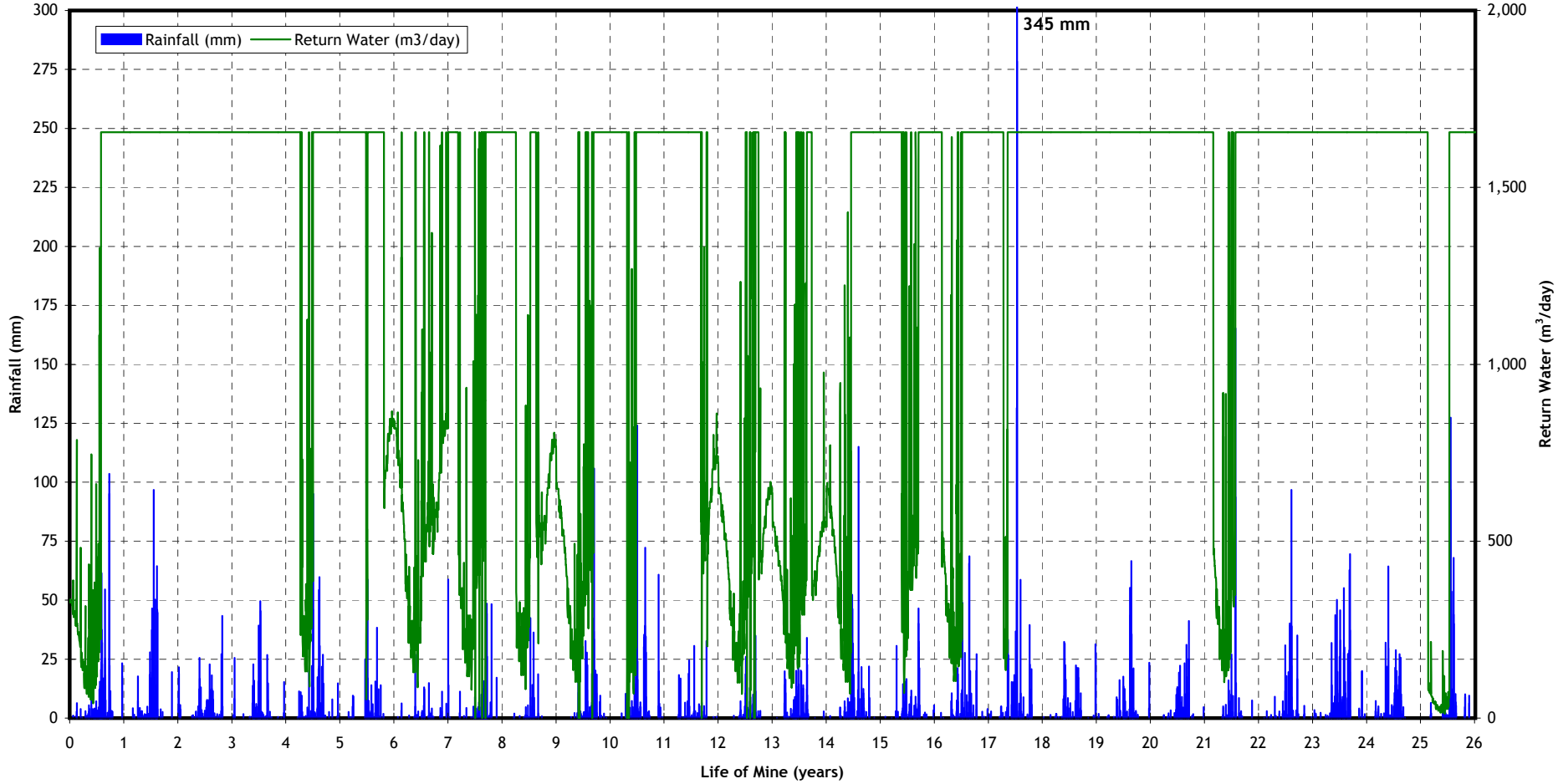
Life Of Mine Daily Water Balance

Date: 30/06/2010 **Job No:** 108003.02

FIGURE I3

J:\2008\108003 Dugald River\02 FS Update 2010\Data & Calcs\CN\Daily Water Balance-based on 2008-10-06-2010-06-04.xls Fig I3

Rainfall and Average Daily Decant Water Return
Run 1 (1893-1918) = 26 Year Period with 1% Chance of Exceedence



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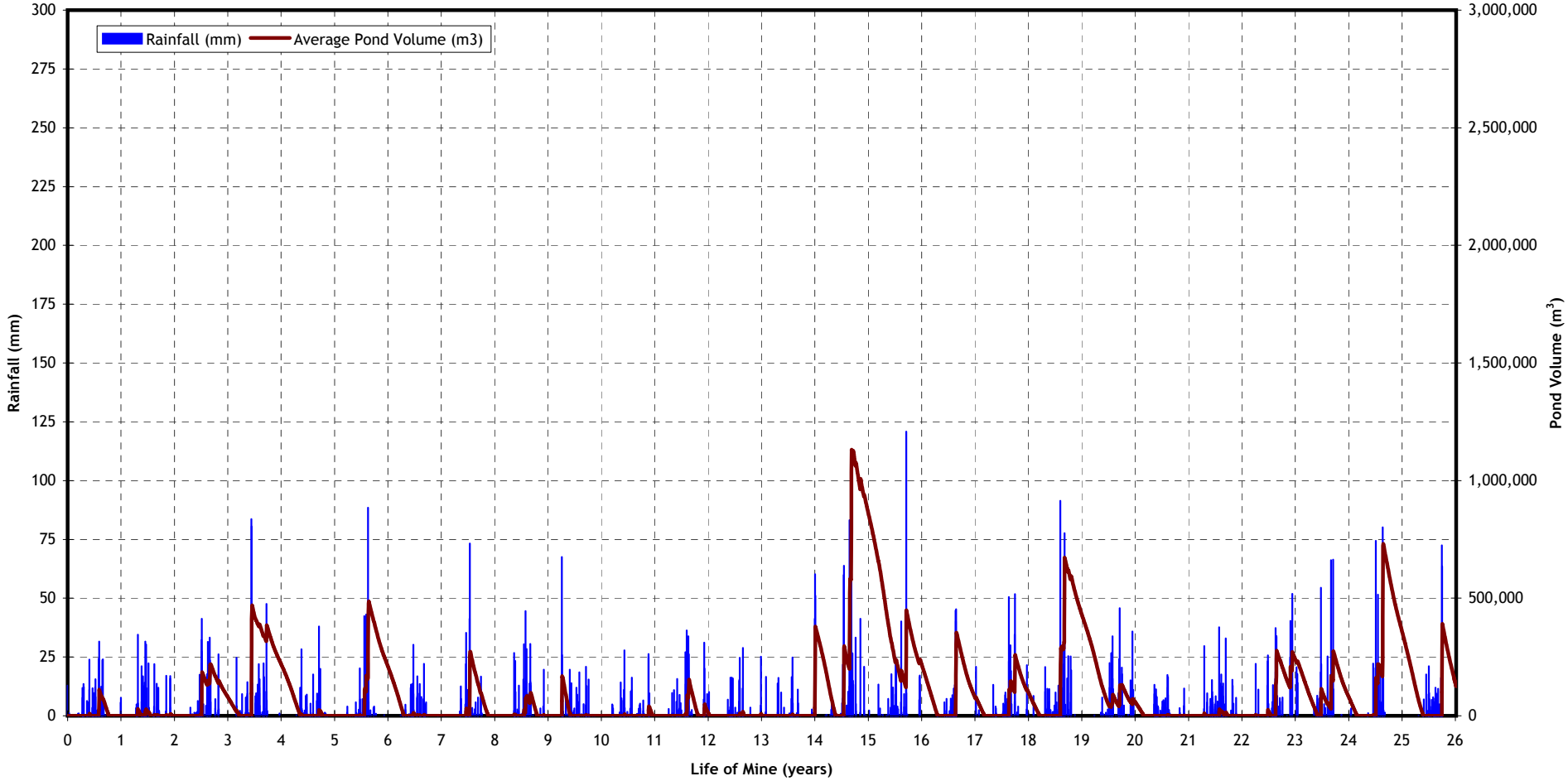
KNAPDALE VALLEY TAILINGS STORAGE FACILITY

Life Of Mine Daily Water Balance

Date:	30/06/2010	Job No:	108003.02	**FIGURE I4**

J:\2008\108003 Dugald River\02 FS Update 2010\Data & Calcs\CN\Daily Water Balance-based on 2008-10-06-2010-06-04.xls Fig I4

Rainfall and Average Pond Volume
Run 2 (1921-1947) = 26 Year Period with 99% Chance of Exceedence



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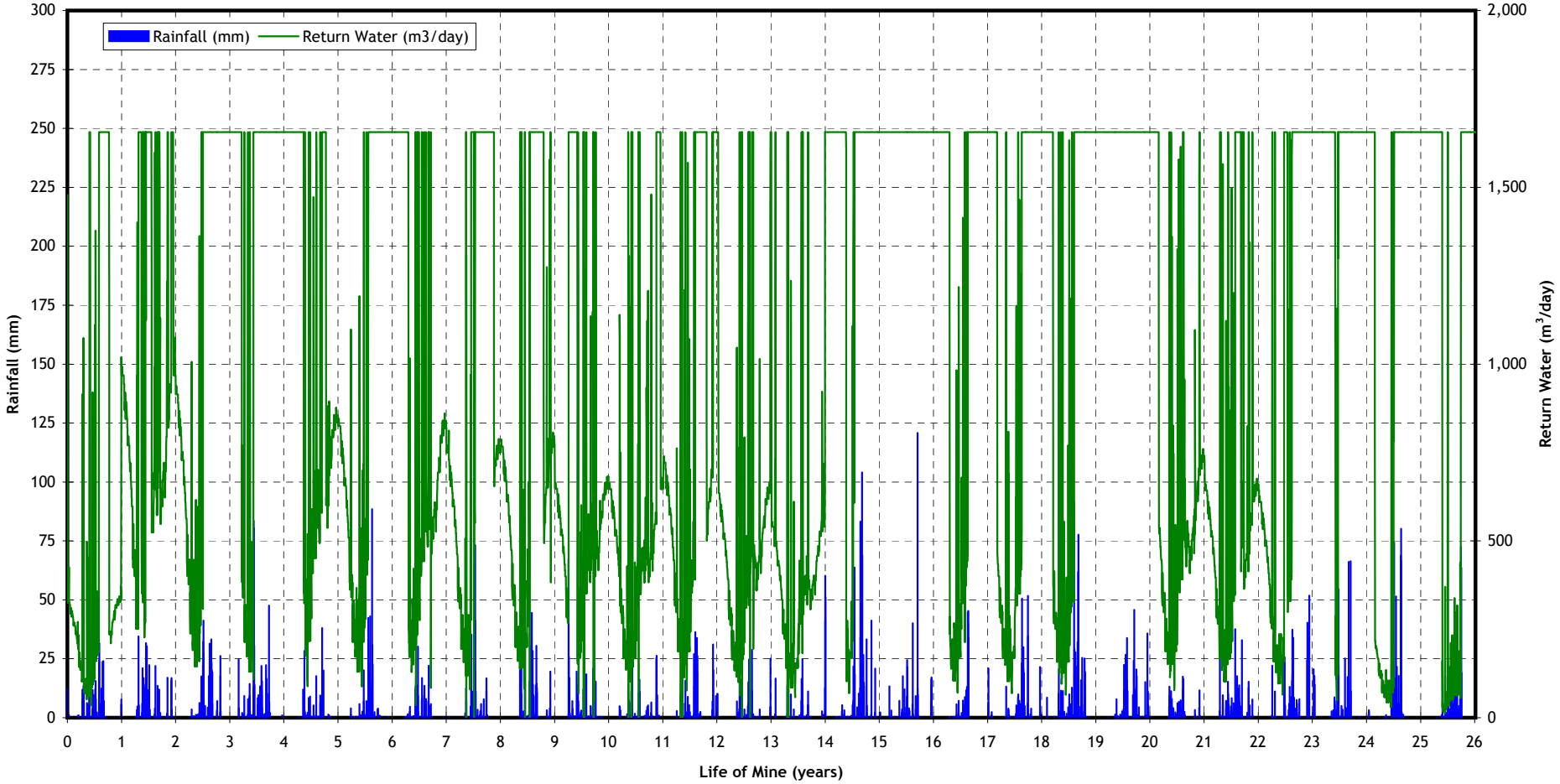
Life Of Mine Daily Water Balance

Date: 30/06/2010 **Job No:** 108003.02

FIGURE I5

J:\2008\108003 Dugald River\02 FS Update 2010\Data & Calcs\CN\Daily Water Balance-based on 2008-10-06-2010-06-04.xls Fig I5

Rainfall and Average Decant Water Return
Run 2 (1921-1947) = 26 Year Period with 99% Chance of Exceedence



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KNAPDALE VALLEY TAILINGS STORAGE FACILITY

Life Of Mine Daily Water Balance

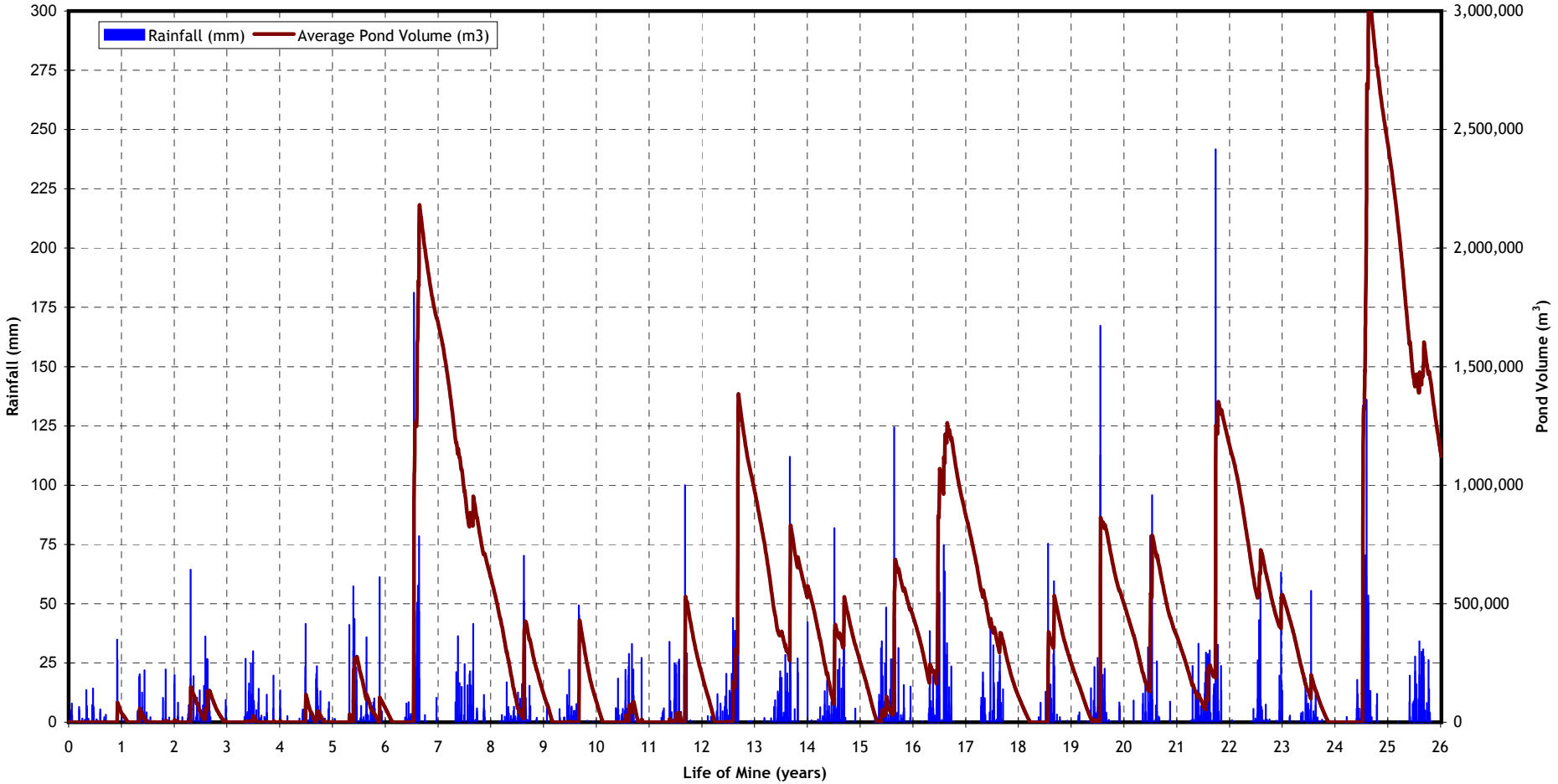
Date: 30/06/2010 **Job No:** 108003.02

FIGURE I6

J:\2008\108003 Dugald River\02 FS Update 2010\Data & Calcs\CN\Daily Water Balance-based on 2008-10-06-2010-06-04.xls Fig I6

Rainfall and Average Pond Volume

Run 3 (1984-2009) = 26 Year Period with 10% Chance of Exceedence, inc. Highest 2 Month & Annual Rainfall (2008)



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KNAPDALE VALLEY TAILINGS STORAGE FACILITY

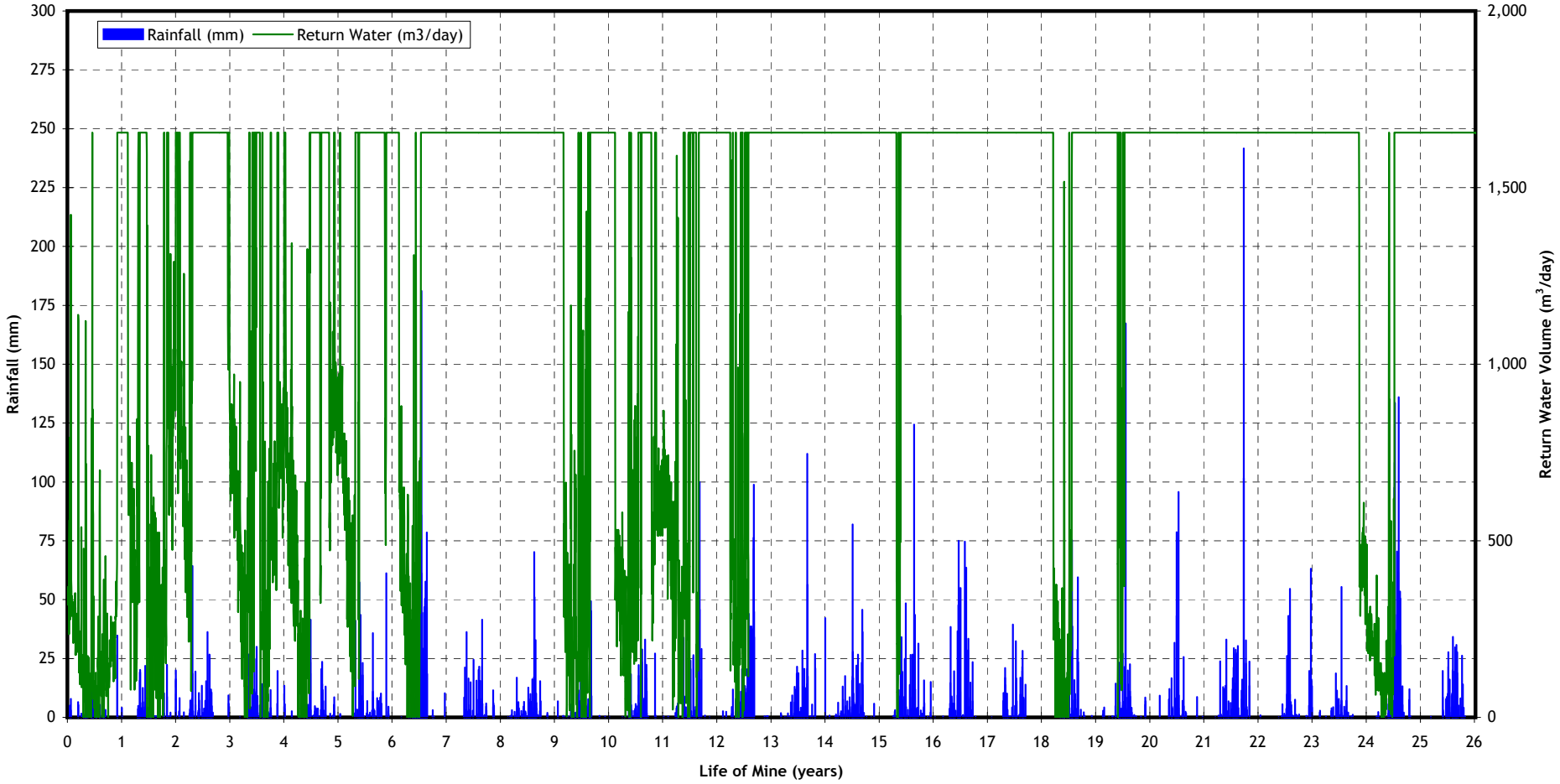
Life Of Mine Daily Water Balance

Date:	30/06/2010	Job No:	108003.02	**FIGURE I7**

J:\2008\108003 Dugald River\02 FS Update 2010\Data & Calcs\CN\Daily Water Balance-based on 2008-10-06-2010-06-04.xls Fig I7

Rainfall and Average Daily Decant Water Return

Run 3 (1984-2009) = 26 Year Period with 10% Chance of Exceedence, Highest 2 Month & Annual Rainfall (2008)



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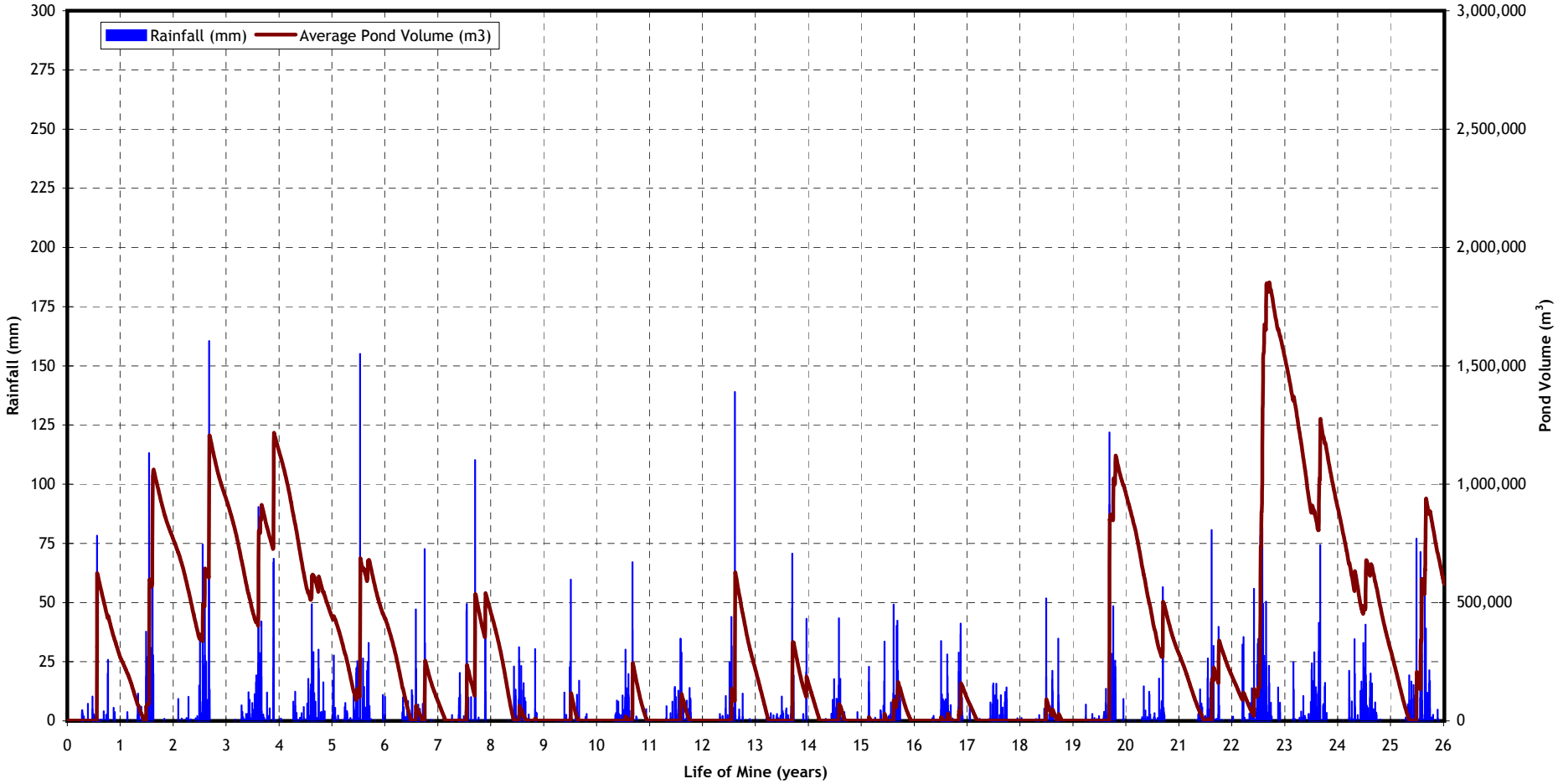
KNAPDALE VALLEY TAILINGS STORAGE FACILITY

Life Of Mine Daily Water Balance

Date:	30/06/2010	Job No:	108003.02	**FIGURE I8**

J:\2008\108003 Dugald River\02 FS Update 2010\Data & Calcs\CN\Daily Water Balance-based on 2008-10-06-2010-06-04.xls Fig I8

Rainfall and Average Pond Volume
Run 9 (1951-1976) = 26 Year Period with 41% Chance of Exceedence



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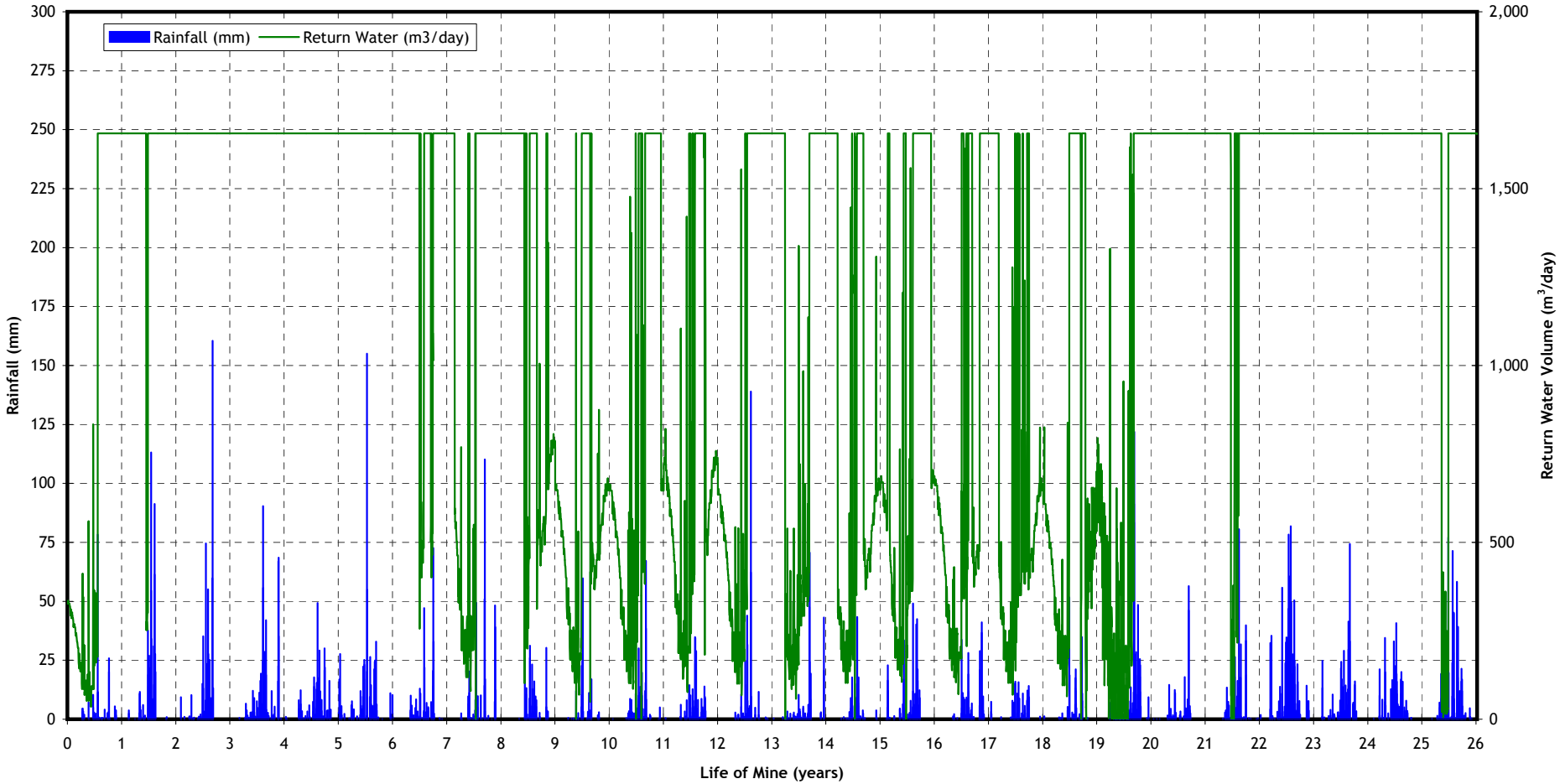
Life Of Mine Daily Water Balance

Date: 30/06/2010 **Job No:** 108003.02

FIGURE I9

J:\2008\108003 Dugald River\02 FS Update 2010\Data & Calcs\CN\Daily Water Balance-based on 2008-10-06-2010-06-04.xls Fig I9

Rainfall and Average Daily Decant Water Return
Run 9 (1951-1976) = 26 Year Period with 41% Chance of Exceedence



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KNAPDALE VALLEY TAILINGS STORAGE FACILITY

Life Of Mine Daily Water Balance

Date: 30/06/2010 **Job No:** 108003.02

FIGURE I10

J:\2008\108003 Dugald River\02 FS Update 2010\Data & Calcs\CN\Daily Water Balance-based on 2008-10-06-2010-06-04.xls Fig I10

Appendix I
Preliminary Landform Evolution Modelling



Preliminary Landform Evolution Modelling

Tailings Storage Facility

Dugald River Mine

Prepared for MMG | 21 July 2020

Project number:	19005
Document title:	Preliminary Landform Evolution Modelling | Tailings Storage Facility
Revision:	V0-1
Date:	21 July 2020
Client:	MMG
Project manager:	T Rohde
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Document history and status

Revision	Date	Description	By	Review	Approved
V0-1	21/07/20	Draft	N Jamson	T Rohde	T Rohde
V0-2	25/02/21	Final	H Vogler	J Vohland	T Rohde

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Important note about your report

This Report is provided for the exclusive use of the Client pursuant to the Scope of Works dated 6 March 2020, which requires us to provide Services relating to preparing a preliminary landform evolution model (LEM) for the tailings storage facility (TSF) at Dugald River Mine (the Mine).

This Report is provided to the Client on the terms and conditions set out in the Standard Terms of SGM Environmental Pty Limited (SGME, we, us or our).

We derive data in this Report from information (or confirmation of the absence thereof) sourced from the Client and, designated laboratories and / or information that has been made available in the public domain at the time or times outlined in this Report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the preliminary LEM for the TSF and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this Report.

SGME has prepared this Report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to any applicable standards, guidelines, procedures and practices outlined in the Scope of Works as at the date of issue of this Report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this Report, to the extent permitted by law.

This Report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by SGME for use of any part of this Report in any other context.

Reporting of the Preliminary LEM for the TSF are based on a desktop assessment of data that has been measured by CLIGEN, SGS Australia Pty Limited and TrilabPty Limited and other third parties.

SGME does not accept any Liability whatsoever for, or in respect of, any use of, or reliance upon this Report by any person contrary to the above or our Standard Terms.

1.0 Introduction

1.1 The mine

Dugald River Mine (the Mine) is an underground zinc (Zn) and lead (Pb) mine located approximately (~) 85 kilometres (km) north-east of Mount Isa and 65 km north-west of Cloncurry in north-western Queensland. The Mine is located within the Mount Isa Mineral Province which is characterised by mineral exploration, mining and pastoral activities. The Mine is located on Roseby Station pastoral leases (the station), owned by Macmillan Holdings and is used for cattle grazing on unimproved pastures.

Ore is mined underground using conventional long hole open stoping and down hole benching methods accessed by twin declines. Ore is trucked to the surface to the run of mine (ROM) pad and concentrated through a flotation separation plant. Metal concentrate is stockpiled in a concentrate storage shed prior to placement in sealed containers for transport by truck. Process waste (tailings) is transferred to the tailings storage facility (TSF) for final disposal or combined with cement to create paste fill to backfill underground voids.

The Mine's TSF is a valley fill TSF with two discharge locations to the north and south. The target tailings solids content is 55% prior to discharge. The tailings beach grades down towards the centre of the TSF. Tailings supernatant pools in the centre of the TSF and are intermittently pumped back to the processing plant for reuse as process water. The TSF is located on mining lease 90211 (ML90211).

1.2 Scope

The scope of this report is to complete preliminary landform evolution modelling of the proposed TSF final landform (the TSF landform) that meets the *Guideline Progressive rehabilitation and closure plans (PRC plans)* (the PRC plan guideline).

The PRC plan guideline states that the PRC plan must include all supporting information required by the Department of Environment and Science (DES) to reach a decision on the 'soundness' of the rehabilitation strategies and delivery techniques to meet the approved land outcomes. This report includes:

- method of determining landform design;
- landform evolution modelling predicting the long-term stability of the TSF landform;
- method of construction;
- quality assurance / quality control (QA/QC) requirements;
- future trials to verify the predicted success of the final landform design; and
- assumptions and limitations of the 3.0Water erosion prediction project (WEPP) model.

2.0 Tailings storage facility

2.1 Completion criteria

Completion criteria for the TSF in the PRC plan related to landform design are listed in Table 1. These criteria incorporate closure commitments and obligations identified in the PRC plan.

Table 1 TSF landform completion criteria

Final land use	Rehabilitation goal	Objectives	Indicators	Completion criteria	Validation method
Native habitat	Stable	Downstream (western) embankment will be reshaped and be resistant to erosion by wind and / or rainfall runoff.	Slope angle.	Slopes of all constructed landforms will be consistent with reference sites and verified by an appropriately qualified person (AQP). All constructed landforms will be safe and stable with no excessive erosion.	Geotechnical and erosional assessment report. Results are verified by a AQP

2.2 The TSF landform

The TSF landform will have the following characteristics:

- the flat top will grade from the northern and southern ends at 1% towards the main embankment crest at ~235 metres reduced level (m RL);
- the flat top will have a store and release cover built on it;
- the slope length from the southern end of the flat top to the main embankment crest will be ~2000 meters (m);
- the slope length from the northern end of the flat top to the main embankment crest will be ~1,150 m;
- the main embankment will be redesigned as a broad spillway rock chute (the rock spillway) and flattened to a slope of 15% with a slope length of ~230 m;
- the vertical height from the crest of the main embankment to the toe will be ~35 m;
- rock used for construction of the spillway chute will be sourced from the main embankment and the non-acid forming (NAF) waste rock dump; and
- Only NAF waste rock will be used in the TSF cover and landform.

The intent of the TSF landform is to create a self-shedding profile that is erosion resistant and stable.

2.3 Target erosion rate

There is currently no broad agreement on what constitutes an 'acceptable' rate of erosion on a rehabilitated mine site. An acceptable erosion rate of 4.5 tonnes per hectare per year (t/ha/y) is commonly adopted for undisturbed rangeland soils and shallow cultivated soils in the USA (McCormack et al. 1982, Wigh & Siddoway 1982 & Rollins 1981). The prediction of *Sheet and Rill Erosion Over the Australian Continent, Incorporating Monthly Soil Loss Distribution* (Lu et al 2001) has relied upon remote sensing technology to determine national and state averages of erosion. The study has found that for Australia:

- the average soil erosion rate is 6.3 t/ha/y;
- that a low rate of erosion is defined as less than 0.5 t/ha/y; and
- that a high erosion rate is defined as greater than 10 t/ha/y.

Landloch (2013) have shown that rehabilitated mine slopes have a low tendency to rill with an average erosion rate of <5 t/ha/y.

Avoiding rill formation will ensure landform stability and reduce the likelihood of excessive erosion. The elimination of rilling will also largely reduce the potential of channelised flow, which can result in gully erosion. A target average erosion rate of <5 t/ha/y has therefore been adopted with the maximum erosion rate at any point on the landform of <10 t/ha/y. It is important to note that erosion rates can vary from year to year depending on climatic conditions. Therefore, maximum annual erosion rate will also be examined as a secondary performance indicator.

3.0 WEPP modelling

The WEPP model is a 2-dimensional, hillslope model initially developed for agricultural purposes by the United States Department of Agriculture (USDA). It integrates hydrology, plant science, hydraulics and erosion mechanics to predict erosion at the hillslope and watershed scale. The WEPP model has been used in the design of landforms for mines across Australia. For example, Howard and Roddy (2012) have shown that observed cumulative erosion rates for mined landforms in Western Australia, generally agree with WEPP model predictions.

The WEPP model has been used in this Project to simulate 100 years of time-series data for rainfall, runoff, and sediment loss for the main embankment as well as the flat top.

3.1 Inputs

The WEPP model inputs can be broken up into five components: climate, material properties, surface conditions and topography.

3.1.1 Climate

A 100-year synthetic climate file was generated using the CLIGEN stochastic weather generator. The model has been widely used and validated in Australia (Yu 2003). The following data was imported into CLIGEN to generate this file:

- 125 years of patched daily temperature (maximum and minimum), rainfall and solar radiation sourced from the Bureau of Meteorology (BoM) SILO data drill (https://www.longpaddock.qld.gov.au/silo/); and
- 49 years of pluviograph (6-minute rainfall intensity) data (85% complete) from the Mount Isa Aero (29127) BoM weather station.

Various parameters were then adjusted in the generated climate file to match the inputted data more closely. Adjustments included average precipitation on a wet day, maximum 30-minute rainfall intensity and time to peak rainfall intensity.

3.1.1.1 Validation

The CLIGEN climate file has been compared to the 125 years of patched data from the BoM SILO data drill to verify the accuracy of the model. The patched data and the CLIGEN climate file show a high level of consistency in terms of both annual rainfall (Figure 1) and extreme storm events (Figure 2). Therefore, the CLIGEN climate data file is appropriate for use in the WEPP model.

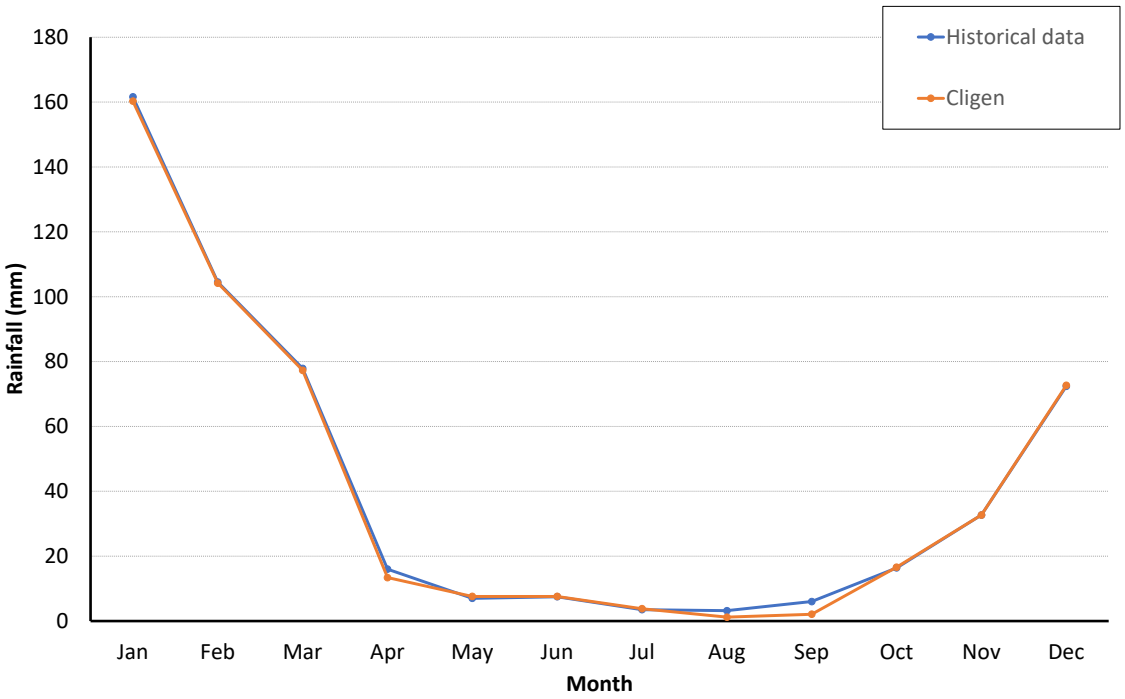


Figure 1 Average monthly rainfall: CLIGEN and historical data comparison

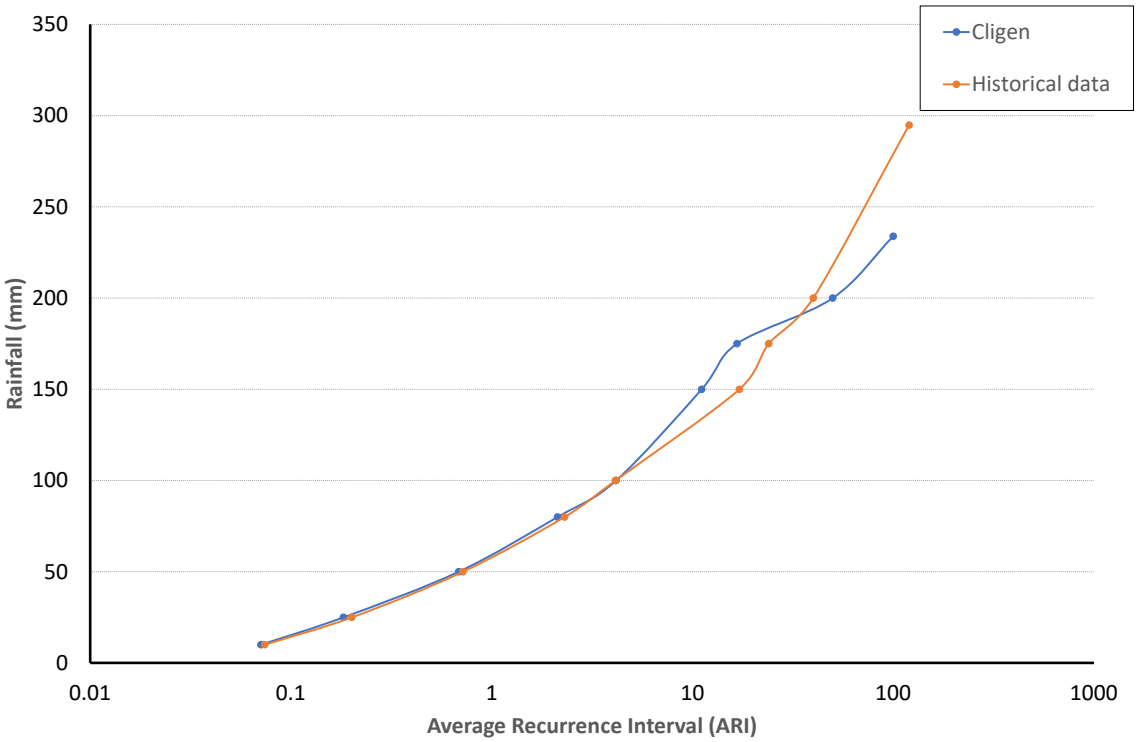


Figure 2 Average recurrence interval: CLIGEN and historical data comparison

3.1.2 Material properties

The TSF store and release cover placed on the flat top is from SGME (2020) and is NAF waste rock. Material properties for the main embankment and the TSF flat top are shown in Table 2 and Table 3 respectively.

Interrill erodibility, rill erodibility, critical shear and effective hydraulic conductivity were calculated via the model for the TSF flat top. Database values for coarse rock was used for the rock spillway.

Table 2 TSF flat top material properties

Layer	Depth (cm)	Sand (%)	Clay (%)	Rock (%)	Organic (%)	Cation exchange capacity (CEC) (milliequivalents per 100 grams of soil (meq/100g)
Soil	0-10	40	12	30	0.5	7
Infiltration storage layer	10-110	20	1	70	0.2	3
Reduced permeability layer	110-160	37	18	27	0.2	10

Table 3 The rock spillway material properties

Layer	Depth	Sand (%)	Clay (%)	Rock (%)	Organic (%)	CEC (meq/100 g)
NAF waste rock	Entire profile	15	2	83	0.2	0.5

3.1.3 WEPP model scenarios

3.1.3.1 The TSF store and release cover

Five scenarios were run for the TSF store and release cover on the flat top in the WEPP model. These were:

- bare soil (representing initial conditions);
- soil with 30% groundcover;
- soil with 60% groundcover;
- soil and competent, NAF waste rock (50:50 mix) (the soil and waste rock mix) with 30% groundcover; and
- the soil and waste rock mix with 60% groundcover.

The final two scenarios were included to provide data on the performance of soil and NAF waste rock combined. This information may be useful should the site have a deficit of soil to be used in rehabilitation of the TSF.

Groundcover was kept constant in each scenario because plant growth rates are unknown.

Rill spacing on the TSF flat top (bare soil) was set to 0.5 m and 0.3 m when vegetated. Surface roughness was set to 0.03 m which is typical of a smooth surface which develops after many rainfall events.

3.1.3.2 The main embankment

The main embankment will be designed as a rock spillway; therefore, the WEPP model has assumed an 80% groundcover of coarse waste rock.

Rill spacing on the rock spillway was set to 0.1 m, being typical of coarse rocky material.

3.2 Limitations

The following limitations apply to the WEPP model:

- it is uncalibrated and requires experimental data (ie sediment loss, runoff and rainfall) for each material to improve accuracy;
- it does not predict deposition patterns;
- it does not adjust hillslope elevation in response to erosion;
- it does not consider gully and tunnel erosion; and
- it does not account for weathering, surface armouring and pedogenesis.

3.3 Results

The average (Table 4) and maximum (Table 5) annual erosion rates over 100 years is predicted below for the two landform elements under various surface conditions.

Table 4 Average annual erosion rate

	Waste rock	**Bare soil**	**Soil with 30% groundcover**	**Soil with 60% groundcover**	**Soil and waste rock with 30% groundcover**	**Soil and waste rock mix 60% groundcover**
Broad spillway rock chute	0.100	N/a	N/a	N/a	N/a	N/a
Flat top	N/a	4.501	0.893	0.333	0.475	0.327

Notes: 1. Units are t/ha/y
2. N/a — not applicable

Table 5 Maximum annual erosion rates

	Waste rock	**Bare soil**	**Soil with 30% groundcover**	**Soil with 60% groundcover**	**Soil and waste rock mix and 30% groundcover**	**Soil and waste rock mix and 60% groundcover**
Broad spillway rock chute	0.52	N/a	N/a	N/a	N/a	N/a
Flat top	N/a	41.40	12.48	5.46	6.76	4.66

Notes: 1. Units are t/ha/y
2. N/a — not applicable

Table 4 and Table 5 show that the rock spillway is likely to experience very low erosion rates (even in extreme rainfall years) that are well below the criteria discussed in Section 2.3. The rock spillway is therefore likely to be safe, stable and resistant to erosion.

Table 4 shows that on average, the flat top is unlikely to develop excessive rilling with any of the surface conditions (ie average erosion rate of <5 t/ha/y). All combinations of vegetation and rock cover are likely to have an erosion rate of <1 t/ha/y. In general, the soil and waste rock mix performed better than soil alone. This can be attributed to the higher coarse fraction present. The soil and waste rock mix with 60% groundcover performed the best with an erosion rate of <0.35 t/ha/y.

Table 5 shows that bare soil with no groundcover will be vulnerable to high erosion rates in the event of extreme rainfall, despite having a low average. This reinforces the importance of establishing groundcover as soon as practicable. All other surface conditions, except for soil with 30% groundcover (moderate erosion rate, 12.48 t/h/yr), had a low maximum annual erosion rate of (<10 t/h/yr).

Table 4 and Table 5 suggest that using a soil and waste rock mix will be more erosion resistant to average climatic conditions as well as extreme rainfall events. In addition to this, this will half the amount of soil required on the flat top which may be important if there is a soil deficit at closure. Therefore, this is the current recommendation for the infiltration storage layer (ie the upper most layer of the store and release cover) on the flat top. Using a soil and waste rock mix will only be feasible if the Mine can demonstrate sufficient vegetation establishment and survival. This will not only be important for erosional stability, but also for cover performance (ie removal of water from the cover via transpiration).

4.0 Conclusions

It is expected that both the rock spillway and the flat top will be safe, stable and erosion resistant in the long-term. WEPP model simulations for the rock spillway showed a maximum annual erosion rate of 0.52 t/ha/y (average of 0.1 t/ha/y). WEPP model predictions for the flat top showed the average erosion rate under all surface conditions is likely to be <5 t/ha/y. Maximum annual erosion rates were very high for bare soil, reinforcing the importance of establishing groundcover as protection against storm events. All other surface conditions, except for soil with 30% groundcover (moderate erosion rate, 12.48 t/ha/y), had a low maximum annual rate of <10 t/ha/y. In general, the soil and waste rock mix performed better on average, and in extreme climatic events, than bare soil alone. This can be attributed to the higher coarse fraction present. The soil and waste rock mix with 60% groundcover performed best with an erosion rate of <0.35 t/ha/y.

It is therefore recommended that a soil and waste rock mix is used for the infiltration storage layer of the store and release cover. This will also half the amount of soil required on the flat top which may be important if there is a soil deficit at closure. It will only be feasible if the Mine can demonstrate sufficient vegetation establishment and survival. This will not only be important for erosional stability, but also for cover performance (ie removal of water from the cover via transpiration).

4.1 Future studies

The following future studies are needed to verify the success of the final landform design:

- the rock spillway will require detailed engineering design to ensure that it remains safe, stable and erosion resistant (including QA/QC requirements);
- the waste rock to be used in the rock spillway will require testing to confirm suitability for use as rock armouring. This may include slake durability testing, particle density and water absorption and particle size distribution;
- the WEPP model will require calibrating in the form of laboratory flumes, rainfall simulator field plots and / or natural field plots, allowing the calculation of interrill erodibility, rill erodibility, critical shear and effective hydraulic conductivity (required to calibrate the WEPP model);
- the field trials, in conjunction with the calibrated WEPP model, should then be used to derive Mine specific input parameters for the 3-dimensional topographic evolution model, SIBERIA; and
- the impact of a soil and waste rock mix on the infiltration storage layer of the store and release cover will need to be explored in terms of vegetation establishment, growth and cover performance (ie seepage).

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Appendix J
Memorandum Groundwater Requirements



Technical Memorandum

To: Jonathon Crosbie (MMG Limited)

From: Frankie Dean and Ray Evans (CDM Smith)

Date: 29 July 2021

Subject: MMG Dugald River Mine Progressive Rehabilitation and Closure Plan – Groundwater Requirements

1 Background

MMG Limited is currently preparing documentation in preparation for the introduction of Queensland's new Progressive Rehabilitation and Closure Plan (PRCP) requirements. PRCP requirements for resource activities came into effect on 1st November 2019 requiring all mines with a site-specific environmental authority (EA) to prepare a PRCP. The plans require EA holders to "plan for how and where activities will be carried out on the land in a way that maximised the progressive rehabilitation of the land in a stable condition".

In early 2020 MMG identified the following data gaps relating to groundwater at the company's Dugald River Mine in relation to the PRCP documentation:

1. An assessment of groundwater interactions and potential lowering of groundwater levels that includes:
    a. consideration of the potential exposure of previously saturated geological formations to air – leading to the potential for acidic metalliferous drainage (AMD) generation; and
    b. consideration of measures to avoid or minimise groundwater discharges to the surface through appropriate mine access planning, including post mining sealing off of tunnels, shafts, adits, boreholes, and other openings.
2. A revised hydrogeological conceptual model[1]
    a. to incorporate understandings specific to the potential for dewatering of the orebody and bounding stratigraphy, and subsequent generation of AMD; and
    b. to consider post-closure groundwater system recovery.

This technical memorandum aims to address the identified data gaps, including the following components:

- Consideration of the potential for AMD to occur within the mine and access infrastructure during mining and after closure;
- Revision to the existing hydrogeological conceptual model and description of the current groundwater condition; and
- A description of existing closure plans and anticipated post mining groundwater conditions at the mine and down hydraulic gradient of the mine.

The site layout is shown in Figure 1-1 and the layout of the underground workings is shown in Figure 1-2.

[1] A hydrogeological conceptual model was developed as part of the Biennial Groundwater Review Project (undertaken by CDM Smith in 2019)

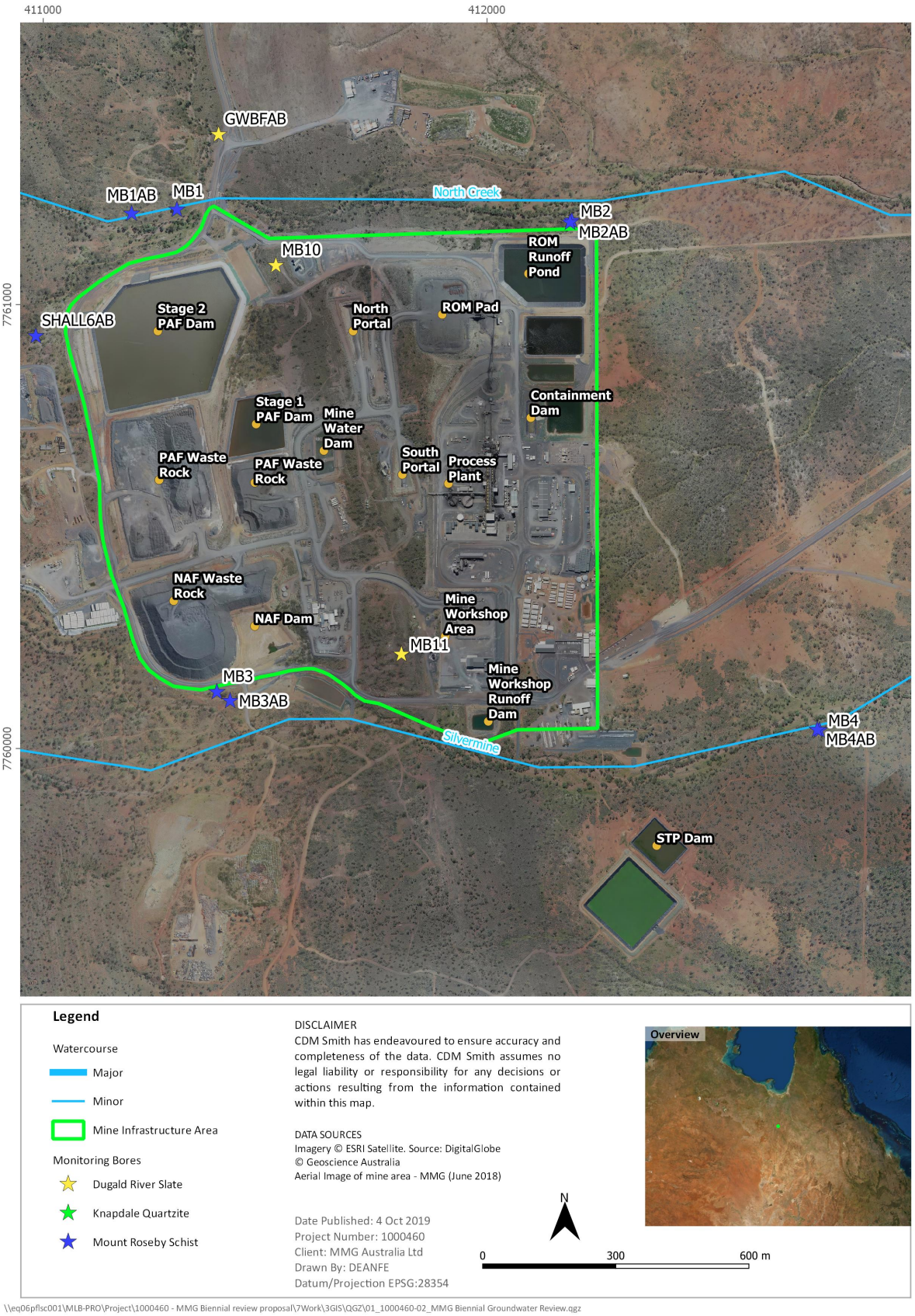


Figure 1-1 Site layout

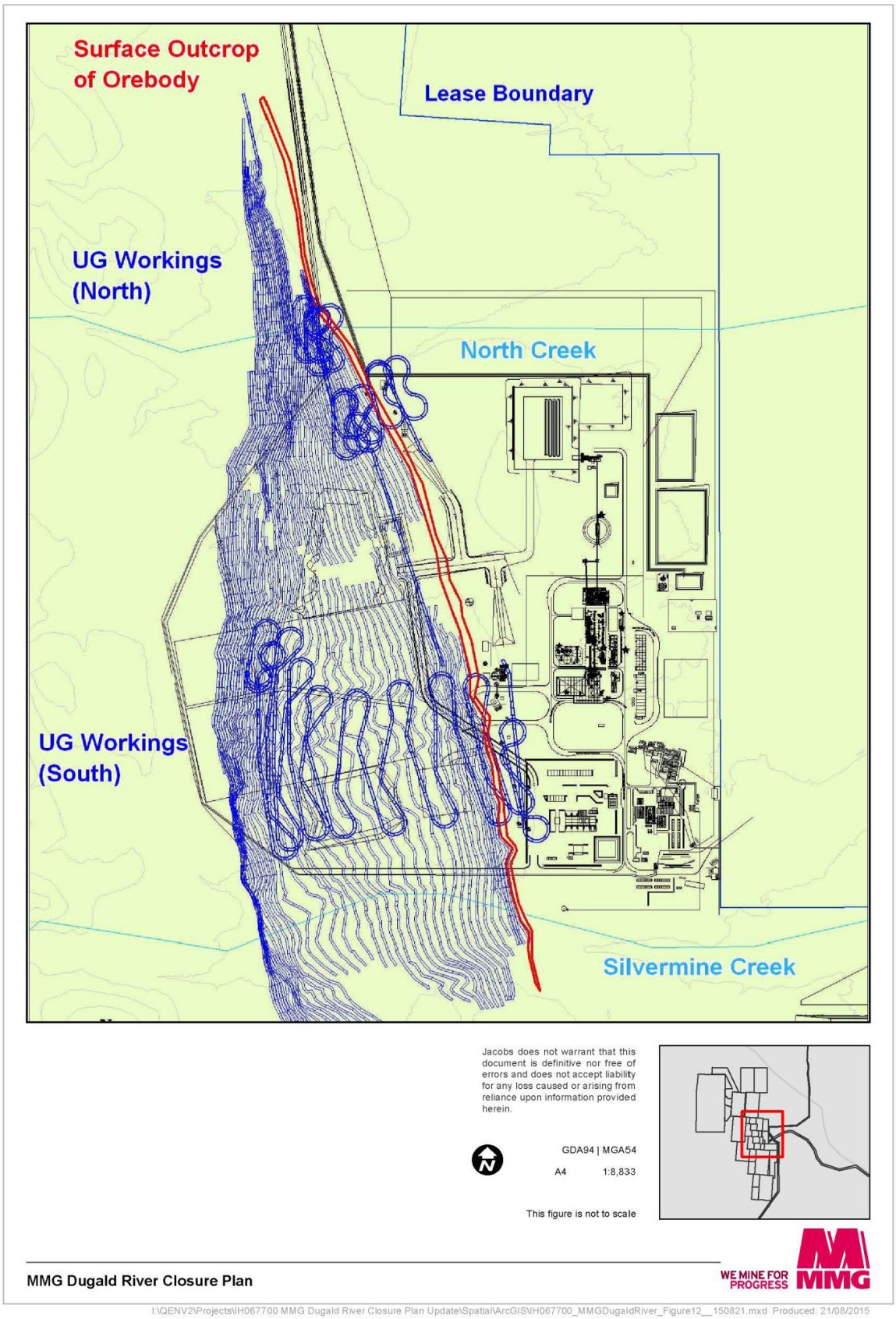


Figure 1-2 Indictive underground workings layout (from Conceptual Site Closure Plan, MMG 2015b)

2 Current Hydrogeological Conceptual Model

2.1 Geology

The geology in the area of the Dugald River Mine comprises Proterozoic metasedimentary rocks of the Mt Isa Inlier (BDH, 2017). The geological units in the study area dip steeply to the west and comprise (from oldest to youngest):

- Knapdale Quartzite – pink, feldspathic, fine-grained, locally micaceous sandstone/quartzite (Geoscience Australia, 2018). The Knapdale Quartzite unit underlies all of the TSF (BDH, 2017).
- Mount Roseby Schist – calcareous silicate metasediments.
- Dugald River Slate – black calcareous slates and black graphite slate, hosts the Dugald River orebody which outcrops at the eastern edge of the unit.
- Lady Clayre Formation – dark brown to black dolomite and dolomitic siltstone with minor quartz sandstone, siltstone and micaceous sandstone (Blake, 1987).

Although the geological units identified above are differentiated by age and the proportions of individual lithologies, they may generally be characterised as mineralised calcareous metasediments (BDH, 2017).

2.2 General conceptualisation of groundwater processes

The existing hydrogeological conceptual model has been developed for the site as part of the regular compliance reporting and is summarised below. A schematic is shown in Figure 2-1, with numbered references related to processes described below. This conceptualisation represents current mining conditions.

- The groundwater system is recharged via rainfall ① in the footslope areas to the east and west of the Knapdale Ranges when rainfall exceeds evaporation. The low permeability of the Knapdale Quartzite probably results in run off rather than infiltration across the outcropping area in the ranges. Recharge is also likely to occur via creek beds when flow events occur ② as these are identified areas of potential structural weakness (i.e. increased fracturing). Groundwater elevations vary seasonally in response to wet season rainfall events.
- Groundwater occurs in secondary porosity features such as fractures and joints to a depth of approximately 70 m (RLA, 2012). The Knapdale Quartzite is only fractured in the upper 10 m and therefore deep fracture-related groundwater in this formation is unlikely (RLA, 2012), however, some groundwater (i.e. in poorly connected fractures) is present. Groundwater (volumetric) flow is likely to be low, given the low hydraulic conductivity values of the host rocks (see BDH, 2014), which range from between 0.002 to 0.5 m/day for the Mount Roseby Schist and 0.009 to 0.3 m/day for the Knapdale Quartzite. The main groundwater flow paths are likely to be in the deeper fractured sections of the Mount Roseby Schist (BDH, 2014) and along structural features ③.
- The groundwater elevation and chemistry in shallow monitoring bores indicate a single continuous groundwater flow system, with no separate shallow groundwater system associated with surficial sediments / regolith. Basement rocks extend to the surface or near the surface with a small and variable thickness of overlying regolith, thus reinforcing the view that the aquifer system is continuous with depth.
- Groundwater flows from the topographically high Knapdale Ranges towards the topographically lower watercourses such as the ephemeral Dugald River to the east and Cabbage Tree Creek to the west ④ (although there is no evidence of groundwater discharge to these watercourses – see below). This results in a groundwater divide that is likely aligned along the Knapdale Ranges running approximately north-south. The Knapdale Ranges also form a surface water divide between the Flinders River tributaries to the east and the Leichardt River

tributaries to the west ⑤. Groundwater flow is ultimately expected to be towards the north in line with surface water drainage basins.

- Groundwater discharge mechanisms could include baseflow to the Dugald River and Cabbage Tree Creek ⑥ (although not likely to occur in the vicinity of the site based on the piezometry and surface elevations), and possibly on a seasonal basis to the very lower reaches of tributary creeks in the area (i.e. North Creek, Silvermine Creek and the unnamed tributary of Cabbage Tree Creek near the Tailings Storage Facility (TSF)). There is no data to support direct groundwater discharge to the creeks and the relative elevations suggest the groundwater levels would only be high enough to discharge to creeks in the height of the wet season when flow in the creeks is high and the flow direction is likely to be from surface water to groundwater (see Section 2.6 for more detail). Deep throughflow is likely to be the primary groundwater discharge mechanism ⑦. Losses to evapotranspiration from riparian zones and where the watertable is shallow enough could occur in the lower reaches of the creeks and at Dugald River after the wet season when groundwater levels are at their highest ⑧. Vegetation is very unlikely to be dependent on groundwater alone.
- Pre-mining groundwater quality data indicates naturally elevated total dissolved solids, fluoride, manganese and zinc occur across the area. Naturally occurring elevated sulfate is also reported for groundwater within the Dugald River Slate, related to sulfide mineralisation oxidation (BDH, 2014), suggesting that the orebody may generate acid conditions under the natural regime.
- Underground operations (voids) occur in the orebody, with decline structures in the Lady Clayre Formation. The mine is actively dewatered, but the overall rates of groundwater inflow are low at less than a few litres per second in total (BDH, 2014). The low permeability of the metasediments is thought to mitigate the vertical and lateral extent of groundwater depressurisation / drawdown in the surrounding hydrostratigraphic units ⑨.
- The TSF began receiving tailings and tailing supernatant in September 2017. Some of the supernatant is recycled in the processing plant, and some is lost to the high evaporation in the area. Groundwater levels measured near the TSF do not indicate any rise in watertable elevation since this time ⑩ indicating minimal seepage has occurred or is occurring, as expected given the very low permeability of the Knapdale Quartzite.

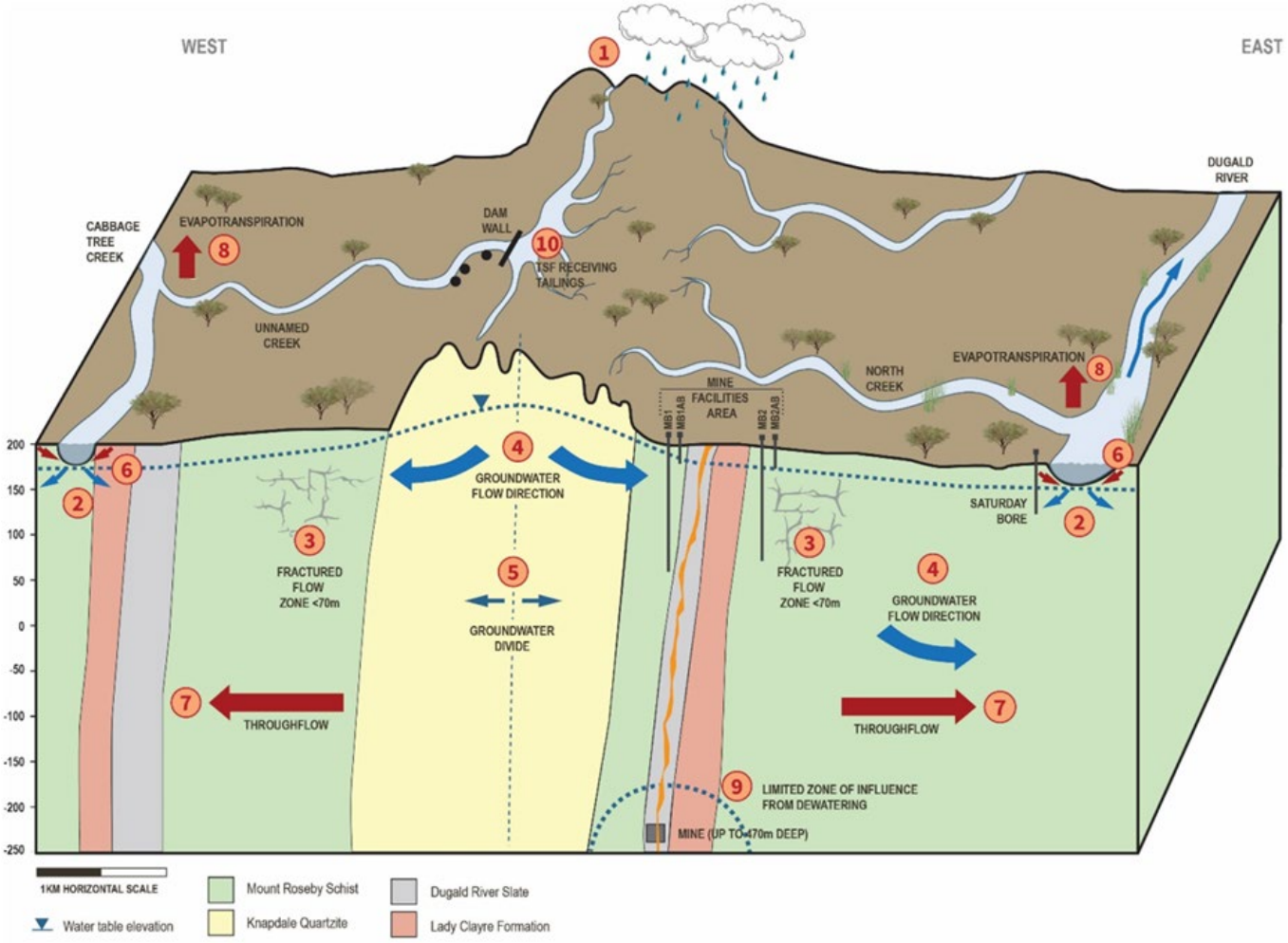


Figure 2-1 Schematic of the hydrogeological conceptual model for the DRM site (note, as discussed above, item 6 (groundwater discharge to surface water) is unlikely to occur in the vicinity of the site and is shown in the block diagram as a conceptualisation of the process, not a location the process is occurring)

2.3 Rock geochemistry conceptualisation

The geochemistry of the rocks surrounding the mine were assessed in 2010 (EGi, 2010) via a geochemical assessment of drill core samples representing waste rock, which for the purposes of this report is considered representative of the rocks hosting the orebody. The geochemistry of the rock is summarised below from the EGi report.

Seven waste lithologies have been identified at the mine site, they are calc-silicate, white mica schist, mafic feldspar porphyry, hanging wall slate, mineralized lode waste, footwall slate, and footwall limestone. The acid forming characteristics of 72 drill core samples were assessed by EGi and combined with the previous sample results (AARC analysed 121 samples in 2008 and AGC-WC analysed 18 samples in 1991) to form a database of 211 samples representing waste rock across the seven lithologies. The acid forming characteristics of the seven lithologies are summarised in Table 2-1.

Table 2-1 Summary of acid forming characteristics of waste rock samples

Lithology	No. samples	PAF	NAF	Comments
Calc-silicate (Mount Roseby Schist)	31	0 (0 %)	31 (100 %)	• Negligible sulfur and high to very high ANC. • Virtually all likely to be NAF and most will have a large excess of neutralising capacity due to high carbonate content.
Mafic feldspar porphyry (Mount Roseby Schist)	7	0 (0 %)	7 (100 %)	• Low sulfur and moderate to high ANC. • A relatively small number of samples tested but results suggest waste rock from this lithology will be NAF, most with a considerable excess of neutralising capacity.
White mica schist (Mount Roseby Schist)	17	2 (12 %)	14 (88 %)	• Low sulfur and variable ANC (from low to high). • Results suggest waste rock from this lithology will predominantly be devoid of sulfur and hence will be NAF, but there is a possibility of some material with low ANC (<10 kg H2SO4/t) which has slightly elevated sulfur (~0.3 %S) that could be PAF, albeit with a low capacity for acid generation.
Hanging wall slate (Dugald River Slate)	52	28 (54 %)	24 (46 %)	• Moderate to high sulfur content and variable ANC. • Results indicate a major portion of waste rock from this lithology will be PAF, some with a very high capacity for acid generation. There will also be some NAF rock, which is primarily distinguished by having high to very high ANC.
Lode waste (Dugald River Slate)	18	13 (72 %)	5 (28 %)	• High to very high sulfur content and variable ANC. • Majority of mineralised waste within the lode will be PAF with a very high capacity for acid generation. Only lode waste with very high ANC (i.e. >200 kg H2SO4/t) will be NAF.
Footwall slate (Dugald River Slate)	44	9 (20 %)	35 (80 %)	• Moderate to high sulfur content and moderate to high ANC. • Results suggest that footwall slate will be predominantly NAF but some footwall slate with low ANC is likely to be PAF.
Footwall limestone (Lady Clayre Dolomite)	42	1 (2 %)	41 (98 %)	• Moderate sulfur content and moderate to high ANC. • Results suggest virtually all footwall limestone is likely to be NAF and will have a large excess of neutralising capacity.

PAF = potentially acid forming, NAF = non-acid forming, ANC = acid neutralisation capacity

An assessment of the ANC of the rock indicates that the ANC in the samples almost all resulted from carbonate forms that were readily available under circum-neutral to weak acidic conditions and would be expected to provide effective buffering of sulfide derived acidity if such material were exposed to atmospheric conditions.

Elemental analyses of selected samples showed:

- No significant metal or metalloid enrichments identified in the calc-silicate, mafic feldspar porphyry and white mica schist.
- Many of the hanging wall slate, footwall slate and lode waste samples were highly enriched with one or more of a range of environmentally important elements in comparison to concentrations typically occurring in background soils.
- The most prevalent enrichments were arsenic, cadmium and zinc. There was also less frequent enrichment with copper, lead, mercury, and selenium.

Elements that exhibited a higher propensity for release under oxidising conditions (under batch extraction tests) included zinc, lead, nickel, manganese, copper, cobalt, and to a lesser extent arsenic. However, significant releases of these elements were almost exclusively confined to PAF waste once acidification had occurred. With the NAF rock producing neutral drainage, the concentrations of environmentally important elements were typically at trace values only. Elements that showed little or no propensity for release regardless of pH included mercury, tin, chromium, selenium and antimony.

2.4 Potential for AMD during operations

AMD could occur during mining operations if the in situ PAF rock is exposed to oxygen and/or oxygenated water. Whether this could occur at DRM is dependent on two factors: the location of the PAF rock and the degree of dewatering that is occurring (noting the difference between depressurisation, where rocks remain saturated, and dewatering).

2.4.1 Location of PAF rock

The PAF rock at DRM is located primarily within the ore body, which is being removed from the mine. The rock that comprises the hanging wall and footwall is the Dugald River Slate and the Lady Clayre Dolomite, respectively. The layout of these rocks is presented in the cross section in Figure 2-2, showing the rocks dipping steeply to the west. The inferred groundwater flow direction on this cross section is from left to right (west to east).

The acid forming characteristics of the rocks that comprise the hanging wall and footwall are a mixture of PAF and NAF. The hanging wall slate is likely to include a high proportion of PAF waste rock, some with a very high capacity for acid generation. There will also be some NAF rock, which is primarily distinguished by having high to very high ANC. The footwall slate is predominately NAF although some footwall slate with a low ANC will be PAF. The footwall limestone is virtually all NAF with a large excess of neutralising capacity.

2.4.2 Dewatering

Groundwater observations during mining were collated in the geology chapter of the pre-feasibility report for the Project (MMG, 2015a). At this time the North Decline and South Decline had been developed to 240 m below the surface, mostly located within the Lady Clayre Formation, and trial mining was underway by long hole open stoping in the Dugald River Slate. The declines are shotcreted immediately after development to provide ground support, which inhibits ongoing monitoring of groundwater inflow to the workings (this also limits oxidation of the rock). Observations made by MMG staff include that the mine is considered a ‘dry mine’ by industry standards, with no requirement to depressurise strata in advance of mining and no requirement for engineered systems to manage groundwater inflow, including the access decline developed in the dolomitic Lady Clayre Formation.

Rates of groundwater inflow during mining have been low, typically less than 1 L/s in zones of new development, and rates of flow have been noted to rapidly decline following mining, although inflows have been more sustained in zones associated with large scale structural features. In these zones, groundwater continues to weep or drip through the shotcreted underground development but does not cause sustained flows.

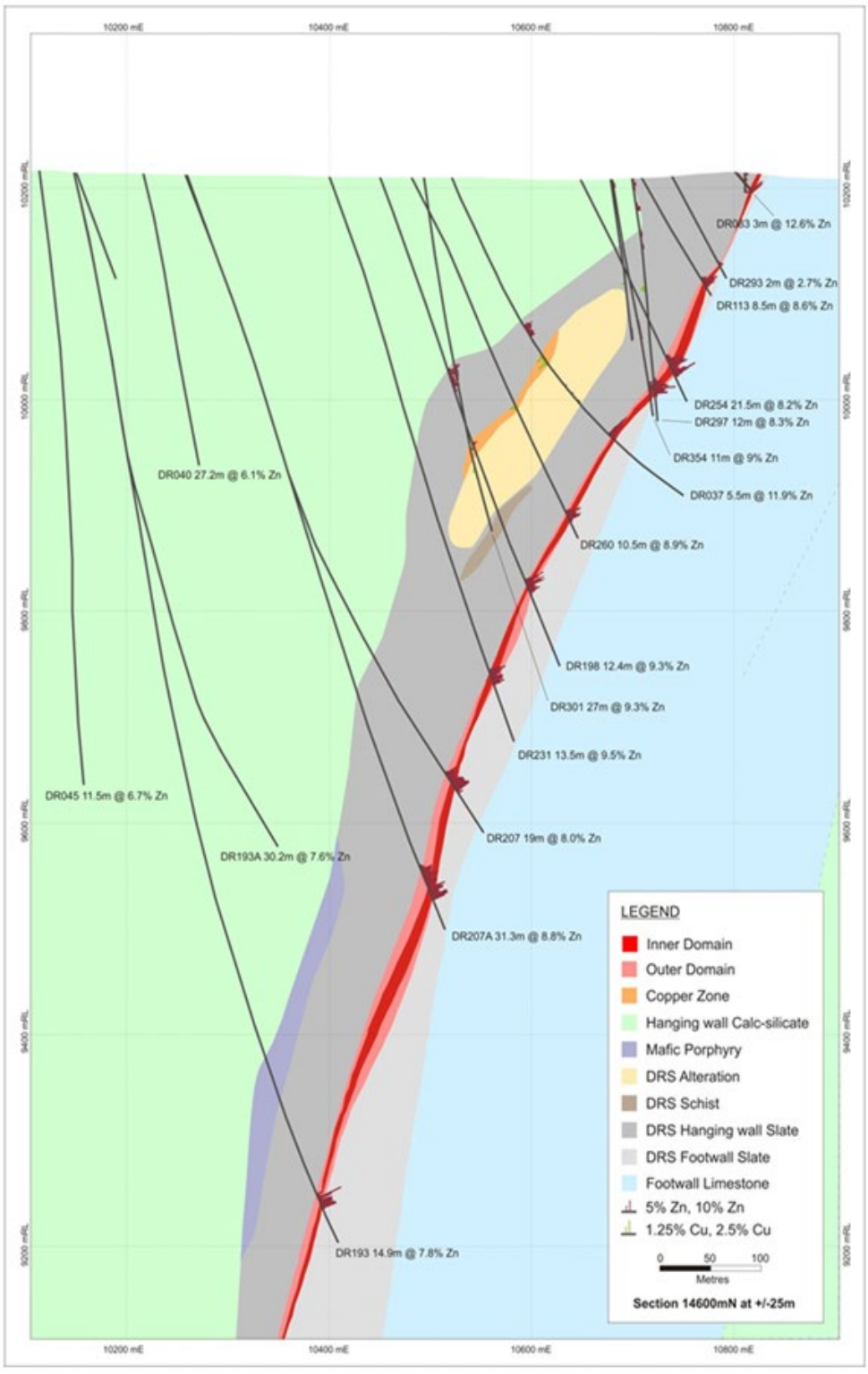


Figure 2-2 Idealised cross section (MMG, 2015a)

During mining operations, a sumping and pumping system is operated to remove water accumulating in the underground workings. Water accumulating underground includes groundwater inflow and flows pumped underground for use in dust suppression, drilling operations, and grouting and shotcreting. Although the contribution of groundwater inflow to the total pumping is not quantified, it is low (less than a few L/s in total) and is small in comparison to the contribution of water used in the mining operations.

Groundwater levels are measured near the mine in monitoring bores installed in the Mount Roseby Schist to a maximum depth of 99 m and one monitoring well in the Dugald River Slate (GWBFAB – 12 m deep). Groundwater levels recorded for these bores (data to mid-2019 available - Figure 2-3) are within 10 m of the surface and show seasonal variations consistent with general rainfall (and expected recharge) trends, with lowest groundwater levels at the end of the dry season and levels rising during the wet season. The seasonal variation is of a similar magnitude (1 to 3 m) in both the shallow and deep bores. There is no long-term trend or evidence of groundwater level decline apparent in any of the monitoring bores in response to mine dewatering.

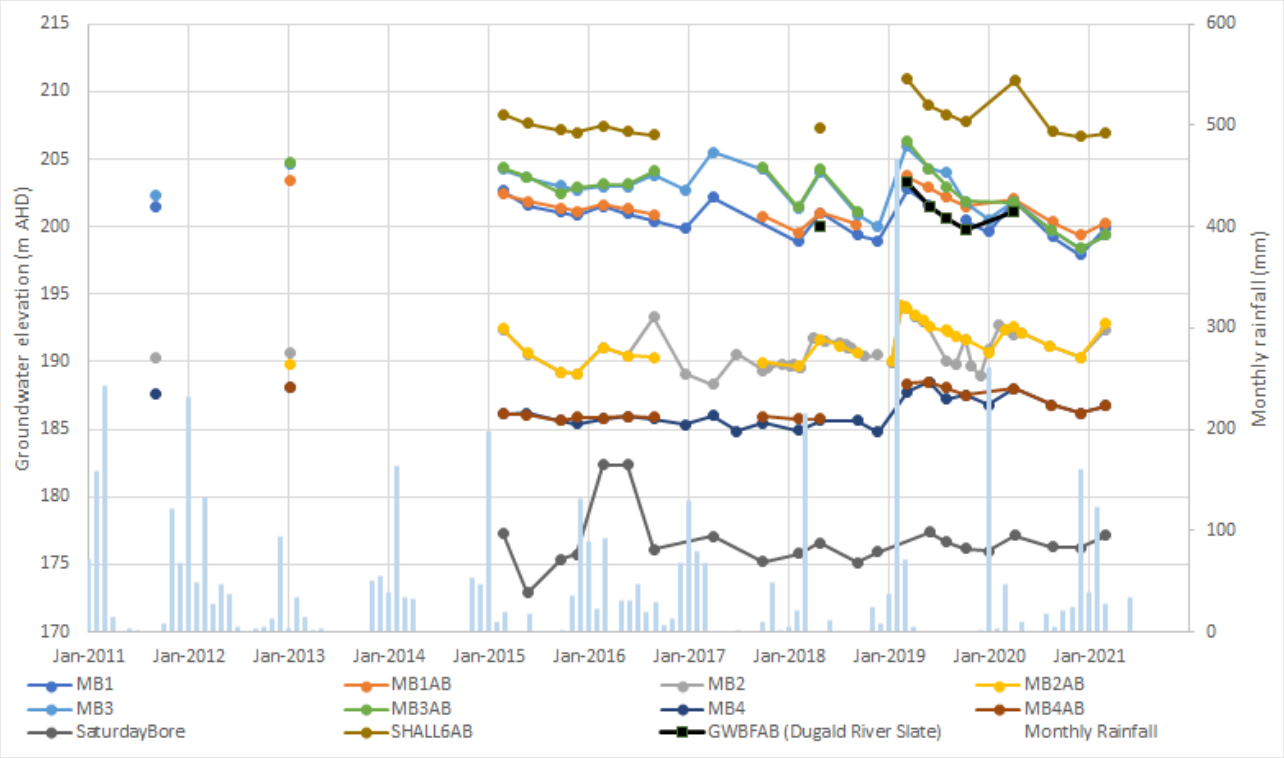


Figure 2-3 Groundwater elevations for bores in Mount Roseby Schist across the Site and GWBFAB, a shallow well in the Dugald River Slate

MB10 and MB11 were installed to monitor groundwater levels near the mine workings in the Dugald River Slate and were screened across various intervals to a depth of 108 m. In Quarter 3 of 2012 these bores were intercepted by the mine workings, rendering them unsuitable for use as groundwater monitoring bores. Prior to mining, the bores recorded groundwater levels similar to those observed in the nearest Mount Roseby Schist (MB3 and MB1). Bore GWBFAB is also screened within the Dugald River slate at 6.3 to 12.3 m depth. Groundwater levels measured in this bore are of a similar level and show seasonal trends similar to the Mount Roseby Schist monitoring bores with no apparent long-term decline.

The contact between the Mount Roseby Schist and Dugald River slate dips to the west and MB1 and MB3 (screened in the Mount Roseby Schist) are located just to the west of this contact. The workings extend below MB1 and MB3 in the Dugald River Slate where it dips below the Mount Roseby Schist. The steady groundwater levels in MB1 and MB3, as well as GWBFAB, suggest that the strata overlying the workings is not being depressurised. It is more likely there is

limited depressurisation of the rocks immediately surrounding the workings and that the low hydraulic conductivity mitigates the zone of influence the mine has on groundwater pressures in surrounding rocks.

Pore pressures within the workings are not recorded and therefore the extent of depressurisation is uncertain. However, given the low volumes of groundwater that is estimated to be extracted from the workings, the dewatering of the rocks in contact with the mine workings is unlikely to extend far from the working faces.

2.4.3 Chemistry of water from mine workings

Water is pumped from the underground workings to the Underground Mine Water Collection Dam (UGMWD). Water samples from this dam indicate neutral to slightly alkaline conditions (pH of 6.15 to 8.39) with alkalinity in the range of 41 to 123 mg/L $CaCO_3$ and low concentrations of key metals. The samples have been taken from March 2012 to January 2020 and over this period there has been a decrease in pH (although still predominately above 7 pH) and alkalinity and an increase in sulfate and filtered and total metals (Al, Pb, Mn, Cd, Ni and Zn). Total and filtered arsenic, copper and nickel have not shown an increase. This data could indicate that limited AMD is occurring within the mine, however, given the suspected low contribution of groundwater to the underground mine water and the reuse of water through the system, this is difficult to confirm.

2.4.4 PAF rock stored at the surface

Basic chemistry suggests that when PAF material is exposed to the air it will commence oxidation and therefore acid production. This acid production is being managed within the PAF rock dumps. Any solutions that are generated within the PAF waste rock dumps are channelled to the two storage dams. These dams fill during the wet season and evaporate during the dry season. The dams are HDPE lined with leak detection and no overflow occurs from the two dams.

2.4.5 Acid generating material backfill

The plan for mine rehabilitation is to emplace all the PAF waste rock within the mine void along with all NAF rock (see Section 3.2). PAF rock will be prioritised for backfill to minimise oxidation at the surface. Bu mixing PAF and NAF rock, there will be a reduced potential for AMD from the PAF as the NAF will provide some buffering capacity. Post mining, groundwater will return to fully saturate the mine workings. At some stage in the future chemical equilibrium will be reintroduced such that the degree of oxidation will reduce to near background levels. This will have the effect of reducing any acid generation in the backfilled material. Section 4 provides more details on post mining groundwater conditions.

2.4.6 Conclusion

The key question to determine whether AMD could be occurring during operations, and whether it will continue to occur post-mining as groundwater levels and pressures recover, is whether PAF rocks exposed by mining have been dewatered and oxidised. This question is difficult to answer due to the data presently available around rock saturation conditions adjacent to mine workings. However, given the low volumes of water extracted from the mine, it is unlikely significant desaturation has occurred and therefore processes that result in AMD are unlikely to have taken place to the extent that they are significant (as indicated by the reported water quality data for water samples collected from the UGMWD).

The most likely source of AMD is the backfilled PAF material which may have begun oxidation at the surface. This material will be mixed with NAF material before backfill to reduce the AMD potential.

The mine has a further 26 years expected life and therefore the extent and consequences of desaturation could be expected to change over that time. Monitoring of the saturation of rock at the mine face and/or the chemistry of groundwater issuing from the surrounding strata should be considered in the ongoing monitoring program.

2.5 Tailing Storage Facility

The TSF is located on the western side of the Knapdale Ranges and was constructed by installing an impoundment across the headwaters of an unnamed tributary to Cabbage Tree Creek (Figure 2-4), a tributary of the Leichardt River. In undisturbed conditions, this ephemeral tributary flowed north within the Knapdale Ranges and then west towards Cabbage Tree Creek. The flow in Cabbage Tree Creek is described as being brief and episodic with little baseflow contribution (TropWater, 2013), and the water course is dry most of the year.

The underlying geological unit at the TSF is the Knapdale Quartzite, which forms the higher elevation Knapdale Range between the mine area and the TSF and is described as calcareous felspathic cross-bedded sandstones, pink quartzite and siltstone. To the west of the Knapdale Quartzite the younger sequence seen on the east of the range is repeated to the west due to an anticline structure.

Three sets of two nested monitoring wells were installed in the Knapdale Quartzite but only one set remains as the others were within the footprint of the TSF. MB9S is installed to 10 m depth and is consistently dry. MB9D is installed to 30 m depth and records groundwater at around 15 m below ground level. MB5 and MB6 are located to the west of MB9D and installed in the Mount Roseby Schist, each installed to 100 m depth. These wells show similar groundwater elevations to MB9D. Historical monitoring in the decommissioned bores (MB7S/D and MB8S/D) indicated groundwater flows from east to west in the vicinity of the TSF, with steeper gradients in the Knapdale Quartzite compared to the Mount Roseby Schist, reflective of the change in topography. Groundwater levels in MB9D show very little seasonal variation (with 0.6 m) whereas levels in MB5 and MB6 vary by almost 3 m seasonally. This could suggest that very little rainfall is recharged through the Knapdale Quartzite compared to the Mount Roseby Schist. This is likely to be due to the very low hydraulic conductivity of the Knapdale Quartzite and the low connectivity of fractures between the surface and the screened portion of the unit at MB9D (18 to 30 m depth).

Groundwater in the Knapdale Quartzite travels within the fracture zones, which occur predominately within 30 m of the surface (BDH, 2017). Hydraulic testing of the Knapdale Quartzite was undertaken as part of the Australian Tailings Consultants (ATC) investigation for the proposed TSF in 2008. Four boreholes (not constructed) were drilled to between 10 and 25 m deep within the footprint of the current TSF and tested at a range of depths using falling head tests and packer tests. The study concluded that the Knapdale Quartzite has a low to moderate permeability with the degree of jointing and fracturing being the dominant factor determining permeability. Permeability values range from 10^{-8} to 10^{-5} m/s. The permeability of the Mount Roseby Schist at MB6 was estimated by pump out tests and indicates a permeability of 10^{-8} m/s.

BDH (2014) describe the occurrence of open fracturing in the Knapdale Quartzite as limited, and although groundwater flow may be locally greater within discrete fracture zones (such as along the local watercourses), on a regional basis groundwater transmission occurs at relatively low rates. No shallow groundwater was identified in the area and it is not thought that groundwater discharges to surface water in the vicinity of the TSF.

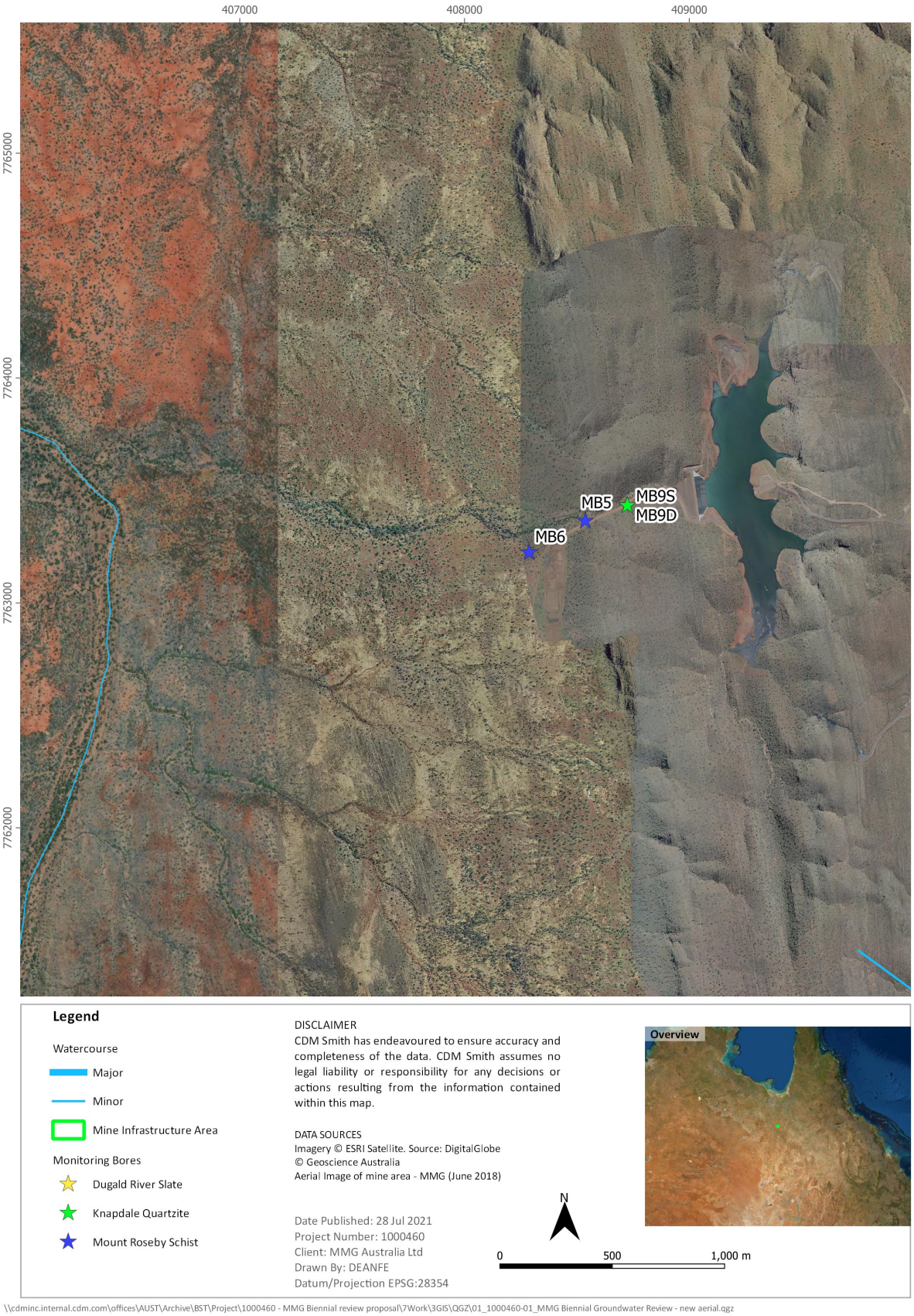


Figure 2-4 Map of TSF showing monitoring bores (note, MMG high resolution imagery only extends to MB6)

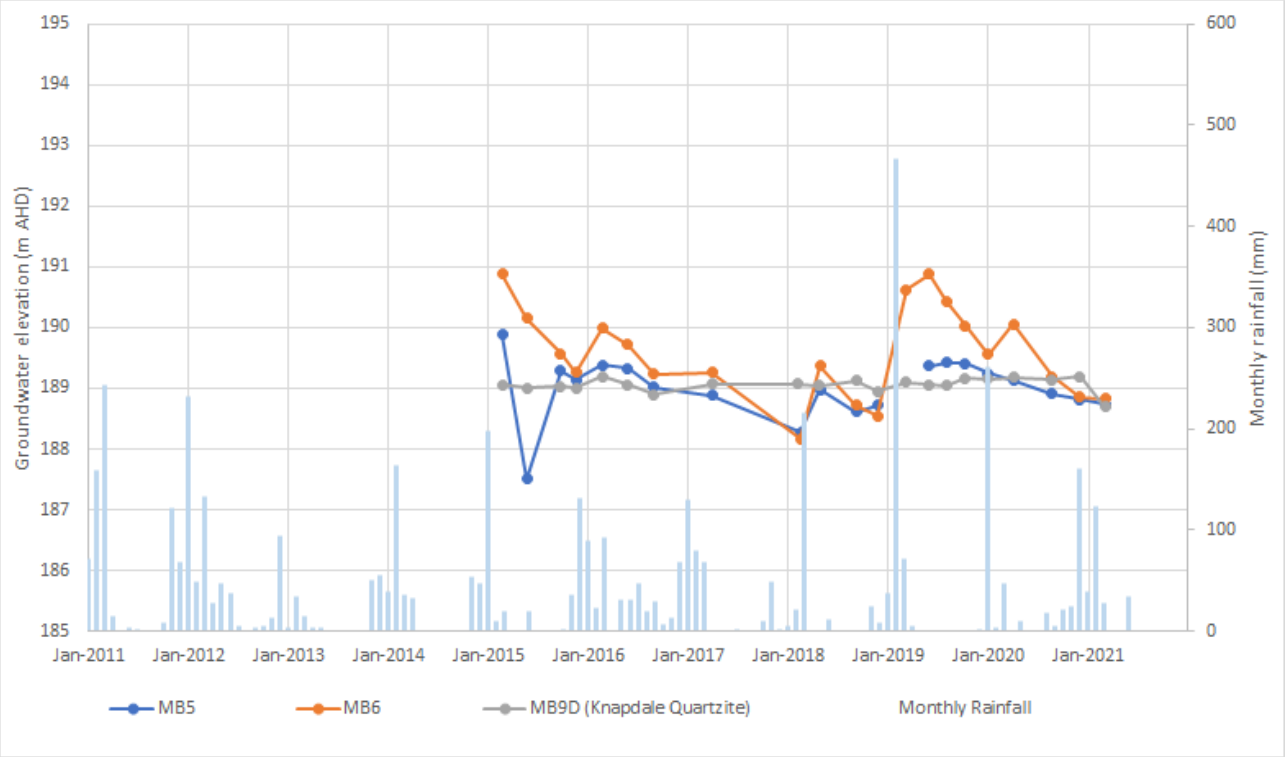


Figure 2-5 Groundwater elevations for bores in Cabbage Tree Creek catchment (note, MB5 and MB6 installed in Mount Roseby Schist, MB9D installed in Knapdale Quartzite)

The TSF embankment was constructed between 2015 and 2016 and the TSF began receiving tailings and tailing supernatant in September 2017. Tailings are introduced to the TSF from the north and the south of the valley, with the intention of forming a low permeability basal layer of tailings across the TSF (tailing consolidation modelling indicates saturated permeability averaging between 10^{-8} to 10^{-7} m/s (ATC Williams, 2016)). The timing for the formation of this low permeability layer is unknown but likely to be within a year or two depending on how the fines dewater (wicking to the surface or gravity drainage). Detailed aerial imagery collected by MMG in June 2018 (dry season) indicates surface water in the TSF (Figure 2-4).

Water is extracted from the TSF and returned to the mine area for use. Water balance modelling indicates there will be periods where no water is available for return, as it is expected that the pond will dry up for extended periods of time depending on the climatic conditions (ATC Williams, 2016).

The TSF does not include impoundment lining, relying instead on the natural low permeability of the Knapdale Quartzite and deposition of low permeability tailings (ATC Williams, 2016). It is expected that water may infiltrate and saturate the 5 m of rock immediately beneath the TSF but that this local groundwater will not move offsite due to the limited fracturing within the rock and the natural shape of the valley (ATC Williams, 2016). The only identified pathway for this local groundwater system to move into the Cabbage Tree Creek catchment is at the embankment which is located at the natural drainage outlet and may represent a zone of relative structural weakness in the rock. The embankment has been constructed with an intercepting key trench and grout curtain at the upstream toe. Seepage water is collected in a HDPE lined pond on the western side of the embankment.

The results of groundwater monitoring to date in the down gradient wells do not show any indication of seepage from the TSF.

2.5.1 TSF source-pathway-receptor model

- **Source:**
  - Tailings impacted water contained in the TSF.
- **Receptors**
  - Aquatic ecosystems in Cabbage Tree Creek catchment. There are no GDEs identified related to Cabbage Tree Creek. The depth to groundwater in the upper catchment near the TSF is 13 to 16 m below ground level (MB5 and MB9D) and in the topographically lower and flat area (MB6) generally greater than 10 m below ground level indicating very low probability of groundwater discharge to surface water in the tributary to Cabbage Tree Creek.
  - Stock watering in the Cabbage Tree Creek catchment. The nearest stock bore is located 5 km north of the TSF (RN38685), which could be downgradient if the flow direction veers north in the Cabbage Tree Creek valley towards the Leichardt River.
- **Potential pathways between source and receptors.**
  - Seepage into the groundwater beneath the TSF in the Knapdale Quartzite, flow downgradient through fractures towards Cabbage Tree Creek and downgradient stock wells.

    The likelihood of this pathway eventuating is considered to be low, given the low permeability of the Knapdale Quartzite, the low permeability sediments at the base of the TSF, the low hydraulic conductivity of the downgradient rocks and the flat hydraulic gradient in the valley (resulting in slow groundwater movement).

    It is possible that some change in groundwater chemistry close to the TSF may occur during the first few years of TSF operation (before the low permeability sediments form at the base of the TSF) representing a low flux of potentially impacted tailings water. However, the impact on down gradient receptors is likely to be low due to dispersion, dilution and attenuation along the flow path between the TSF and down gradient receptors.

    The TSF has been operational for around 2 years and no change in down gradient groundwater chemistry has been identified. Monitoring of groundwater will continue during operation, however given the likely groundwater travel times (around 20 m/year in the Mount Roseby Schist – see Section 4.1), it could be decades before any impact can be discerned.

2.6 Groundwater surface water interaction

Depth to groundwater across the site is generally greater than 4 m, with most monitoring bores located in close proximity to ephemeral surface water and drainage features (i.e. North Creek, Silvermine Creek and Cabbage Tree Creek). It is unlikely that groundwater contributes baseflow to surface water features in the vicinity of the mine based on the depth to groundwater compared to creek bed levels, and the ephemeral nature of the streams.

Bore hydrographs do not appear to intersect ground surface and it is unlikely groundwater – surface water interaction occurs in the area of the MIA. The only time that groundwater levels may be high enough to intersect the ground surface could be during the height of the wet season. However, during this time the flow in the creek is likely to still result in an overall gradient from surface water to groundwater and recharge is likely to dominate the groundwater-surface water interaction. This observation is supported by interpretations presented in the EIS for the Project (*Ref: Environmental Impact Statement (EIS) Report under the Environmental Protection Act 1994 – Dugald River Project, November 2011*), that localised natural groundwater discharge does not occur in the project area.

The Groundwater Dependent Ecosystems (GDE) Atlas (BoM) shows the Dugald River as a low potential GDE (presumably in association with either riparian vegetation or baseflow fed aquatic ecosystems) based on national assessment. Saturday Bore is close to Dugald River and shows water levels below the base of the river, and therefore it is very unlikely that groundwater support aquatic fauna in the river near the site. This is supported by the flow duration curve for a monitoring station 6 km downstream of the site (915206A Dugald River At Railway Crossing) which indicates the river is dry for 75% of the record period (50 years). When groundwater levels are high it is possible that some groundwater discharge occurs through evapotranspiration of riparian vegetation, although given the variable groundwater levels, vegetation is not likely to be solely reliant on groundwater.

North Creek, Silverman Creek and Cabbage Creek were not identified as potential GDEs in the Atlas.

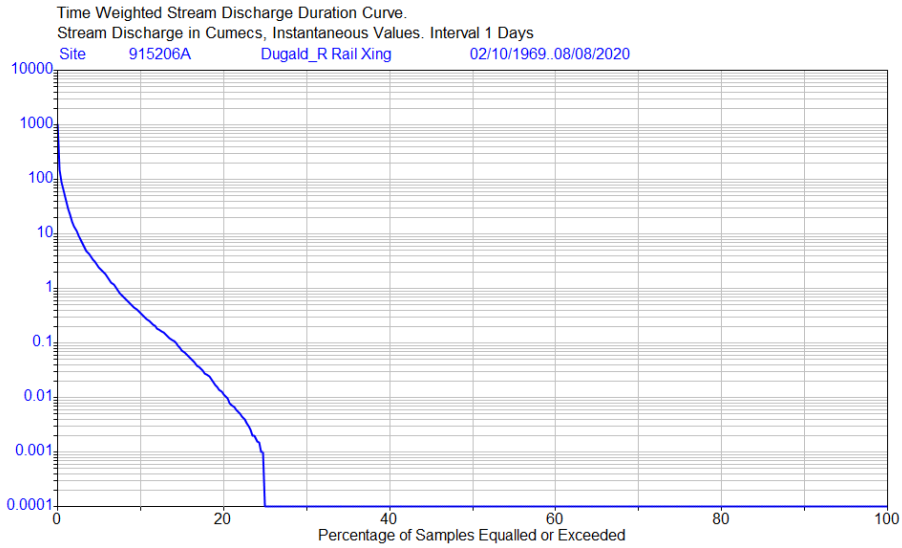


Figure 2-6 Flow duration curve for 915206A Dugald River At Railway Crossing (Queensland Government, 2021)

2.7 Stock watering

The primary environmental value of groundwater in the area (given the low probability of groundwater discharge to creeks) is abstraction for stock watering of cattle on pastoral stations overlying and surrounding the mine (BDH, 2014). The closest identified bore which is hydraulically down-gradient of the Dugald River mine and could potentially be used for stock watering is Saturday Bore. Saturday bore is located adjacent to the Dugald River at the confluence of North Creek and Silvermine Creek just before they join the Dugald River. This is 2.5 km down gradient from the mine workings.

The 2014 Groundwater Monitoring Program (GMP) (BDH, 2014) describes the potential for stock watering as follows:

- *"Much of the country around the Dugald River mine has been de-stocked in response to the drought conditions and groundwater abstraction for stock watering is not occurring in the mine area.*
- *In many locations, baseline groundwater quality within the fractured metasediments is unsuitable for potable consumption, due to naturally occurring concentrations of major ions and fluoride.*
- *Abstraction of groundwater for potable use in the area down-gradient of the Dugald River mine was not identified during the hydrogeological studies completed during mine development."*

Recent groundwater monitoring at the site (2019-2020) indicates fluoride in the groundwater between 0.4 and 6.5 mg/L. In relation to fluoride, the GMP provides the following information (BDH, 2014):

"Elevated concentrations of fluoride in groundwater from fractured formations of the Mt Isa Inlier, and in groundwater sourced from the Great Artesian Basin in western Queensland are a well-documented, naturally occurring phenomenon. Background fluoride concentrations exceeding 10 mg/L have been recorded in groundwater sampled in the general region of Cloncurry. Elevated fluoride concentrations in groundwater in western Queensland were identified as early as the 1940s during investigations into the potential for dental fluorosis to occur in stock being watered from groundwater."

A number of mitigation measures have been implemented relating to stock watering including preventing abstraction within the mine leases and general practices at the mine to contain impacted water (i.e. lined dams).

3 Mine Closure Plans

The current Life of Mine (LOM) plan for the DRM is outlined below (MMG, 2015b):

- Late 2015 – commencement of underground mining
- Early 2018 – completion of processing plant construction and commence commissioning
- 2046 – mine operations cease (assumed 28-year mine life)

3.1 Underground mine operations

The underground mine will be approximately 1,600 m along strike and 1,000 m deep and accessed by twin declines that will be used to haul ore and waste rock from the mine. All ore and waste will be drilled and blasted. The mine will be ventilated by eight vertical shafts (MMG, 2015b). Dewatering of the mine has commenced with water extraction rates estimated at around 3 L/second (MMG, 2015b), although only a small proportion of this is expected to be groundwater and the remainder is makeup water introduced from the surface. The underground infrastructure will potentially be decommissioned prior to cessation of the production plant or decommissioning of the TSF.

The closure goal for the underground infrastructure is that on completion of mining activities, the underground declines and the box cut voids will be returned to safe and stable landforms, to allow the intended post mining land use. The preferred closure design is to use PAF paste backfill to backfill underground voids and seal portals. The box cut void and underground portal entrances will be backfilled with NAF waste material, capped with concrete and then covered with NAF material. Ventilation and egress shafts will be backfilled with NAF material and then capped with concrete to prevent any subsidence. These capped structures will be covered in growth medium and topsoil and native species seeds, if required.

If insufficient material exists for backfilling shafts, the final closure design may involve an engineered concrete plug for the shaft and no backfilling. This would be expected to include steelwork to 5m below surface and then concrete.

3.2 Waste rock management

MMG has produced estimates of the quantities of PAF and NAF materials to be produced for the life of the mine (MMG, 2015b). Of the 7 million tonnes of waste produced, 3.5 million tonnes are expected to be PAF material and 3.7 tonnes NAF material. All PAF and some NAF material will be progressively returned underground as stope fill. NAF and PAF waste rock will be stored in dedicated rock dump areas located on the western side of the processing areas.

The PAF waste rock dump will contain PAF and high sulfur NAF material on the surface until this material can be returned underground for stope fill. Stringent engineering and surface water drainage controls are employed in the construction of the dump areas to ensure that the generation of contaminated leachate is avoided or minimised and that no discharges occur to surface water or groundwater resources. All runoff from the PAF waste rock dumps are directed to and collected in Stage 1 PAF Pad Run Off Dam and the Stage 2 PAF Pad Run Off Dam. The PAF waste rock dumps were constructed with a 1 m layer of well compacted low sulfur NAF waste rock at the base of the dump.

The closure goal for the waste rock dumps is that at the end of mine life, all PAF and high sulfur NAF material within the PAF waste rock dump areas will have been removed and disposed of underground as part of operational stope-filling requirements.

3.3 Tailings Storage Facility

At closure the Tailings Storage Facility (TSF) is anticipated to be rehabilitated with an infiltration storage cover system, to limit rainfall seeping into the potentially acid forming tailings. Very little reprofiling of the TSF surface will be required other than the embankment which will be converted to a rock lined spillway. The spillway will move excess water (rainfall runoff and cover seepage) off the top surface of the rehabilitated landform, preventing ponding.

Through cover column trials and a semi-calibrated model, MMG have determined the TSF cover will likely require a 1 m thick infiltration storage layer (ISL) to reduce the potential for seepage into the potentially contaminating tailings (SGME, 2019). Run-of-mine NAF waste rock blends will be used in the TSF final cover. The preferred cover option is yet to be scaled up to a field trial to validate the column results, however, this is planned to be completed by MMG in the future.

Groundwater levels measured near the TSF currently do not indicate any rise in the watertable elevation since tails deposition began, indicating minimal seepage has occurred or is occurring. This is to be expected given the very low permeability of the Knapdale Quartzite. This, coupled with the column trial results, indicates that it is unlikely that significant AMD seepage from the TSF would impact groundwater post closure.

4 Post Mining Groundwater Conditions

Dewatering will continue to occur throughout the life of the mine to maintain dry conditions in the workings. The deeper sections of the mine are not expected to contribute significantly to groundwater inflows, as the intersected hydrostratigraphy is known to be tighter (less permeable and lower storativity) at depths greater than 100 m. To date, there has been no apparent impact on groundwater levels in the surrounding Mount Roseby Schist or the shallow Dugald River Slate.

Recharge to the aquifer in this region is via infiltration of rainfall and surface water flows when the ephemeral creeks flow. Estimations of groundwater recharge were made in the EIS for the project (RLA, 2012) by examining rainfall and evaporation data as well as groundwater level trends. RLA concluded that although evaporation consistently exceeds rainfall throughout the year, groundwater recharge does appear to be occurring based on the groundwater hydrographs. More recent data supports this, with groundwater elevations showing seasonal variation linked to higher rainfall, and potentially occurrences of streamflow. RLA estimated annual recharge is likely to be in the order of 10 mm/yr, although this is likely to occur preferentially along watercourses with minimal recharge occurring across the rest of the landscape.

Even at a mine dewatering rate (i.e. groundwater only, not including water introduced to the mine) of less than a few L/s, it is expected that limited 'mining' of groundwater is occurring in association with mining (i.e. groundwater is being abstracted at a rate higher than recharge replenishment). Over time, it may be reasonable to expect the groundwater monitoring network shows some depressurisation of the shallow groundwater system in response to mining and dewatering, but dewatering of overburden hydrostratigraphy back to surface is very unlikely to occur.

Following cessation of dewatering, groundwater will begin to inundate the remaining voids. An estimate of the remaining void at the end of the mine life has been made by MMG to be around 2,200,000 m^3, including a 10% overbreak. Assuming an inflow rate of 1 L/sec and no desaturation of the surrounding formation, a timeframe of greater than 70 years would be expected for the void to become fully saturated and repressurisation of surrounding rocks to commence. In reality, limited dewatering of bounding rocks is likely, but the dewatered volume is likely to be small relative to the void remaining after completion of mining. The expected timeframe for full recovery (back to around pre-mine conditions) is more than 100 years.

Where PAF materials are exposed to oxygen, on the mine working walls and for some relatively small distance back from the walls in the unmined rock, the potential for generation of AMD to impact on groundwater filling the mine

voids exists, albeit low based on the geochemical studies described in Section 2.4. Backfilled material also has the potential to be a source of AMD, as the oxidation processes may have started in this rock whilst stored at the surface, as discussed in Section 2.4.4.

Whilst recovery is occurring, potentially impacted mine water quality will be hydraulically contained (by pressure gradients) and only after recovery has occurred will this mine water have the potential to move away from the filled mine voids under established hydraulic gradients (expected to be toward the east consistent with hydraulic gradients observed today). If this water continues to be impacted by acidity after decades of accumulation in the voids, the risk posed to possibly sensitive groundwater receptors is considered low due to the following:

- Groundwater does not discharge to the surface in the vicinity of the mine.
- Groundwater is not used to support stock and domestic water supplies in the area of the mine.
- Groundwater may discharge to downstream aquatic ecosystems associated with Dugald River, for example, but only after very long flow paths through hydrostratigraphy having
  - Very low permeability (i.e. very long residence time)
  - Large excess of acid neutralising capacity.

4.1 Post closure source-pathway-receptor model

4.1.1 Potential sources

The potential sources of groundwater contamination from the mine post closure are:

- AMD generation within the mine voids and from backfilled waste rock underground – possibly could occur
- Seepage from the TSF – unlikely to occur due to post closure design of cap)

4.1.2 Potential receptors

The potential receptors of groundwater in the area are:

- Abstraction bores for stock watering – the nearest is Saturday Bore in the Dugald River catchment (2.5 km down gradient) and RN38685 in the Cabbage Tree Creek catchment (5 km downgradient) – these receptors are likely to occur
- Aquatic ecosystems associated with transpiration in the riparian zone at Dugald River – unlikely to be reliant on groundwater

4.1.3 Pathway linkages

The potential linkages between the identified potential sources and the identified potential receptors are described below:

- Dugald River catchment:
  - It is expected that groundwater flow direction in the immediate vicinity of the mine will be towards the void until pressure equilibrium has been restored (around 100 years).
  - Under natural flow conditions, groundwater flows from west to east toward Dugald River. Flow in the rock is dependent on interconnected fractures, which only occur at depth. Assuming a hydraulic conductivity in the Mount Roseby Schist of 0.05 m/day, a hydraulic gradient of 0.01 (30 m over 3 km based on water level data) and an effective porosity of 1%, groundwater velocity would be in the order of 20 m/year, with a

travel time between the mine working and the nearest stock bore over 100 years. The volume of water moving along this flow path is likely to be very low, considering the low effective porosity.

  - There is significant acid neutralising capacity with the rock along the groundwater flow path between the mine meaning which will result in significant attenuation along the flow path.

- Cabbage Tree Creek catchment
  - Groundwater flow direction is from the east to the west and any impacted groundwater would migrate through the Knapdale Quartzite and Mount Roseby Schist. Similar hydraulic gradients, effective porosity and hydraulic conductivity values can be considered for the Knapdale Quartzite as the Mount Roseby Schist for the purpose of this assessment, resulting in travel times of around 250 years between the TSF and the nearest stock bore.
  - Dispersion, dilution and attenuation along the flow path between the TSF and down gradient receptors is likely to be significant given the distance.

4.1.4 Conclusion

The likelihood of the potential source-pathway-receptor linkages are shown in Figure 4-1.

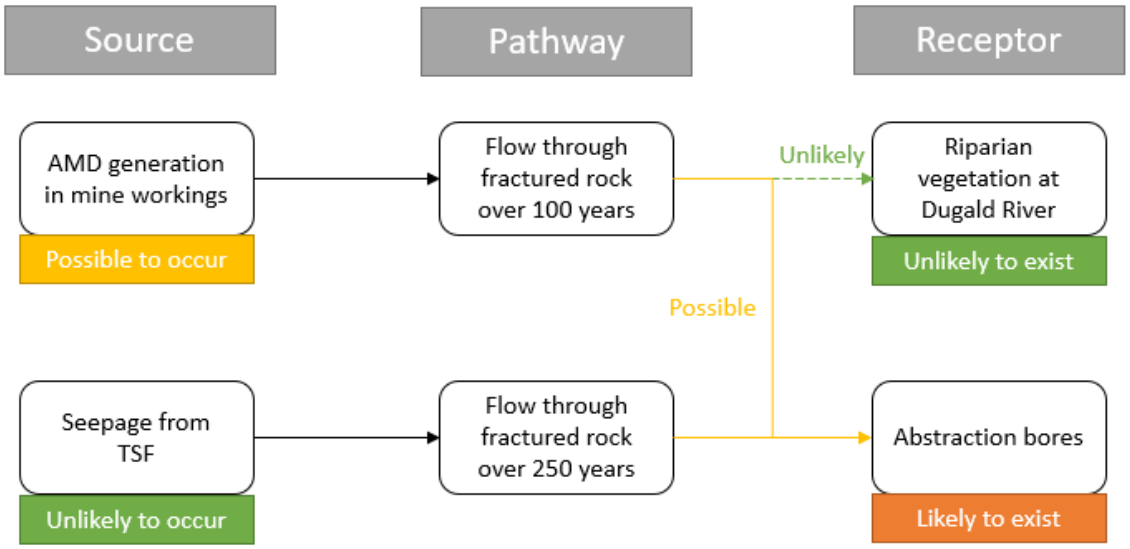


Figure 4-1 Likelihood of potential source-pathway-receptor linkages

The only likely source-pathway-receptor linkage (i.e. source likely to occur, receptor likely to exist and linkage possible) is migration of AMD impacted water in groundwater from mine working to stock watering bores. However, the consequence of this event occurring is considered to be low due to the high acid neutralising capacity of the rock which will result in attenuation of the impacted water. The quality of water reaching the stock bore in 100 years is unlikely to be unsuitable for stock watering, with the exception of the naturally elevated fluoride in the area.

5 Summary

5.1 Assessment of groundwater interactions and potential for generation of AMD

The rocks with the highest potential for AMD (ore body) will be removed from the mine for processing, with waste rock stored in a suitably constructed waste rock dump prior to its disposal underground as part of backfilling operations. The rock surrounding the mine voids may be subject to limited desaturation as part of dewatering activities and some of these formations (i.e. hanging wall slate, up-hydraulic gradient) contain PAF materials, whilst other (i.e. foot wall limestone, down-hydraulic gradient) have excess neutralisation capacity.

The current groundwater conditions close to the mine are unknown and therefore the degree of desaturation is unknown. Over the life of the mine it is likely that some desaturation of PAF materials hosting the ore body could occur and the backfilled waste rock does have the potential to be acid forming and a source of AMD. However, given the neutralising capacity of the surrounding formations, particularly down hydraulic gradient of the mine, any migration of acidic groundwater that may arise away from the mine is unlikely.

Additionally, given the very low permeability of the Knapdale Quartzite (the base of the TSF), the expected low hydraulic conductivity of the basal TSF settled sediments and the results of the column trials, it is unlikely that AMD seepage from the TSF would significantly impact groundwater post closure.

5.2 Hydrogeological conceptualisation of groundwater recovery post-mining

Groundwater does not discharge to the surface in the vicinity of the mine, nor is there any evidence it did prior to commencement of mining. Water extracted from the mine is contained and reused in mining operations. Mine closure planning includes sealing off of underground infrastructure such that groundwater in the voids will be effectively disconnected from the surface. In addition, it is unlikely that groundwater levels / pressures after mining will recover back to surface (i.e. higher than pre-mining levels / pressures) to pose a risk in this regard.

The degree of current depressurisation around the mine is unknown but likely to be minimal due to the very low permeability of the rocks hosting and including the ore body. By the end of the life of the mine (26 years from now) this is unlikely to have changed significantly, i.e. dewatering of the overburden back to surface is very unlikely. There is currently no evidence of watertable decline due to existing mine dewatering operations. Based on observed groundwater dewatering rates and estimates of recharge, groundwater mining is occurring in association with the mining operation. It is expected that groundwater recovery (involving filling of the mine voids remaining at mine closure and repressurisation of the groundwater systems) is expected to take more than 100 years, after which groundwater filling the mine voids may commence to move away from the workings.

If groundwater that eventually begins to move away from the former workings is impacted by AMD, the risk posed to possibly sensitive groundwater receptors is considered low because (i) there is no existing use of groundwater in the area for stock and domestic purposes, and (ii) of the neutralisation capacity of the hydrostratigraphy through which flow will occur, and the expected long-residence time of groundwater moving between the former mine and possible downstream receptors.

Given the above, the conceptual model developed to date is deemed suitable for the assessment of risk to meet the PRCP requirements at this time. The conceptual model should be reviewed and updated with further relevant information as it becomes available. Any further groundwater modelling (e.g. analytical or numerical) is not currently considered necessary for the assessment of risk to groundwater, given the low risk identified from the available data.

6 References

Environmental Authority EPML007312134

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Appendix K

Ecosmart Ecology Rehabilitation Monitoring Plan



Rehabilitation Monitoring Plan

Dugald River Mine

Prepared for MMG Australia Ltd

January 2021

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1.0 INTRODUCTION

1.1 Purpose and Scope

The purpose of this document is to describe the Rehabilitation Monitoring Program undertaken at MMG Dugald River Mine (DRM) to provide a guideline for rehabilitation requirements and monitoring of rehabilitation success.

This monitoring program has been designed to meet the requirements of Environmental Authority (EA) EPML00731213, Schedule I – Rehabilitation Monitoring Program, Conditions I19 to I21.

This Rehabilitation Monitoring Program does not include post mine land use or post closure rehabilitation requirements of surface infrastructure or the Tailings Storage Facility (TSF).

1.2 Site Description

DRM is located within the semi-arid region of North West Queensland approximately 65km north-west of Cloncurry and 20km northwest of Quamby in northwest Queensland.

DRM is an underground zinc and lead mine which commenced commercial operations in 2018. Ore is mined underground using conventional long hole open stoping and down hole benching methods. The mine is accessed by twin declines. Ore is trucked to the surface to the Run Of Mine (ROM) pad and concentrated through a flotation separation plant. Metal concentrate is stockpiled in a concentrate storage shed prior to placement in sealed containers for transport offsite by truck. Process waste (tailings) is transferred to the TSF for final disposal or combined with cement to pastefill underground voids. Non-ore grade waste rock is either used as backfill underground or transferred to the surface and stored in waste rock dumps.

The site also includes a processing mill, workshops, office facilities, accommodation infrastructure, access roads and water containment infrastructure. All disturbance areas of the surface operations are actively used and will continue to be used until end of mine life which is currently estimated at 2037.

1.3 Predicted future disturbance activities

Geological exploration activities across the Dugald River owned mining leases are the only predicted additional surface disturbance activities planned for areas outside the operational infrastructure area.

Several drill pads and their associated access roads (hereafter "disturbance sites") at the DRM are required to be naturally rehabilitated. These disturbance sites are located throughout the lease in a variety of topographical locations and vegetation types. This document outlines the methodology and reporting for rehabilitation and monitoring of disturbance sites of <1ha in area. Disturbed areas >1ha are under operation and will be assessed at end of mine life, and are not considered in this plan.

1.4 Existing Vegetation

The Dugald River mining leases are located on Mt Roseby Station, which is a low density grazing operation. The local landscape is dominated by the Knapdale Range and its associated slopes,

with low-lying areas of alluvial flats and hummock grass-dominated woodland. Based on remnant vegetation mapping 24 Regional Ecosystem types (Queensland Herbarium, 2018) are recognised on the leases, although the majority of these comprise <1% of the lease area.

The vegetation of the range, slopes and flats is dominated by a sparse snappy gum (*Eucalyptus leucophloia*) woodland, with an *Acacia* spp.-dominated shrub layer, and a dense ground layer of soft spinifex (*Triodia pungens*). Localised communities variously consisting of inland bloodwoods (*Corymbia capricornia* and *C. terminalis*) and Cloncurry box (*Eucalyptus leucophylla*) with a sparse to dense *T. pungens* ground layer occur in low-lying areas. Steep rocky slopes and gullies have localised communities of rough-leaved ghost gums (*Corymbia aspera*) and/or desert peach (*Terminalia aridicola*) with a sparse ground layer of native tussock grasses and/or *T. pungens*. On top of the range trees typically exhibit a more stunted growth form, and *T. pungens* density is lower, than on the slopes and low-lying areas.

Two main weed plants are present across the lease: kapok bush (*Aerva javanica*) and buffel grass (*Cenchrus spp.*), both of which are early colonisers following disturbance. Kapok bush is abundant along access road verges, while buffel grass occurs throughout the lease, particularly in association with alluvial soils and creeklines, but also in patches of high density on the western slopes of the Knapdale Range.

2.0 REHABILITATION PLAN

2.1 Methodology

Disturbance sites will be mechanically ripped to loosen compacted soil and provide furrows and rills in which native vegetation can re-establish. Ripping of sites should be completed within 12 months from completion of works. Where the disturbance site is located on a slope, the site should be ripped perpendicular to the slope to minimise the risk of gullying. The existing seed bank within the soils is expected to be sufficient to allow natural regeneration.

2.2 Control Sites

At least three control sites should be established in undisturbed areas to develop a representative sample of the range of pre-disturbance states of disturbance sites. Transects currently established by EcoSmart Ecology for ongoing monitoring of purple-necked rock-wallaby populations may potentially be co-opted for this purpose but will need to be assessed for suitability. Control sites will not need to be monitored until such time as a disturbance site begins to approach the condition of an appropriate control site based on a visual comparison.

Control sites will consist of a transect of 100m length, with start and end point photographs to be taken at 0m and 100m facing along the transect. Permanently marked (with white spray paint) ground cover plots of 1x1m will be spaced every 10m from 0m to 90m (10 plots total) on alternative sides of the transect. In each plot the following estimates of percentage ground cover will be recorded:

- Bare ground/debris
- Spinifex
- Other native grass

- Native forbs
- Buffel grass
- Kapok bush
- Other exotic grass*
- Other exotic forbs*

*It is expected that buffel grass and kapok bush will form the majority of exotic plant cover observed. If other exotic plants are recorded within a plot, these should be estimated separately to buffel grass and kapok bush as "Other exotic grass" or "Other exotic forbs".

2.3 Scheduled Monitoring

Monitoring of sites should be conducted six months post-ripping, 12 months post-ripping, and thereafter annually at the end of the wet season until rehabilitation criteria are met (see Section 3). The following outlines the monitoring protocols required for each site.

2.3.1 Photo-point Monitoring

At each monitoring interval photo-point photographs will be taken from the centre of the site, facing north, east, south and west (four photos). Ideally, photographs will not be taken facing into the sun. A star picket will be located at the photo-point for future reference and removed once completion criteria have been met.

2.3.2 Ground-cover Surveys

Four ground cover monitoring plots will be set up using a 1x1m quadrat. Plots will be located to the north, east, south and west, midway between the centre point of the site and the edge of the disturbance footprint, and permanently marked (with white spray paint). At each plot, a photograph will be taken of the plot and it's vegetation cover at 1.5m above the ground. In each plot, ground cover percentage estimates will be recorded as per control site plots. Average percentage ground cover estimates will be calculated for each site as the average of estimates from all four plots.

2.3.3 Land Stability

General observations of rills and gullying at each site should be made. Details of erosion-associated features with a depth >30cm should include:

- Max rill/gully depth, and
- Rill/gully length (including extensions outside the disturbance area).

Photos of the erosion feature should be taken for future comparison and reference.

2.4 Trigger Mechanisms and Corrective Actions

Certain triggers will require intervention. Specifically these trigger mechanisms include exotic flora proliferation, and deep gullying. In instances where these controls are triggered, intervention should be carried out within six months of the initial trigger.

2.4.1 Exotic Flora

Where the ground cover percentage of either buffel grass, kapok bush, or a combination of both species, exceeds 20%, this will trigger exotic flora control. This control may be via mechanical removal or chemical spraying of individual plants. At sites where the edge of disturbance adjoins an area in which buffel grass or kapok bush is already established, control will not be required.

2.4.2 Lack or Poor Native Recolonisation

Where no native spinifex has established in any of the 1x1m plots associated with an individual disturbance area within 10 years of disturbance, seeding should occur to accelerate native revegetation.

2.4.3 Gullying

If erosion-associated gullies in the area of disturbance exceed 50cm depth, control will be required to avoid further erosion from occurring.

3.0 COMPLETION CRITERIA

A site will be considered rehabilitated if it can be demonstrated that the ground cover composition of the site is similar to that of an equivalent control site. The appropriate control site for comparison will be selected based on the topographic location and ecosystem description of the disturbance site. As the primary aim of rehabilitation is to stabilise the soil and limit the establishment of weeds, rehabilitation of disturbance sites at Dugald River will be assessed on ground cover estimates as ground cover plants are largely responsible for both of these criteria. Soft spinifex in particular is important as it is abundant throughout the lease. The following criteria will therefore be used to determine if a disturbance site should be deemed rehabilitated:

- Average total ground cover (all ground cover categories aggregated) is no less than the 15 percentile of equivalent control site
- Average soft spinifex cover estimates are no less than the 15th percentile of equivalent control sites
- Buffel grass cover estimates exceed no more than the 70th percentile of equivalent control sites
- Kapok bush cover estimates exceed no more than the 70th percentile of equivalent control sites

For further clarification on these criteria, refer to Appendix A.

4.0 REPORTING

4.1 Annual Report

Reporting on rehabilitation will require an annual report with photo-point photographs, ground cover plot photographs, and the results of ground cover percentage estimates. Reports should also make note of any observations of extensive gullying and/or weed proliferation and outline the intervention actions taken or planning to be taken, along with a timeline of these actions.

The final report should include comparison with at least one control site to demonstrate completion criteria have been met.

5.0 REFERENCES

Queensland Herbarium. (2018). Biodiversity status of 2017 remnant regional ecosystems – Queensland. Version 11. Available at: http://qldspatial.information.qld.gov.au/catalogue/custom/search.page?q=%22Biodiversity%20status%20of%202017%20remnant%20regional%20ecosystems%20-%20Queensland%

Appendix A:
Hypothetical Completion Example

A Hypothetical Example of Completion Criteria

The following outlines two hypothetical disturbance sites and one hypothetical control site to illustrate how the completion criteria may be applied. Disturbance Site A would not be deemed rehabilitated as average spinifex cover is less than the 15 percentile of Control Site 1, and average buffel grass cover is greater than the 80th percentile. Disturbance Site B would be considered rehabilitated as average spinifex is greater than the 15 percentile, and buffel grass and kapok less than the 70th percentile of Control Site 1.

Hypothetical Control Site 1

	1	2	3	4	5	6	7	8	9	10	Average	15%ile	70%ile
Spinifex	35	45	67	25	43	54	55	50	45	40	45.9	31.5	54.8
Native grass	5	1	0	0	0	2	5	1	1	0	1.5	0.0	4.4
Buffel	0	3	0	0	1	1	0	0	0	0	0.4	0.0	0.7
Kapok	1	0	0	0	2	0	1	0	0	0	0.3	0.0	0.7

Hypothetical Disturbance Site A

	1	2	3	4	Average
Spinifex	15	32	34	16	24.25
Native grass	0	0	1	0	0.25
Buffel	1	0	5	1	1.75
Kapok	0	0	0	0	0

Hypothetical Disturbance Site B

	1	2	3	4	Average
Spinifex	65	45	37	64	52.75
Native grass	0	2	14	6	5.5
Buffel	0	0	0	0	0
Kapok	0	0	0	0	0

Appendix L

Carpentarian Antechinus Management Plan



SEPTEMBER 2015

Carpentarian Antechinus (*Pseudantechinus mimulus*) Management Plan

Dugald River Mine Project, Queensland

Prepared for: MMG Dugald River Pty Ltd (MMG)

OPENLINES
Environmental consulting

ecosmart ECOLOGY

Carpentarian Antechinus *(Pseudantechinus mimulus)* management Plan, Dugald River Mine Project. Queensland

Prepared for MMG Dugald River Pty Ltd

Date September 2015

Open Lines Environmental Consulting

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1. Introduction

The Carpentarian Antechinus (*Pseudantechinus mimulus*) has been found to occur within the Knapdale Range, and there is potential for the species to be impacted by proposed activities associated with the Dugald River Mine expansion project. This Carpentarian Antechinus Management Plan (hereafter referred to as 'the Plan') provides a detailed analysis of the species in the context of the Dugald River Mine expansion project and outlines the management strategies that will be implemented to provide for its ongoing protection. The structure and content of the Plan is consistent with the Department of the Environment's (DoE) *Environmental Management Plan Guidelines 2014*.

There are recognised gaps in our current understanding of the species' ecology and distribution. Expert input has been used in the preparation of this Plan to address this issue. The information used is the best available, and the interpretation of relevant impacts and identification of suitable mitigation strategies is informed by extensive field experience.

The primary purpose of the Plan is for use by MMG personnel responsible for implementation.

The Plan has also been developed as part of a package of information to support an EPBC Act referral for the Dugald River Mine expansion project. In this way the Plan has a broader audience and purpose, which is to provide regulators and the general public with:

- an understanding of the values of the Dugald River Mine tenement to the local population of the Carpentarian Antechinus;
- an understanding of the relevant impacts associated with mining and the range of measures that will be implemented to manage them; and
- confidence in MMG's commitment to managing the species as part of mining operations and in the outcomes that will be delivered.

1.1. OBJECTIVES OF THE PLAN

The objective of the Plan is to ensure construction, operation and rehabilitation activities of the Dugald River Mine expansion project are undertaken with sufficient controls and management strategies to ensure protection of the local Carpentarian Antechinus population.

To achieve this objective the Plan provides:

- background to the Carpentarian Antechinus and detailed information regarding the baseline values of the Dugald River mine tenement for the local population;
- an assessment of potential impacts to the Carpentarian Antechinus as a result of the proposed mine expansion;
- identification of environmental management measures and performance targets required to mitigate relevant impacts and provide for ongoing protection of the local population;
- a residual risk assessment to identify and understand key areas of risk to the species from project activities; and
- an outline the relevant systems for environmental management, reporting, monitoring, review and audit.

2. Project description

The Dugald River Mine is located approximately 65 km north-west of Cloncurry, Queensland. MMG Dugald River Pty Ltd (MMG) proposes to further develop the Dugald River Mine, which is estimated to contain 53 million tonnes (Mt) of zinc/lead/silver and copper resource.

The mine will use conventional underground mining techniques to recover and process approximately 1.5 Mtpa producing approximately 300,000 T of zinc/silver concentrate and 25,000 T of lead/silver concentrate. Once the mine is fully operational it will operate 24 hours a day, 7 days a week over an estimated 28 year mine life.

The mine was initially established in 2011. Current infrastructure present at the site includes:

- two mine portal entrances;
- two underground mine declines (North and South mines);
- Potentially Acid Forming (PAF) & Non Acid Forming (NAF) pads and ponds;
- mine access roads;
- a water pipeline which provides raw water supply to site (from the Lake Julius/ Ernest Henry Pipeline);
- raw water pipelines between the process plant and the accommodation camp;
- sewage treatment plans and STP dam;
- telecommunications infrastructure;
- camp accommodation; and
- a main access road to the site.

Clearing had been undertaken on the site for future construction of the process plant and associated infrastructure.

MMG proposes to further expand the existing infrastructure at the Dugald River Mine site.

The proposed action involves the construction and/or operation of the following mine components:

- a Tailings Storage Facility (TSF) and associated pipelines/access roads;
- a 60 km power line from Chumvale substation to the Dugald River Mine site;
- accommodation facilities (expansion of existing accommodation camp); and
- mine infrastructure (process plant, administration buildings etc.) and operation.

Further exploration will be undertaken and resource appraisal activities are ongoing in order to further map and evaluate the ore body within the mine tenement.

Figure 1 illustrates the location of the infrastructure components and exploration activities proposed within the mine site. Figure 2 illustrates the location of the proposed power line.

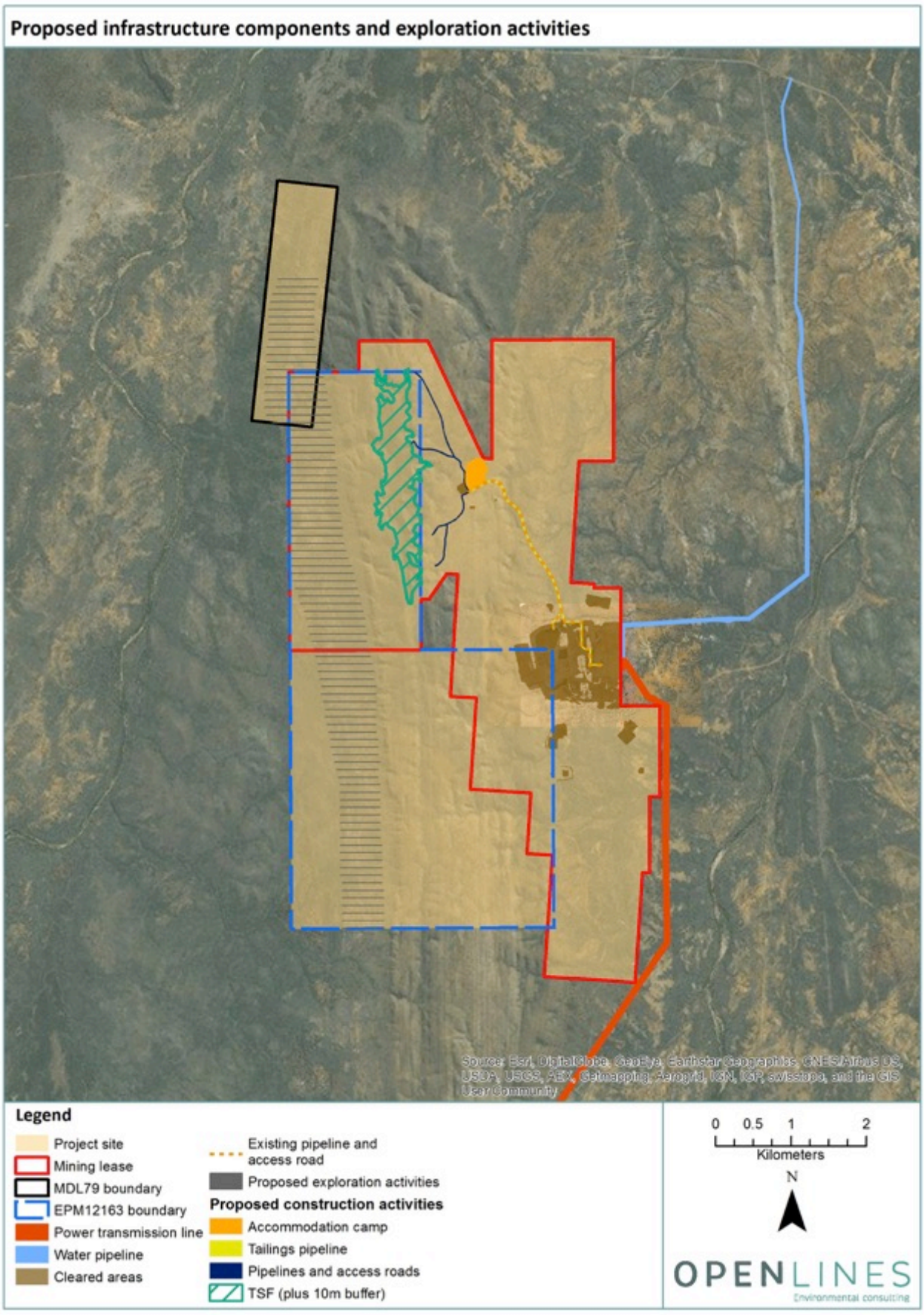


Figure 1: Proposed infrastructure components and exploration activities within the Dugald River Mine tenement and Knapdale Range.

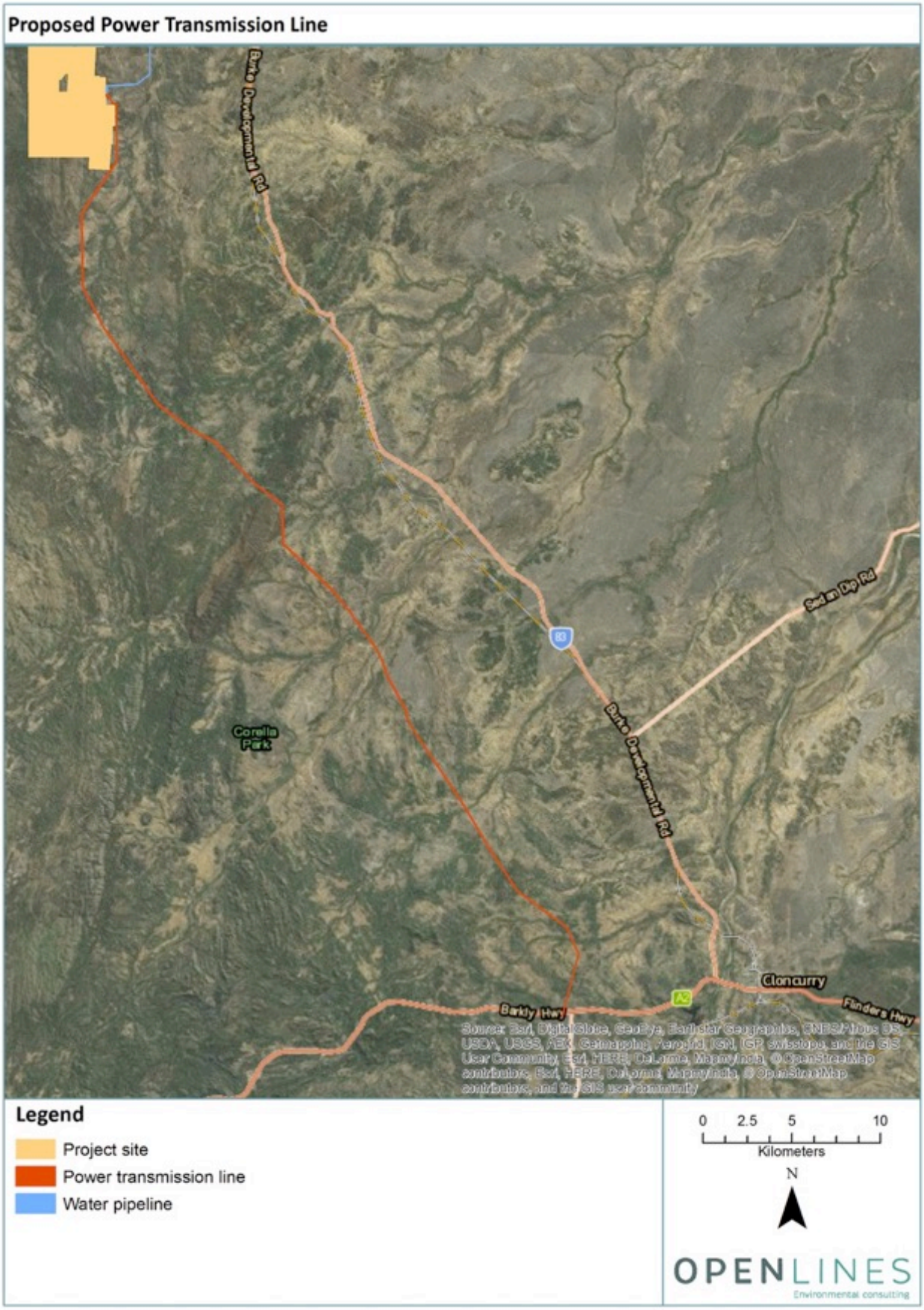


Figure 2: Proposed power line for the Dugald River Mine

2.1. LOCATION

The Dugald River Mine is located approximately 85 km north-east of Mt Isa and 60 km north-west of Cloncurry in north-western Queensland. The proposed 60 km power line will run in a northerly direction from an existing substation at Chumvale (10 km west of Cloncurry) to the mine site. The location of the project is shown in Figure 3.

The Knapdale Range is a key environmental feature within the Dugald River Mine tenement. The Range is a rocky outcrop which rises to an elevation of 300 m above sea level, and 100 m above the surrounding land. The Range runs in a north-south direction to the west of the mine entrances and proposed process plant and has recently been found to support a population of the EPBC Act listed Carpentarian Antechinus (*Pseudantechinus mimulus*) (EcoSmart Ecology 2015).

Several mines currently operate near the project site. The nearest mine is the Little Eva mine (also known as the Roseby Copper Project) which is proposed to begin production in the near future. This open cut copper mine (3 – 4.5 Mtpa) is directly adjacent to and east of the project site and is operated by Altona Minerals.

Latitudes and longitudes for the project are given in Table 1 and Table 2.

Table 1: Latitude and longitudes for power line.

Power line	
Latitude	**Longitude**
-20.7201	140.4038
-20.7193	140.4041
-20.6883	140.4129
-20.6744	140.4062
-20.6561	140.3799
-20.6340	140.3646
-20.6121	140.3510
-20.5698	140.3212
-20.5638	140.3200
-20.5466	140.3105
-20.5378	140.3070
-20.5311	140.3031
-20.5188	140.2939
-20.5133	140.2897
-20.5027	140.2807
-20.4789	140.2542
-20.4591	140.2535
-20.4482	140.2390
-20.4265	140.2171
-20.4202	140.2038
-20.4075	140.1868
-20.3684	140.1577
-20.3483	140.1468
-20.3105	140.1462
-20.2836	140.1655
-20.2722	140.1654
-20.2554	140.1656
-20.2542	140.1632
-20.2502	140.1605
-20.2498	140.1600

Table 2: Latitude and longitude for mine site.

Mine site		
Location	**Latitude**	**Longitude**
North eastern corner	-20.17561	140.18662
North western corner	-20.17561	140.11273
South western corner	-20.28965	140.11273
South eastern corner	-20.28965	140.18662

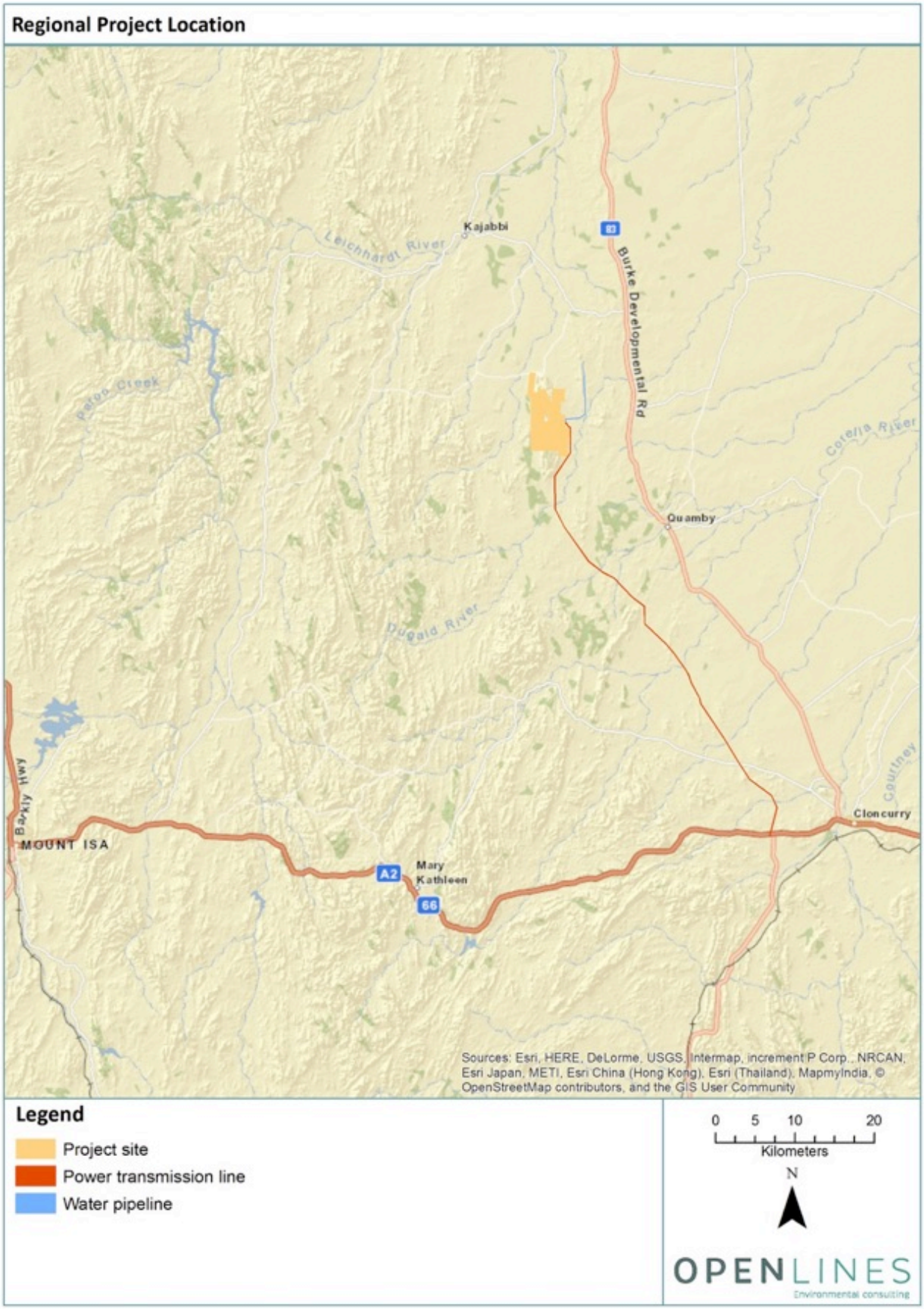


Figure 3: Regional location of the Dugald River Mine tenement and power line

2.2. PROJECT ACTIVITIES

This Plan considers potential impacts to Carpentarian Antechinus as a result of construction, operation and rehabilitation phases of the mine expansion. The project involves construction, operation and decommissioning of the following five components:

- a Tailings Storage Facility and associate pipelines/access roads;
- a 60 km power line from Chumvale substation to the Dugald River Mine site;
- accommodation facilities (expansion of existing accommodation camp);
- mine infrastructure (process plant, administration buildings, etc); and
- exploration drilling.

The locations of these project components is given in Figure 1. A summary of the activities to be undertaken for construction, operation and decommissioning of each of these components is given below.

2.2.1. Tailings storage facility

Tailings from the processing plant will be disposed of to a purpose built Tailings Storage Facility (TSF). The TSF will be located in a long, narrow bifurcated valley running north-south on the western side of the Knapdale Range (shown in Figure 1). Containment will be almost entirely provided by the valley's natural topography.

2.2.1.1. Construction activities

Construction of the TSF will be from the inside of the valley floor and will involve:

- clearing of vegetation within the valley floor using scrapers and graders;
- stockpiling of topsoil for rehabilitation;
- construction of a main embankment to enclose the main opening of the valley;
- construction of embankments and bunds using rock fill to constrain tailings within MMG's mining tenure; and
- construction of a seepage collection pond.

Three pipelines will be constructed between the processing plant and the TSF. These pipelines will allow tailings to be pumped to the TSF and return decant water to the process plant. They include:

- a tailings pipeline running to the northern end of the TSF;
- a tailings pipeline running towards the southern end of the TSF; and
- a raw water pipeline running from the TSF in an easterly direction to the accommodation camp.

The tailings pipelines will be a low pressure system constructed from steel with Victaulic style couplings. An easement along the edge of the existing access road includes longitudinal bunds that will contain any leaks. The steel line will be constructed above ground on concrete sleepers to provide clearance below.

The pipelines will be installed alongside the existing access road and water pipelines which exist between the processing plant and accommodation camp. Between the accommodation camp and TSF, the pipelines will be positioned within a bunded easement alongside new access roads. These roads will be single lane, dirt tracks requiring an average 20 m width for construction.

2.2.1.2. Operation activities

Zinc and lead tailings will be combined with a carbon pre-flotation cleaner concentrate and pumped to the tailings thickener. The slurry will be thickened, then pumped to the TSF via the tailings pipelines (or to the paste-fill plant for use in the underground mine operations). Tailings thickener overflow water will be recycled through to the process-water circuit. Water will be decanted from the TSF and returned via the tailings pipelines to be recycled through the plant process-water circuit.

The process control system will detect and alarm on blocked flow, low pressure or other abnormal flow situations. Daily visual inspections of the tailings line will be carried out during operation.

The access roads will be operational for the life of mine with an operational footprint of 8 m. This width allows for a nominal 4 m wide road with a 2 m shoulder either side and bunded section for the pipelines. During construction of the TSF, the roads will be used by construction vehicles during the day. Following TSF construction, traffic is expected to be a light vehicle once daily during daylight hours for inspection purposes only.

2.2.1.3. Decommissioning activities

Due to the potentially acid forming nature of the tailings, rehabilitation of the tailings storage facility will include a capillary break, a low permeability sealing layer and a water-shedding layer of waste rock as capping material. This will be covered with

topsoil and revegetated with shallow-rooting native species. This area will be rehabilitated with a view to re-create habitat for the threatened Carpentarian Antechinus (see further information in Section 8.3.1.2 below).

2.2.2. Power line

MMG propose to construct a 220 kV line running south-east from the Dugald River Mine to the Chumvale substation west of Cloncurry to provide a permanent electricity supply to the mine (shown in Figure 2).

2.2.2.1. Construction activities

A 100 m power line corridor has been identified. Determination of the location and number of poles within this corridor is awaiting detailed design. Avoidance of potential habitat for the Carpentarian Antechinus will be one of the key factors in identifying the final design. As an indication, it is expected that up to 182 poles will be required and these will be spaced at an average distance of 300 – 350 m apart. The poles are proposed to be single steel pole structures approximately 35 m high.

During construction a nominal 6 m wide access track will be required along the full length of the line within the 100 m power line corridor. At each pole location a pad approximately 15 m by 20 m (300 m^2) will be cleared on the high side of the pole to allow for erection of the pole. Approximately every 4 km a larger area will be cleared to enable the placement of conductor winching machines for drawing the conductors.

Construction of the power line is scheduled to commence as weather conditions become favourable around March 2016 and is estimated to take approximately 1 year and 3 months.

2.2.2.2. Operation activities

Vegetation clearance envelopes will be maintained along the power line corridor to ensure protection of the line from fire and/or physical damage once constructed.

2.2.2.3. Decommissioning activities

The power transmission line will be retained on mine closure as this this infrastructure may be of beneficial use to the region or future mining operations.

2.2.3. Accommodation facilities

Employees of the Dugald River Mine are housed in an onsite accommodation camp during their time at the mine. Accommodation facilities for 100 employees are currently established at the project site. These facilities are located north-west of the existing mine operations area, on the eastern side of the Knapdale Range. MMG propose to expand these facilities to accommodate an additional 250 employees (350 person camp). An additional 9.6 ha will be cleared directly adjacent to the existing facilities to allow for construction of the expanded accommodation camp (see Figure 1).

2.2.3.1. Construction activities

The accommodation camp will be cleared of vegetation using a grader and/or dozer with topsoil being stripped by scrapers or dozers and trucks and placed nearby. The accommodation units will be delivered to site by road trains and lifted into place using cranes. Services to the buildings will then be connected.

Construction of the accommodation camp is scheduled to commence as weather conditions become favourable around March 2016 and is estimated to take approximately 6 months.

2.2.3.2. Operation activities

The accommodation camp will be operational 24 hours/ 7 days a week. Movement of people, general activity and lighting will all be associated with an operating camp.

Treated sewage effluent from the accommodation facility (and production facilities, see description below) will be disposed of to the STP Dam. All general waste on site will be removed and recycled where possible.

2.2.3.3. Decommissioning activities

The accommodation camp areas will be rehabilitated to pre-existing condition.

2.2.4. Mine infrastructure

Additional mine operation infrastructure will be constructed within an existing cleared area which currently supports a number of buildings constructed for the establishment of the mine (shown in Figure 1).

2.2.4.1. Construction activities

Additional mine operation infrastructure to be constructed includes:

- a crushing and grinding circuit;
- flotation plant including associated regrind, lead thickening, zinc thickening and filtration;
- concentrate storage; seven days bulk storage of zinc concentrate on site (supplementary storage will be in containers). All lead concentrate storage will be in containers;
- reagents storage facility and vehicle wash bay;
- Paste Fill Plant; Cement Rock Fill and paste fill plant for life of mine;
- plant workshop and warehouse;
- laboratory, crib and ablution building, weighbridge, bus stand and walkways; and
- buildings including change house and mine training, heavy and light vehicle wash down area.

2.2.4.2. Operational activities

The deep zinc/lead/silver ore will be mined from underground by conventional mechanised methods (longhole open stoping and modified benching). The mine will be approximately 2.0 km along strike and 1.0 km deep. Twin declines (already established) will be used to haul ore and waste from the mine in diesel powered trucks. All ore and waste will be drilled and blasted. The mine will be ventilated via five vertical shafts. The twin declines separate the mine into two distinct operating areas, the South Mine and the North Mine. Each area will have independent networks for ventilation, power, water and drainage and they will be joined by link drives every 150 m vertically. Mined out voids will be backfilled with either rock fill, using waste rock, or paste fill, using process plant tailings.

There will be a separate processing plant circuit for the zinc/lead/silver ore. Processing of the zinc/lead/silver ore will be through a conventional flotation and concentrating plant producing approximately 300,000 tpa of zinc/silver concentrate and 25,000 tpa of lead/silver concentrate. Total concentrate production at full production will be approximately 325,000 tpa. The final concentrate products will be stored in a fully enclosed shed, prior to being transported off site.

The main form of excavated waste produced by the mine will be waste rock from the underground workings. Waste rock will be disposed of underground, stockpiled at surface, or used for construction of roads, mine pads, or other site infrastructure. Some non-acid forming waste rock will also be used for encapsulating potentially acid forming material in a specifically designed waste rock dump. The other excavated waste during the construction phase will be in the form of civil cut materials which will be removed from the stormwater dam and sediment pond areas at the mine and processing area during construction. On mine closure the majority of non-acid forming material remaining on the surface will be used in the rehabilitation of the TSF.

The concentrates will be stored onsite in half height closed containers adjacent to the ore processing facility. A forklift will load the containers onto triple road trains that will transport the containers on the existing sealed highway from Dugald River to a container handling facility just east of Cloncurry. The containers will be loaded on an intermodal train for transportation along the existing Mt Isa System to the rail yard in Townsville. The containers will be lifted off the wagons and transported to registered stevedoring storage areas within the Townsville Port precinct. The concentrate will either be stored in the containers or discharged into a concentrate storage facility. The concentrates will then be reclaimed and loaded back into a container to be loaded into the vessel hold by a rotainer system. Contracted vessels will then deliver concentrates via established east coast shipping routes to market destinations in Asia.

This supply chain is comprised entirely of existing infrastructure and facilities. Concentrates from the Dugald River mine will contribute to an incremental increase in the number of trucks and ships which are already operating along these routes. As a result, there are no facilitated impacts expected from the Dugald River mine in relation to this supply chain.

2.2.4.3. Decommissioning activities

On closure and decommissioning of the Dugald River Mine, it is proposed to return the majority of disturbed land to a condition similar to the pre-existing condition of low intensity grazing, native habitat or an agreed beneficial use.

Potentially acid forming waste rock will be disposed of underground. Non-acid forming waste rock will be disposed of underground or used for rehabilitation site infrastructure or Carpentarian Antechinus habitat.

Most of the stormwater dams, sediments ponds and roads on site will be returned to their pre-mining land use and suitability. The stormwater dam downstream of the rehabilitated waste rock dump will be retained to remove sediment from rainfall runoff from this permanent land form.

The water pipeline will be retained on mine closure as this infrastructure may be of beneficial use to the region or future mining operations. The access road may also be retained through written agreement with the landholder.

2.2.5. Exploration drilling

MMG propose to undertake further exploration of the ore body on the western side of the Knapdale Range (see Figure 1).

2.2.5.1. Construction activities

Construction of exploration drilling sites will involve clearing and conduction earthworks along a series of exploration drilling lanes to allow for 4WD access.

Exploration drilling lines are spaced 100 m apart. The total footprint of the proposed exploration drilling program will be 28.5 ha.

2.2.5.2. Operation activities

Exploration drilling operations include drilling of short holes every five metres along each drilling lane.

2.2.5.3. Decommissioning activities

The areas disturbed from exploration drilling will be rehabilitated to pre-existing condition at completion of the program.

2.3. SCHEDULE OF ACTIVITIES

An indicative schedule for the Dugald River Mine expansion project is provided below.

Table 3: Proposed schedule of activities for the expansion of the Dugald River Mine

Activity	Proposed Timing
Construction of TSF and associated pipelines/access roads	Construction is planned to commence around June 2016 and take approximately six months.
Construction of accommodation camp	Construction is planned to commence as weather conditions become favourable around March 2016 and take approximately three months.
Construction of power line	Construction is planned to commence as weather conditions become favourable around March 2016 and take approximately 15 months.
Construction of mine operation infrastructure	
Exploration drilling	
Operation of TSF	Operation will commence after TSF construction has progressed to an appropriate phase and continue until the TSF is remediated.
Operation of accommodation camp	Existing accommodation on site is already in use. Additional capacity will be filled as it comes online and continue for the life of the project, notwithstanding future accommodation camp upgrades.
Operation of power line	Operation will commence once the infrastructure in online and continue for the life of the project, notwithstanding future infrastructure upgrades.
Operation of mine (processing of ore)	The mine is already in operation. Operations will expand as new working faces come online and onsite processing plant is completed.
Decommissioning and rehabilitation	

3. Environmental management roles and responsibilities

3.1. SITE MANAGER

The Senior Site Executive maintains the overall responsibility for the management of risks to Carpentarian Antechinus from the Dugald River mine.

3.2. PERSONNEL

The SHEC Superintendent is responsible for the maintenance of the plan and monitoring compliance with the plan.

All site MMG and Contractor supervisors are responsible for their subordinates' compliance with this plan.

All site personnel are required to adhere to this plan.

4. Reporting

This section describes the reporting requirements associated with this Plan.

4.1. STANDARD REPORTS

4.1.1. Monthly report

An environmental report will be prepared on a monthly basis while construction activities are underway. The report will be developed by the SHEC Superintendent and will be provided to the Senior Site Executive for review. The report will be provided to the Senior Site Executive no later than two weeks following the end of the reporting month.

The report will provide monthly monitoring/reporting results documenting the loss of Carpentarian Antechinus habitat in accordance with the habitat clearing protocol described in Section 8.3.1.2 of this Plan. The report will include details of:

- The amount (ha) and type of habitat cleared, as recorded in the 'Carpentarian Antechinus Habitat Loss Register'.
- The location and purpose of the clearing.
- The time period in which clearing occurred.
- Whether clearing was undertaken in accordance with the habitat clearing protocol. Where actions have not conformed with this protocol, the report will need to identify the reasons for this, if corrective actions were required and the outcome of these actions.

4.1.2. Bi-Annual Report

A bi-annual environmental report will be developed by the SHEC Superintendent and will be provided to the Senior Site Executive. The report will be provided to the Senior Site Executive no later than two weeks following the end of the reporting month. The report will provide bi-annual monitoring results undertaken as part of:

- Declared Feral Animal Control Plan.
- Declared Weed Control Plan.
- Confirmation of weekly TSF and daily pipeline inspections.
- Confirmation of TSF construction high visibility fencing inspections.
- Records of personnel environmental training (as undertaken during site inductions).
- Results of the bi-annual Carpentarian Antechinus monitoring program.

4.1.3. Annual report

An annual environmental report will be developed by the SHEC Superintendent and will be provided to the Senior Site Executive. The report will be provided to the Senior Site Executive no later than four weeks following the end of the reporting year. The annual report will document conformance against all relevant elements of this Plan, including the cumulative amount of loss of Carpentarian Antechinus habitat (ha) from construction activities and inundation of the TSF (as recorded in the 'Carpentarian Antechinus Habitat Loss Register'.

Any non-conformances will be reported and further actions recommended.

The report will provide results of any annual monitoring programs including:

- Site rehabilitation monitoring (once rehabilitation works have begun).
- Light guard condition and notification of any defects and recommended actions.

4.1.4. Incident report

The SHEC Superintendent will provide incident reports to the Senior Site Executive where the following occurs:

- clearance of Carpentarian Antechinus habitat in a form that is inconsistent with this Plan;
- fire outbreaks within Carpentarian Antechinus habitat; and
- TSF pipeline leakage or other contamination within Carpentarian Antechinus habitat.

Incident reports will follow the procedures and guidelines in MMG's Environment Recording and Reporting Work Quality Requirements (document number 3166986), and record at a minimum the:

- location and timing of the incident;
- personnel present;
- description of possible impacts to Carpentarian Antechinus habitat;
- incident response;
- outcomes or results of the response; and
- recommendations for the prevention of repeat incidents.

5. Environmental training

All personnel seeking to access or conduct work at Dugald River Mine are required to complete the site induction. The induction outlines the roles and responsibilities of individuals in the management of environmental risk associated with site activities; including the protection of listed species and importance of biodiversity. The site induction further includes procedures for incident notification and consequences for non-compliance with site procedures.

Secondary methods for communication of general awareness of environmental matters are via pre-start meetings and site bulletins.

Records of all training conducted are maintained and include:

- the person receiving the training;
- the date the training was received; and
- the name of the person conducting the training.

6. Emergency contacts and procedures

Emergency contacts and procedures are contained in the Dugald River Emergency Management Plan and Emergency Response Plan. Although these documents deal with separate levels of crisis management, they remain integrally linked.

6.1.1. Emergency Management Plan

The Emergency Response Plan assists DRM management to respond to and recover from significant events of consequence that threaten people, environment, asset, or reputation. The plan contains emergency related processes, organisation structures, duty cards, support tools, and resources that will support an effective site-wide response to significant events of consequence.

This plan has been designed to:

- build MMG DRM's preparedness for responding to an emergency;
- define an appropriate structure for managing emergencies;
- identify roles and establish responsibilities of each team member;
- provide response tools for the Emergency Management Team;
- identify appropriate response actions to resolve the identified key risk scenarios;
- demonstrate integration with the Corporate Crisis Management Team and site Emergency Response Teams;
- ensure critical processes are followed;
- ensure information is handled appropriately during emergencies; and
- support the recovery process and speed the resumption of business once the event is over.

6.1.2. Emergency Response Plan

The Emergency Response Plan assists the DRM Emergency Response Team to respond to emergency events that threaten people, environment or asset. The plan contains emergency related processes, organisation structures and resources that will support an effective site response to emergency events.

This plan has been designed to:

- identify roles and establish responsibilities of each team member;
- provide response tools for the Emergency Response Team;
- identify appropriate response actions to resolve the identified key risk scenarios;
- demonstrate integration with the DRM Emergency Management Team;
- ensure critical processes are followed; and
- ensure information is handled appropriately during emergencies.

7. Carpentarian Antechinus (*Pseudantechinus mimulus*)

7.1. CONSERVATION STATUS

EPBC Act: Vulnerable, NC Act: Least Concern, IUCN: Endangered, Near Threatened: Woinarski *et. al.* 2012 (Action Plan for Australian Mammals)

7.2. ECOLOGY OF THE SPECIES

The ecology of the Carpentarian Antechinus is poorly understood. Much of the ecological information for the species is based on captive specimens or inferences from sibling species. The species is nocturnal and feeds primarily on invertebrates (particularly termites) but may also prey on small vertebrates such as skinks (Johnson *et. al.* 2008, Ward 2012, Burnett 2014, Woinarski 2014).

Carpentarian Antechinus are monoestrous and have a single breeding season each year. The species has a type II dasyurid life strategy. After the breeding season the majority of breeding-age adults die, with only limited numbers surviving to breed in a second year (Lee *et. al.* 1982). Breeding is thought to occur in winter. Pouch young are typically detected in July and August, and females with enlarged teats (indicative of post-breeding) detected during October (Johnson 2008, Woolley 2011, Woinarski 2014). One individual has been recorded with six pouch young (Woolley 2011). This life-cycle results in a temporary reduction in the population each year and may explain why the species is less likely to be detected after August (Burnett *et. al.* 2014).

Home range and movement patterns are unknown. *Pseudantechinus macdonnellensis*, a slightly larger sister species which inhabits a similar ecological space has home ranges averaging between 0.76 and 1.14 ha, with males having larger home ranges than females (Pavey *et. al.* 2003).

7.3. HABITAT REQUIREMENTS

The habitat requirements and biology of the Carpentarian Antechinus are poorly understood. Habitat descriptions for records prior to 2012 are provided in Table 4. Recent studies have found more individuals in Queensland than previously detected, and an increased likelihood of the species occurring in habitat that includes massive rock features (boulders, outcrops, rubble, and scrapes) (Burnett *et.al.* 2014).

Carpentarian Antechinus are found in a variety of vegetation communities, and are commonly associated with Hummock Grass (*Triodia* spp.). Spinifex habitats often support termites, which are an important prey species for Carpentarian Antechinus (Morton and James 1988). Records of the species in recently burnt areas and possible observations in waste rock dump areas suggest that vegetation type may not be a limiting factor in the species' habitat preference (Burnett *et. al.* 2014).

The most reliable predictor of suitable Carpentarian Antechinus habitat is the presence of massive rock features, which may include a variety of geology and lithology types.

Table 4. Habitat features for documented Carpentarian Antechinus records*

Habitat description	Location and source
Sandstone outcrops and hills with a pebbly to rocky surface. Scattered tree layer dominated by *Eucalyptus tetrodonta*, relatively dense shrub layer and a hummock grass ground layer dominated by curly spinifex (*Plectrachne pun*gens).	Sir Edward Pellew Islands, Northern Territory (Johnson *et. al.* 2008).
Among rocks and spinifex (*Triodia* spp.).	Rifle Creek Dam, Queensland (Woolley 2011).
Side slopes or bases of rocky sandstone ridges supporting open woodland of *Eucalyptus leucophloia, E. normantonensis, Corymbia terminalis, Atalaya hemiglauca* and *Acacia* spp.) over hummock grass (*Triodia* spp.).	Vicinity of Mount Isa, Queensland (Baker and Griffiths 2005).
Cliff base and slope of deeply weathered granite mesa with numerous boulders. Sparse tree layer dominated by *Eucalyptus leucophloia, E. leucophylla and Acacia shirleyi*. Shrub layer dominated by *Acacia chisholmii*. Diverse native grass layer dominated by *Triodia* spp., with *Aristida* spp., *Enneapogon* spp. and *Themeda triandra*. RE 1.7.1/1.12.1.	West of Gorge Creek (Abbott *et. al.* 2011)

Midslope of rocky hillside with abundant boulder piles of igneous or metamorphic rock. Very sparse tree layer dominated by *Eucalyptus leucophloia* and *E. leucophylla*. Shrub layer dominated by *Terminalia aridicola* and *Acacia* spp. Grass layer dominated by *Triodia* spp.RE 1.11.2a/1.11.2x4/ 1.12.1.	South of Mount Frosty Mine (Abbott *et. al*. 2011)
Rocky ridge and hill-slope of igneous rock, adjoining existing power line. Tree layer dominated by *Eucalyptus leucophloia*, *E. leucophylla* and *Terminalia aridicola*. Sparse shrub layer dominated by *Acacia* spp. Grass layer dominated by *Triodia* spp., with *Enneapogon oblongus* and very limited invasion by the environmental weed *Pennisetum ciliare*. RE 1.12.1/1.12.1x1.	Near Lunch Creek (Abbott *et. al.* 2011)
Rocky ridge and hill-slope of metamorphic or igneous rock, adjoining existing power line. Tree layer dominated by *Eucalyptus leucophloia* and *Atalaya hemiglauca*. Mid-dense shrub layer. Grass layer dominated by *Triodia* spp., with *Enneapogon oblongus* and patchy invasion by the environmental weed *Pennisetum ciliare*. RE 1.11.2a/1.11.2x1/1.12.1x1.	Squirrel Hills (Abbott *et. al.* 2011)
Fractured sandstone escarpments	Pungalina-Severn Emu (Woolley 2011, Baker 2015)
An open woodland of Snappy Gum (*Eucalyptus leucophloia*) with an understorey of spinifex grasses (*Triodia molesta* and *T. longiceps*) on variably brecciated calc-silicate that consisted of coarse (`2mm) particles that readily crumbled under pressure.	(Sanders and Slater 2002)

*Adapted from Lloyd *et. al.* 2013.

7.4. DISTRIBUTION AND POPULATION TRENDS

7.4.1. Distribution

Carpentarian Antechinus have been recorded in the north-eastern Northern Territory and western Queensland.

Observations from the Northern Territory were first made at Alexandria Station in 1906. The species has not since been recorded in the area. Recent observations were recorded on the Northern, South-West, Centre and Vanderlin Islands of the Sir Edward Pellow group and the adjacent mainland in an Australian Wildlife conservancy reserve (Kitchener 1991, Johnson *et. al.* 2008, Woolley 2011, Woinarski and Ward 2012). These records suggest the species may be more widespread in the Northern Territory than previously thought.

Recent recordings have been made in Queensland near Mount Isa and across 69 sites in the Selwyn Ranges (south of Cloncurry). The species was recorded near the Dugald River mine in May 2015. Subsequent studies found four individuals in the Knapdale Range (within proximity to the Dugald River mine and approximately 22km north-west of Quamby) and a fifth individual in a rock outcrop approximately 1.5km north-west of Quamby. These records represent the north-eastern limit of the species known range. The current Extent of Occurrence and known records are shown in Figure 4.

If the Queensland and Northern Territory populations are contiguous, the species has an estimated occurrence of 124,800km^2 12,480,000 ha. If the two populations are disjoint, the estimated occurrence of Carpentarian Antechinus is 2,100 km^2 210,000 ha in the Northern Territory and 16,900 km^2 1,690,000 ha in Queensland. These estimates do not account for regions of unsuitable habitat within the mapped areas of occupancy and the species is unlikely to occur uniformly throughout these regions.

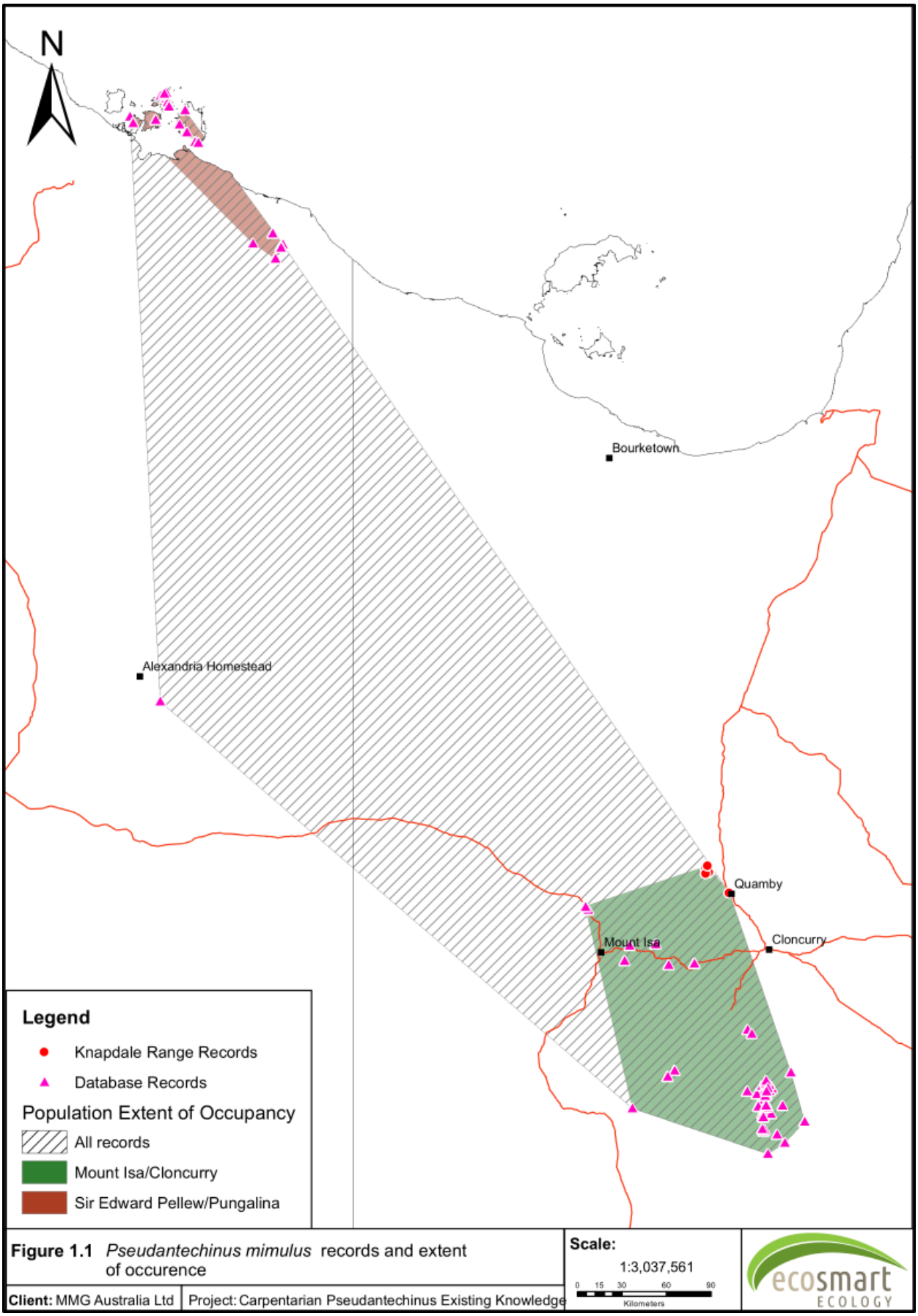


Figure 4: *Pseudantechinus mimulus* records and Extent of Occurrence

Studies have found no evidence of deep genetic breaks between the scattered, disjoint populations of Carpentarian Antechinus in north-west Queensland and north-east Northern Territory (A. Baker pers. comm.). Further evidence is required to determine the species' distribution and genetic structure.

In the absence this evidence, it is prudent to treat the Queensland and Northern Territory populations as individual conservation units, both essential to the survival of the species. This assessment is consistent with the multi-species recovery plan for the Carpentarian Antechinus, Butlers Dunnart and Northern Hopping-mouse (Woinarski 2004) which states:

"*All species [which includes P. mimulus] are characterised by highly disjunct populations and, given the limited known occurrence of each species, it could be argued that each of these disjunct populations is important for the maintenance of these species. However, some populations may be more substantial than others, and some may be more likely to be managed successfully*."

7.4.2. Abundance and Population Trends

There is no available population estimate for the Carpentarian Antechinus. Capture rates of the species are low, typically <1% in the Northern Territory (Woinarski *et. al.* 2012), and lower in Queensland (e.g., 0.3% Lloyd *et. al*. 2013; 0.5-4 EcoSmart Ecology 2015). Trap rates are low in known areas of occupied habitat (Burnett *et. al.* 2014). The species appears to be more readily detected by camera trap surveys than standard live-trapping (Woinarski 2012, Burnett *et. al.* 2014, EcoSmart Ecology 2015). It is not clear whether the low trap rates represent low numbers of individuals or whether the species is wary of traps.

Repeated survey data in known populations of Carpentarian Antechinus is limited. Repeated surveys from the Sir Edward Pellew islands have no established population trends except for a possible decline on North Island (Woinarski *et. al.* 2011, 2014). This may reflect low trap rates. The number of records of the species in Queensland within the last four years has increased substantially, as has the known range of the species within the state. This increase may reflect improved survey methodology and increased survey effort.

7.5. THREATS

Documented threats to Carpentarian Antechinus are provided in Table 5, which extends on and uses criteria published in Woinarski *et. al.*. 2014.

Table 5. Documented threats to *Pseudantechinus mimulus**

Threat	Consequence rating	Extent over which the threat may operate	Evidence base
Inappropriate fire regimes	Severe	Large	Not demonstrated, but plausible. Impacts of severe fires demonstrated for the similar Sandstone Antechinus (Begg *et. al.* 1981).
Predation by feral cats	Moderate	Large (cat impacts may be reduced in rugged areas)	Not demonstrated, but plausible.
Habitat change associated with invasive weeds (particularly Buffel Grass *Cenchrus ciliaris*)	Moderate	Moderate	Noted as a threat (mostly through driving increased fire impacts) for parts of the range (White and Mason 2011, Lloyd *et. al.* 2013).
Poisoning by Cane Toads *Rhinella marina*	Moderate	Moderate	Not demonstrated, but possible, however many records post-date toad invasion.
Pollution (lead and other deposits)	Minor	Minor	Reasonable correlative evidence from structured sampling across a pollution gradient around Mt Isa (Baker and Griffiths 2005)
Mining	Severe	Localised	A number of mining related activities have located species within proposed areas of impact (Wilson and Mittermeier 2015).
Grazing	Minor	Large	Not demonstrated, but plausible.

* Modified from Woinarski *et. al.* 2014.

7.6. CARPENTARIAN ANTECHINUS WITHIN THE DUGALD RIVE MINE PROJECT AREA

The recent records of Carpentarian Antechinus from within the Dugald River Mine tenement represent the most northeasterly records of the species to date. The species was recorded at four sites on the Knapdale Range within the Dugald River Mine tenement, as shown in Figure 5 (EcoSmart Ecology 2015). All records were made in rocky habitats; three in areas with massive boulders and rock formations, and one (DRM03) in an area of smaller rocks. Similar habitat is present across the Knapdale Range (Sanders and McNab 2015) and the species is likely to occur throughout the range.

Recent surveys found one individual to the south on a rock outcrop near Quamby (EcoSmart Ecology 2015). Further research is required to determine the distribution of the species in the area. Aerial imagery suggests that potential habitat to the north is limited. To the east, Mount Rose Bee (approximately 5 km east) appears to be the last suitable rock outcrop before expansive black-soil plains. Large areas of suitable habitat occur to the west, with very extensive rock habitats becoming common place approximately 10 km west.

7.6.1. Habitat mapping for Carpentarian Antechinus within the Dugald River Mine project area

Carpentarian Antechinus habitat mapping was undertaken to identify the extent and location of potential habitat areas across the mine tenement (EcoSmart Ecology 2015a).

The mapping approach and methodology was developed based on the following key pieces of information (EcoSmart Ecology 2015a):

- Previous records and recent studies (Burnett *et. al.* 2014) demonstrate that the species is absent from areas that have little or no rocks. These areas have been mapped as 'unsuitable habitat'.
- Previous records and studies also demonstrate that areas of consolidated rock (larger more exposed rock, difficult to move by hand) provide suitable habitat including rock fissures, cracks and crevices for shelter. These areas have been mapped as 'suitable habitat'.
- Little is known about the use of unconsolidated rock areas (smaller, rounder rocks on bare earth or on lose rocks of similar size) for movement or foraging by Carpentarian Antechinus, however it can be assumed that the species uses areas of unconsolidated rock when in close proximity to consolidated rock. A conservative approach has been applied to areas containing a mix of unconsolidated and consolidated rock, which have been mapped as 'suitable habitat'.

In identifying these suitable habitat areas, the mapping was conducted at two levels:

- More refined identification of potential habitat within the key disturbance areas of the TSF and the accommodation camp area. This mapping identified three categories of habitat including:
    - 'little/no rock', which are considered unsuitable for the species;
    - 'consolidated rock', which is expected to contain areas of good, highly suitable habitat; and
    - 'mixed rock', which represents areas likely to contain a mosaic of both 'unconsolidated' and 'consolidated' rock of varying proportions. It is expected that this category may also contain good, highly suitable habitat, though the abundance of this quality habitat will be less and may be more restricted.
- Broad identification of potential habitat across the whole of the mine tenement using two categories:
    - 'little/no rock', which represent areas of no habitat for the species; and
    - 'rock', which represent areas of potential habitat for the species.

Results of this approach are shown in Figure 6.

Separating rocky habitats into 'consolidated' and 'unconsolidated rock' requires some visual experience. The more refined level of mapping was only possible for the key disturbance areas due to increased field experience within these areas. Across the whole of the mine tenement a more broad-scale approach was needed. Rocky habitats were able to be distinguished from non-rocky habitats based on aerial interpretation and topography.

It should be noted that the maps produced through this work represent *potential* habitat. They were produced at a desktop level using previous field experience, aerial imagery and topographical data and provide a good level of confidence that the areas identified as potentially suitable or unsuitable will generally meet these definitions on the ground. Importantly, the habitat mapping is considered adequate in providing a baseline understanding of habitat values across the tenement against which potential impacts can be analysed.

Table 6 provides the areas (ha) of suitable and unsuitable habitat throughout the mine tenement.

The mapping has identified potentially suitable habitat for the Carpentarian Antechinus across the Knapdale range running north to south through the middle of mine tenement. Suitable mapped areas are associated with steep slopes, gullies, outcrops

and ridges. The core mine processing and operating areas are situated to the east of the Knapdale range on flat plains that do not contain the rocky features required to support the species. The elements of the mine expansion project that occur within areas of potential habitat include the accommodation camp, access roads/pipelines and the TSF.

Table 6: Extent of suitable and unsuitable Carpentarian Antechinus habitat within the proposed Dugald River Mine (EcoSmart Ecology 2015a).

Location	**Habitat type**		**Extent (ha)**
Disturbance zone	Little/no rock	Unsuitable	36.98
	Mixed rock	Suitable	145.62
	Consolidated rock	Suitable	87.75
Surrounding area (excluding disturbance area)	Little/no rock	Unsuitable	2184.15
	Rock (Mixed + Consolidated rock)	Suitable	1152.92

Based on the potential habitat mapping, the Dugald River Mine tenement contains approximately:

- 2,221 ha of unsuitable habitat; and
- 1,386 ha of potential habitat.

Areas of potential habitat were also identified along the power line corridor. Mapping of these areas involved identification of potential rocky outcrops using the information contained in the AARC (2012) survey report and Google Earth imagery. The power line corridor has not been visually assessed for suitable habitat. Aerial imagery shows limited rocky areas and the corridor is unlikely to contain substantial suitable habitat. Rocky areas within the current alignment appear small, isolated and insignificant.

Approximately 0.09 ha of rocky outcrops have been identified within the corridor as shown in Figure 7.

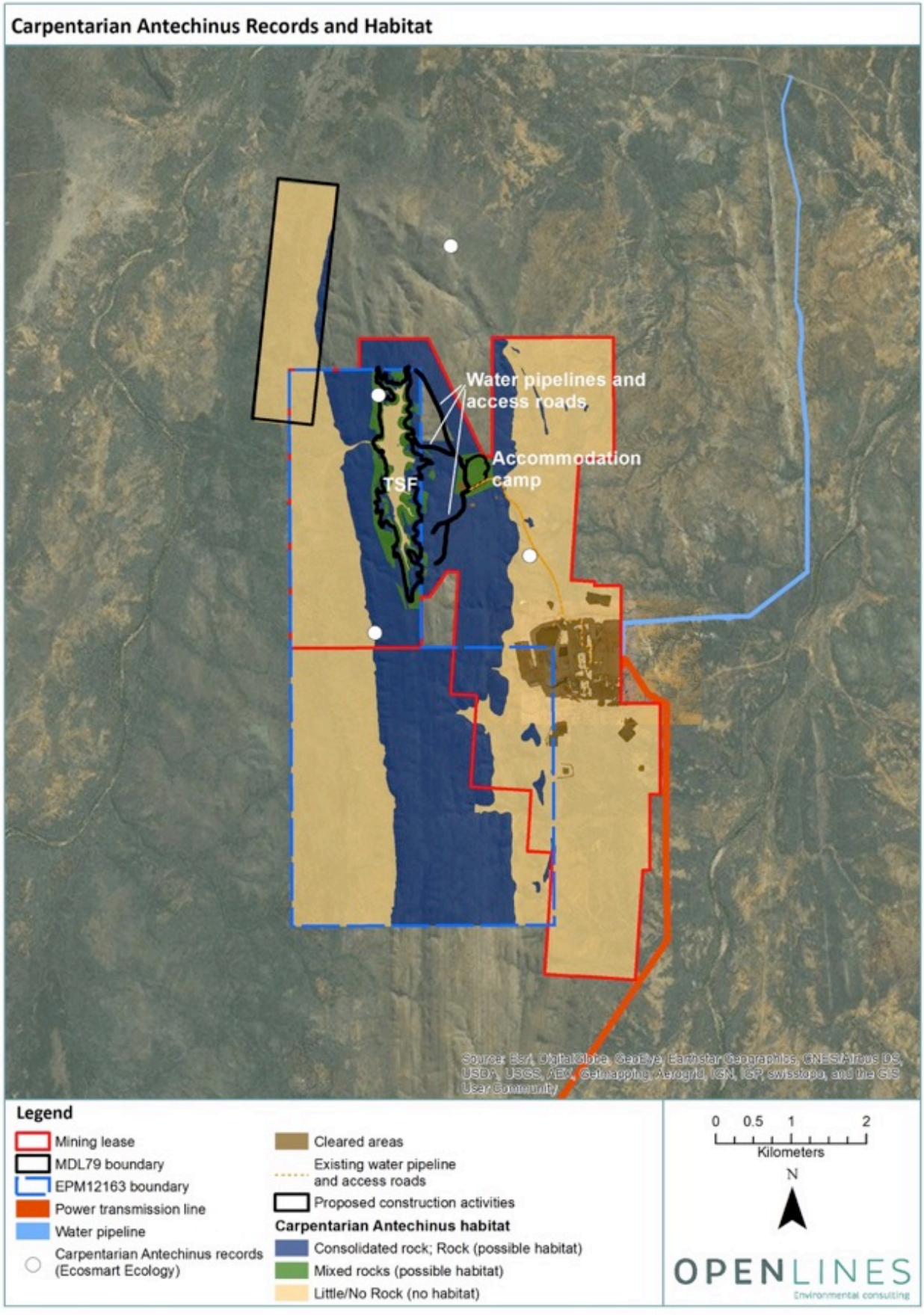


Figure 5: *Pseudantechinus mimulus* records from the Knapdale Range and local area.

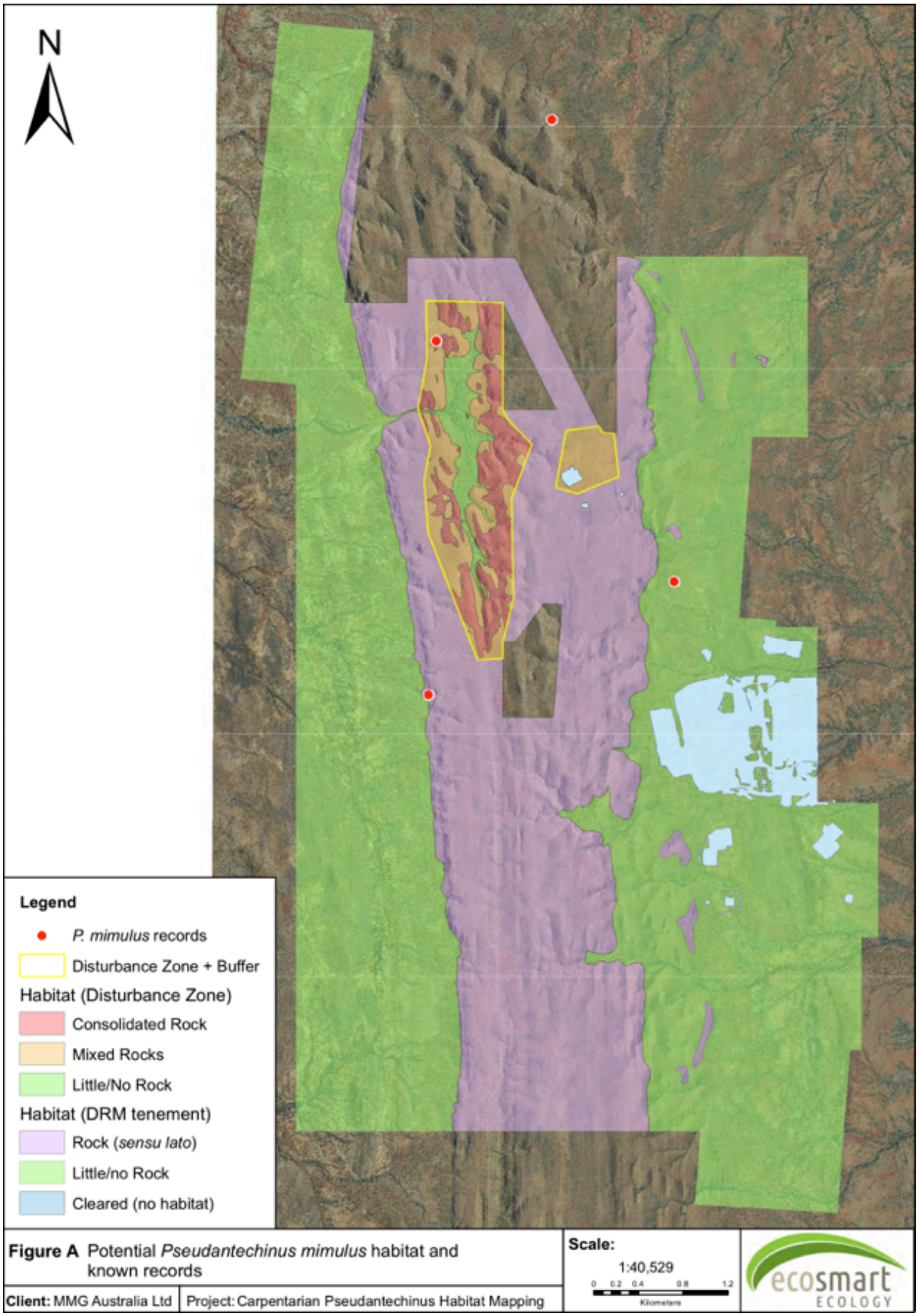


Figure 6: Habitat mapping for Carpentarian Antechinus in the Dugald River Mine tenement.



Figure 7: Rocky outcrops in the proposed power line corridor.

7.7. IMPORTANCE OF THE DUGALD RIVER MINE AREA TO THE CARPENTARIAN ANTECHINUS

The population of Carpentarian Antechinus within the Knapdale Range (located in the north-western portion of the Dugald River Mine tenement) is likely to be considered an important population of the species under the EPBC Act for the following reasons:

- the population may be important for maintaining genetic diversity of the species;
- it may be a key source population of Carpentarian Antechinus for either breeding or dispersal;
- the population extends this species range in Queensland by 50 km.

Suitable habitat for the species is associated with rocky areas, in particular massive boulders or rock features. Within the mine tenement, these habitats are typically found within the Knapdale Ranges, which run north-south through the middle of the tenement. Outside of the Knapdale ranges, the tenement contains little to no rock and is unlikely to support Carpentarian Antechinus.

8. Potential environmental impacts and management measures

8.1. BACKGROUND AND APPROACH

The Dugald River Mine is an existing mine and is conditioned to operate under a range of measures to manage potential environmental impacts. These measures address issues relating to erosion and sedimentation, weeds, fire, feral animals, noise and vibration, land contamination and changes to ground and surface water. This section of the Plan considers the potential impacts of the proposed expansion of mining operations on the Carpentarian Antechinus within the context of these existing controls. Additional management measures are defined here where they are considered necessary or prudent for the protection of the local population.

There are recognised gaps in our current understanding of the species' ecology and distribution. Expert input has been used in the preparation of this Plan to address this issue. The information used is the best available, and the interpretation of relevant impacts and identification of suitable mitigation strategies is informed by extensive field experience.

Section 8.2 describes a number of general measures intended to improve understanding of the species' habitat and presence in the Dugald River Mine tenement. These measures, including monitoring and refined habitat mapping, will better inform the implementation of specific management measures for the potential impacts of mining activities outlined in Section 8.3.

8.2. GENERAL MEASURES

8.2.1. Species monitoring

The Carpentarian Antechinus monitoring program will be conducted annually in each wet and dry season. The program will be designed to:

- provide data on species presence, distribution, abundance and use of habitat within the mine tenement;
- inform an understanding of the species' use of habitat within and adjacent to mining and any potential disturbances associated with operations;
- provide an understanding of habitat rehabilitation success; and
- measure changes over time.

The program will include:

- Monitoring for species presence within representative habitats across the mine tenement.
- Use of the most suitable survey methods and techniques for detecting the species.
- Collection of data relating to threats.
- Provision of a report following each survey that provides:
    - An outline of methods, survey locations and details of the personnel that undertook the monitoring.
    - Details of the timing and climatic conditions during monitoring.
    - Results of the monitoring including support for findings as follows:
        - Site photos showing monitoring equipment placement and habitat structure.
        - Photos/records of the species, scats or other evidence of presence.
        - Summary tables with measurements and diagnostic observations from captures, as relevant.
    - Comparative analysis and identification of trends using previous monitoring or surveys, as appropriate.

8.2.2. Refined habitat mapping

As outlined in Section 7.6.1, a desktop mapping exercise was undertaken by EcoSmart Ecology in August 2015 to identify areas of potential habitat across the mine tenement.

This mapping will be refined through ground truthing within mine disturbance areas to:

- Confirm the suitability of mapped habitat for the Carpentarian Antechinus.
- Identify the habitat type or category. Terms defined in EcoSmart Ecology (2015) such as 'consolidated rock', 'unconsolidated rock within proximity to consolidated rock' or 'little/no rock' may be used as appropriate.
- Refine the boundary of areas considered likely or unlikely to support the species.

This refined mapping will be used:

- during the detailed design phase to inform micro-alignment of infrastructure (described below) in order to avoid habitat wherever possible;
- as the baseline data in the Carpentarian Antechinus Habitat Loss Register which will be used to monitor and report on habitat loss over time and ensure the area of loss does not exceed the limit specified in this plan; and
- to guide reinstatement of habitat within temporary construction areas and at mine closure.

This refined mapping will need to be completed in a timely manner to support each of these three uses.

8.2.3. Research program

MMG will support research into Carpentarian Antechinus over three years to improve understanding of the species distribution, habitat preferences and ecology.

The proposed research project will be jointly conducted by the University of Sunshine Coast, Queensland University of Technology, and EcoSmart Ecology. The project aims to:

- map distribution and model habitat throughout Queensland and the Northern Territory; and
- undertake regular monitoring at sites of known occurrence to improve data on seasonal detectability of the species.

There is a lack of targeted survey data for the species from Qld and NT. It is not clear whether current gaps in the known occurrence of the species are accurate or reflect an absence of appropriate surveys. The proposed research will conduct surveys across potential rocky habitats in the Southern Gulf, Desert Uplands, Einsleigh Uplands, Brigalow Belt, and Mitchell Grass Downs bioregions in Queensland, and adjacent areas in the Northern Territory. Surveys will use baited trail cameras to improve distribution data and assist in the development of a habitat model for the species.

Repeat baited trail camera surveys will be conducted across 20 sites in the Selwyn Ranges (known to support Carpentarian Antechinus) at two month intervals for a year. Data from these surveys will be used to model seasonal detectability for the species, which will improve the design of future survey and monitoring programs.

This research is estimated to cost $300,803.

8.3. POTENTIAL IMPACTS AND MANAGEMENT MEASURES

The proposed action has the potential to impact on the Carpentarian Antechinus. A range of direct and indirect impacts have been identified as potentially relevant including:

- loss of suitable habitat;
- mortality of individuals;
- human disturbance,
- noise and vibration;
- artificial lighting;
- introduction and spread of weeds;
- proliferation of feral predators;
- changes to surface water;
- erosion and sedimentation;
- contamination;
- disruption of connectivity; and
- changes to the fire regime.

The following sections discuss the relevance, extent, and key management measures of these impacts.

8.3.1. Loss of habitat

8.3.1.1. Description of impact

Total loss of potential habitat from proposed activities will be limited to a maximum of 79 ha over the life-of-mine.

The following activities will contribute to this habitat loss:

- direct clearing during construction of the TSF;
- direct clearing during construction of access roads and pipelines;
- direct clearing during construction of the accommodation camp; and
- gradual inundation as a result of operation of the TSF.

The majority of habitat loss from this project (around 82%) is caused by the gradual inundation of the TSF. This will occur over the life-of-mine, and this area of habitat will be lost incrementally over this period.

8.3.1.2. Environmental management measures

MMG will seek to minimise and avoid loss of habitat wherever possible. Three key measures will be used to minimise the effect of habitat loss on the Carpentarian Antechinus and ensure that the level of loss does not exceed the specified limit:

- avoidance of impacts through micro-alignment;
- use of a Habitat Loss Protocol; and
- avoidance of impacts through site rehabilitation.

These measures are detailed in Table 7, and relate to actions carried out within rocky habitats on the Knapdale Range which may be inhabited by Carpentarian Antechinus (see Figure 6).

Avoidance of impacts through micro-alignment

During the detailed design phase MMG will avoid areas of habitat wherever possible. The micro-alignment procedure will require:

- Ground truthing of disturbance areas in order to identify the location suitable habitat and delineation of unsuitable habitat areas. This ground truthing will be carried out as part of the habitat mapping refinement described in Section 8.2.2.
- Identification of alignments that maximise the areas of unsuitable habitat within the development footprint as far as practicable.

This micro-alignment procedure will be used to inform design of:

- the access road and pipeline corridors, where the aim will be to minimise loss of habitat as far as practicable;
- the power line corridor and location of poles and construction envelopes, where the aim will be total avoidance of habitat; and
- the lanes for exploration drilling, where the aim will be total avoidance of habitat.

Habitat loss protocol

The Habitat Loss Protocol will require:

- Development of the Carpentarian Antechinus Habitat Loss Register ('the Register'). This Register will provide a process for recording and monitoring habitat loss over time. It will include as its baseline the mapping generated through the refined habitat mapping described in Section 8.2.2.
- For any construction works:
    - identification and demarcation of areas required for clearing prior to construction;
    - assessment of this area against the baseline mapping to ensure that it is within the specified limit;
    - entry of clearing details into the Register; and
    - provision of a monthly report documenting cumulative habitat loss, as described in Section 4.1.1.
- For inundation of the TSF:
    - monitoring and recording of TSF levels in the Register as part of annual monitoring required for the TSF;
    - entry of TSF levels into the Register; and
    - reporting on cumulative habitat loss in the annual report, as described in Section 4.1.3.

Mitigation of impacts through site rehabilitation

Habitat will be reinstated progressively within temporary construction footprints and following mine closure across the majority of disturbed areas.

The progressive reinstatement of habitat relates to the access roads and pipelines and is expected to mitigate the short-term loss of at least 20% of this impact.

The reinstatement of habitat at mine closure will occur in relation to the:

- processing plant/mining area;
- accommodation camp area; and
- TSF.

The type and location of habitat to be reinstated will be informed by the refined habitat mapping described in Section 8.2.2.

Table 7: Summary of key control measures to manage loss of habitat impacts

Control Measure	Timing	Performance Target
Undertake ground truthing to map Carpentarian Antechinus habitat in the disturbance areas.	Prior to construction.	Ground truthing of proposed disturbance areas completed before commencement of construction.
Micro-alignment of access roads, TSF pipelines, the power line and drilling lanes to minimise clearing of suitable habitat.	Ongoing through project design and construction.	Avoid and minimise loss of suitable habitat due to project construction.
Areas requiring mechanical clearing will be clearly identified and demarcated prior to clearing, with the area (ha) and type of habitat to be cleared recorded in the Carpentarian Antechinus Habitat Loss Register.	Prior to mechanical clearing.	Loss of habitat from mechanical clearing will be recorded, monitored and not extend outside of demarcated areas.
Annual monitoring of TSF levels and associated area of habitat loss (ha) recorded in the Carpentarian Antechinus Habitat Loss Register.	Annually.	Loss of habitat from mechanical clearing will be recorded and monitored against the maximum habitat disturbance limit.
Rehabilitation of areas not required for life-of-mine operation (i.e., temporarily cleared areas).	Within 6 months of end-of-construction.	• Rock piles scattered through rehabilitation area at a density of at least 2 per hectare. Piles should be a minimum of 3x3m in area and consist predominantly of rocks > 30 cm in diameter. • Seeding using native ground cover species, particularly endemic spinifex. • Buffel Grass will not be used to consolidate soils. • No exotic woody species (trees or shrubs)
Rehabilitation of operational areas (mine-closure)	Within 12 months of mine closure.	• Reinstatement of habitat within disturbance areas associated with the TSF, accommodation camp and access roads. • Rock piles scattered through rehabilitation area at a density of at least 2 per hectare. Piles should be a minimum of 3x3m in area and consist predominantly of rocks > 30 cm in diameter. • Seeding using native ground cover species, particularly endemic spinifex. • Buffel Grass will not be used to consolidate soils. • No exotic woody species (trees or shrubs)

8.3.1.3. Environmental Management Maps and Diagrams

Cleared areas that will be rehabilitated on mine closure are shown in Figure 1.

8.3.1.4. Environmental monitoring

Monitoring of clearing will be conducted throughout project construction in accordance with the Habitat Loss Protocol and using the Carpentarian Antechinus Habitat Loss Register. This Register will include the mapping refined through ground truthing within mine disturbance areas. This mapping will be used as a baseline against which habitat loss will be recorded and monitored.

Monitoring of rehabilitated areas will be undertaken once yearly in accordance with the Environmental Authorisation for the Dugald River Mine. Monitoring to ensure that rehabilitation areas provide similar suitable habitat for Carpentarian Antechinus to the habitat that was lost during mine construction and operation.

8.3.1.5. Corrective actions

Corrective actions will include:

- Re-establishment of demarcations if mechanical damage or accidental 'over-clearing' occurs. Any areas accidentally cleared beyond the demarcated clearing zones will be rehabilitated within 6 months of end-of-construction according to the targets outlined in Table 7.
- Weed species will be monitored and controlled in rehabilitation areas (see Section 8.3.6 for weed control measures).

8.3.2. Mortality

8.3.2.1. Description of impact

Mortality of individuals will occur through the direct loss of habitat during construction, as well as a result of gradual flooding of the TSF.

The species is unlikely to be able to rapidly relocate from their shelter sites during construction, or have the ability to outpace clearing. Translocation is infeasible as the species is difficult to capture. Mortality of individuals within clearing zones is considered to be an unavoidable impact.

Natural mortality is also likely during the gradual inundation of the TSF. Research has established that vertebrates dislocated from their home ranges and territories are less competitive than resident animals. As such, gradual flooding of the TSF is likely to lead to increased mortality.

It is not possible to quantify the likely reduction in the local Carpentarian Antechinus population as a result of the proposed action. The area of habitat loss will not exceed 6% of habitat available within the immediate vicinity, so it is likely that only a small proportion of the population will be affected. The significant natural attrition which the population undergoes following breeding is far more substantial by comparison.

Carpentarian Antechinus spend daylight hours hidden in crevices and cracks within the rocks. Sheltering individuals cannot be located or safely extracted prior to construction. The species is difficult to trap, with trap rates as low as 1 individual in 1000 trap nights in favourable conditions (Burnett *et. al.* 2014), and will be impossible to relocate prior to construction or inundation.

The difficulty of detection or translocation during construction therefore limits options for potential mitigation measures for this impact. However, measures to avoid and minimise habitat loss will mitigate this impact. The measures outlined in Section 8.3.1, including the commitment to a maximum disturbance limit, adequately address this issue.

8.3.2.2. Environmental management measures

No mitigation in addition to that identified in Section 8.3.1.2 is considered necessary.

8.3.3. Human Disturbance

8.3.3.1. Description of impact

The Carpentarian Antechinus is a nocturnal species which inhabits massive rock outcrops. During the day they are expected to reside down deep rock crevices and are unlikely to respond to minor surface activity (including human movement or light vehicle operation along designated tracks). Human actions during daylight hours are not expected to impact on the species.

It is theoretically possible that foraging efficiency, and perhaps mate location, may be negatively affected by frequent human activity at night. However, the proposed action does not require visitation of large rock outcrops, and human activity across the Knapdale Range at night outside of the accommodation area is extremely unlikely. The risk and rate of human activity at consolidated rock areas will be extremely low.

Both the risk and the likely magnitude of impacts to the Carpentarian Antechinus from human disturbance are likely to be negligible.

8.3.3.2. Environmental management measures

No further mitigation is considered necessary.

8.3.4. Noise and vibration

8.3.4.1. Description of impact

Noise will primarily occur as a result of:

- light and heavy vehicles on the project site and accessing the project site;
- hauling and dumping operations;
- surface vent fans;
- crushing; and
- ore processing.

Surface vibrations will occur from underground blasting. Vibration is monitored as peak particle velocity (measured as mm/s). Existing surface limits for vibration are:

- 1 mm/s night time;
- 5 mm/s day time with 4 out of every 5 blasting having to be less than this value; and
- 10 mm/s absolute limit

There have been no studies of the response of the Carpentarian Antechinus to increased noise and vibration. It is possible that the species will show temporary change in behaviour within affected areas (e.g. becoming startled) - particularly if the levels are high compared with background levels, sudden, or unpredictable and novel.

The majority of the noise and vibration generated from the proposed action will be associated with the main mine processing and operating areas located on flat plains east of the Knapdale Range. It is considered unlikely that the noise and vibration levels generated within this area will affect the Carpentarian Antechinus for the following reasons:

- This area does not contain the necessary rocky features to support the species. The noise and vibration generated from this area may extend to the west where the species habitat occurs. However, the levels will be diffused over this distance.
- The Dugald River Mine has already been in operation for a number of years. The noise and vibration levels generated from existing operations are expected to be the same or in some instances greater than those that will occur as a result of the proposed action (noting that underground mine operations will get progressively deeper, lessening surface impacts). The species' persistence within habitats across the mine tenement suggests that the species is likely to be habituated to existing noise and vibration levels and that they are not negatively affected. Similar conclusions can be drawn for other populations known to persist within proximity to mining elsewhere (for example, Exco Resources Mt Colin project).

There will be construction activities within and adjacent to potential habitat that will lead to low levels of increased noise for short periods of time during daylight hours. These activities will be associated with the construction of TSF infrastructure, access roads/pipelines and the accommodation camp. Impacts on the species use of habitat is expected to be negligible given they will occur during daylight hours and will only occur in the short term.

Operational noise within habitat areas will be restricted to the accommodation camp. Noise sources associated with the camp will include general human noise (laughing, talking etc.) and power generation units (generators). This noise will be localised and minor and unlikely to affect individual Carpentarian Antechinus in immediately adjacent habitats. Generators will only operate while the power lines are under construction and as a backup after the power lines are operational. Noise from generators will occur throughout the night, but noise levels will be low and continuous and likely to be tolerated by the species.

The mine is subject to existing noise and vibration controls and limits and undertakes ongoing monitoring of these potential impacts. With these controls in place, the anticipated impact from construction and/or operational noise and vibration at the mine site on Carpentarian Antechinus is negligible.

8.3.4.2. Environmental management measures

No further mitigation is considered necessary.

8.3.5. Lighting

8.3.5.1. Description of impact

The effect of lighting on the behaviour and ecology of the Carpentarian Antechinus is unknown. However, given that the species is shy and reclusive, individuals may be reluctant to move through or around well-lit areas, possibly as a function of perceived predatory risk.

Most operations at the Dugald River Mine will be restricted to areas which do not contain suitable habitat. Lighting sources in these areas will have no impact on the species. The accommodation camp is the only area in which light sources are anticipated to impact on the Carpentarian Antechinus.

Walkways and access ways around the accommodation camp will be lit throughout the night using fluorescent or LED tube lights. These lights will typically have a cool to white colour (3000K to 3500K) and are low intensity. Light spill from these sources quickly dissipates beyond approximately 15 m. Many of these lights will be separated from natural habitats by buildings and other solid structures which reduce direct light spill into adjacent natural areas. As the camp will be surrounded by a fire break of approximately 3 m, the area that might be affected will be relatively small, particularly compared to the available habitat in the vicinity.

The camp is located well away from massive rock outcrops. Exposed rock in the vicinity is smaller and more restricted in its extent. While this may still provide value for the species, it is likely that the animals, if present, are less abundant in this area. Both these factors suggest that the risk and possible impact of light spill from the accommodation camp on the species is likely to be minor.

8.3.5.2. Environmental management measures

Environmental Management Activities, Controls and Performance Targets

The impact of lighting on Carpentarian Antechinus is likely to be minor. A conservative mitigation strategy will be applied to minimise and localise light spill. The measures outlined in Table 8 below will assist in reducing the risk of light impacts.

Table 8: Control measures to manage lighting

Control Measure	Timing	Performance Target
No night lighting used along access roads to, or around the TSF facility	Throughout operation	No nocturnal lights along the TSF access road.
No night lighting along the accommodation camp road	Throughout operation	No nocturnal lights at the accommodation camp road.
Low-use areas which are not subject to frequent visitation but require lighting will be lit with uni-directional (or use light guards), low-intensity (wattage) long wavelength (orange) light.	Throughout operation	Low-intensity long wavelength (orange) lights used in low frequency use areas.
Light guards or uni-direction lights used where lighting is needed around the periphery of the accommodation camp (as required) to prevent spill into surrounding 'natural' habitats.	Throughout operation	Light spill reduced

Environmental Management Maps and Diagrams

N/A

Environmental monitoring

The condition of light guards will be audited annually.

Corrective actions

Light guard defects will be repaired within one month.

8.3.6. Introduction and Spread of Weeds

8.3.6.1. Description of impact

Declared weed species are not prolific in the dry skeletal soils associated with the Mount Isa/Cloncurry region, and the risk of declared weeds being accidentally introduced from mining related activities into Carpentarian Antechinus habitats is extremely low. Two declared weed species, Calotrope (*Calotropis procera*) and Rubbervine (*Cryptostegia grandiflora*), are currently known from a small number of outbreaks within the mine tenement near the Dugald River. Both of these species are highly unlikely to survive on the Knapdale Range.

Buffel Grass (*Cenchrus ciliaris*) is a non-native grass species which is considered an environmental weed and favoured by pastoralists. It has been demonstrated to negatively influence biodiversity and potentially lead to altered fire regimes (Smyth et al 2009, Marshall et al 2012). Buffel Grass is currently present within the mine tenement and established at selected locations in and around the Knapdale Range where it is typically associated with creeklines and plains with a deeper soil profile and potentially higher moisture content.

There remains a small risk that some plants may become established where soil disturbance occurs such as adjacent to tracks, roads and infrastructure. Erosion in association with these structures could lead to localised sediment collection and allow the species to establish.

Despite the low risk of impacts from weeds on Carpentarian Antechinus habitats within the Dugald River Mine tenement, weeds are broadly recognised as a relevant threat to the species. As such, a number of measures will be implemented to ensure management of this potential impact.

8.3.6.2. Environmental management measures

Environmental Management Activities, Controls and Performance Targets

The Dugald River Mine will continue to use its existing Weed Control Program. This plan will be updated to reflect the recent records of Carpentarian Antechinus found within the Knapdale Range. The most important amendment is the inclusion of a management strategy for Buffel Grass. The risk of Buffel Grass outbreaks increases with disturbance and human/mechanical activity. Control and monitoring will focus on controlling mining related Buffel outbreaks. These are typically new infestations located adjacent to infrastructure, roadways and activity areas. Natural outbreaks across the broader Knapdale Range are extremely unlikely, but could occur following propagule dispersal by cattle. These are not considered mining related impacts.

Table 9: Control measures to manage weed introduction and spread

Control Measure	Timing	Performance Target
Buffel Grass (*Cenchrus ciliaris*) will be added to the list of weed species of concern (Table 2), making it subject to control actions and monitoring.	Within 6 months of approval	Buffel Grass prevented from becoming established within rocky habitats within 500m of mining related activities or disturbance.
Existing Weed Management Plan to be updated with trigger values for control of all weed species: • No new outbreaks within 500m of mining related disturbance on the Knapdale Range • Existing outbreaks within 500m of mining disturbance/activities on the Knapdale Range not to increase by >10%	Within 6 months of approval	• No new weed outbreaks due to mining related actions on the Knapdale Range; • Existing outbreaks within 500m of mining related activities on the Knapdale range not to increase by >10%.
Existing Buffel Grass infestations within 500m of mining activities on the Knapdale Range will be subject to monitoring and control.	Biannual weed monitoring Control actions, if required, undertaken within 2 months or during the appropriate time of the species growth cycle.	Existing Buffel Grass infestations within 500m of mining on the Knapdale Range will not expand more than 10% of current distribution.
No-go-zones will be established around existing Buffel Grass infestations	Within 6 months of approval	Spread of Buffel Grass not caused by mining related activities.
Areas subject to weed control measures (all	Monitoring to commence	Weed control actions successful in

species) will be monitored every second month for six months to ensure the control measures are successful.	within two months of weed control actions.	removing (new infestations) or reduce the extent (existing infestations) of weed outbreaks.

Environmental Management Maps and Diagrams

N/A

Environmental monitoring

Weed mapping will be conducted biannually, consistent with the existing Weed Control Plan. Control of existing Buffel Grass outbreaks within 500 m of mining related activities (if present) will occur when its extent increases by 10%.

Corrective actions

Initial control of Buffel Grass will be undertaken by site based maintenance using mechanical (physical) removal of plants and/or general herbicides. If unsuccessful follow-up works using external weed control contractors will be undertaken.

8.3.7. Proliferation of Feral Predators

8.3.7.1. Description of impact

A number of exotic pest species are known to occur within and surrounding the Knapdale Range including feral pigs, dingo/wild dogs, and feral cats. MMG already implements feral animal monitoring and control procedures for pest species at the Dugald River Mine, including securing waste foods. These measures will reduce the risk of feral animal proliferation.

Feral Pigs

Feral Pigs are predominantly restricted to the creeklines and plains which surround the Knapdale Range. In these areas they can cause considerable damage to vegetation and habitat while foraging. However the Knapdale Range has hard skeletal soils with abundant rock and these features inhibit pig foraging. Pigs are highly unlikely to occur with any frequency on the Knapdale Range and are unlikely to be a threat to Carpentarian Antechinus. No additional control or monitoring of this species is required.

Dingo/wild dog

Dingo/wild dogs have been recorded both in the plains and creeklines surrounding the Knapdale Range, as well as on the Knapdale Range. While dingos/wild dogs prey upon a wide variety of native fauna, they are unlikely to take wary and agile Carpentarian Antechinus and are unlikely to have a significant negative effect on the species. Dingos/wild dogs may have a positive effect on Carpentarian Antechinus by reducing the much more relevant threat of feral cat activity (Johnson et. al. 2007, Wang 2011, Kennedy 2012).

Feral Cats

Feral cats are a major predator of small native mammals and are a listed threatening process. High numbers of feral cats are likely to increase predatory pressure on small mammals of the Knapdale Range, including Carpentarian Antechinus. The severity of this threat will vary according to feral cat populations and alternative prey abundance (e.g., Common Rock-rats, small lizards, birds etc).

Feral cats can benefit from human activity, especially through an increase in prey or food associated with careless disposal of perishable food waste and an increase in hiding and shelter areas in built environments. MMG employ measures at the Dugald River Mine to appropriately dispose of food scraps. It is not anticipated that feral cat abundance will substantially increase as a result of the proposed action.

While existing mitigation measures make it unlikely that the proposed actions will increase predator abundance, MMG will undertake monitoring of feral cats and control where required to ensure any potential impacts are avoided or minimised. These measures are described in detail in Section 8.

8.3.7.2. Environmental management measures

Environmental Management Activities, Controls and Performance Targets

The Dugald River Mine has an existing Feral Animal Control program which will be updated to ensure that mine-related increases in feral animals do not adversely affect Carpentarian Antechinus. Feral cats are the most influential feral predator on Carpentarian Antechinus populations. The control measures outlined in Table 10 target this species.

Table 10. Control measures to manage feral cats

Control Measure	Timing	Performance Target
A feral cat register will be established to document all cat observations. Staff will be advised of MMG obligations to monitor and control cats through inductions and communications outlined in the existing Feral Animal Control program. Feeding or encouraging feral cats around infrastructure will not be tolerated.	Within 6 months of approval	Register audited annually
Feral cat monitoring using IR cameras established at strategic locations around infrastructure (particularly in areas where food is kept or feral cats may shelter) and baited with a specialised cat attractant (e.g., cat nip/cat urine).	Biannually coinciding with Purple-necked Rock-wallaby monitoring	No cats discovered around infrastructure areas.
Feral cat presence will be recorded in the feral cat register if detected during Rock-wallaby monitoring. This will monitor Feral cats across the broader Knapdale Range.	Biannually	Feral cats not recorded during two sequential rock-wallaby surveys.

Environmental Management Maps and Diagrams

N/A

Environmental monitoring

As per above, biannual monitoring.

Corrective actions

Feral cat control will be undertaken if performance targets are not achieved. Control actions should target those locations where individuals have been recorded and the immediate vicinity. Feral cats are difficult to control. MMG environmental staff will work with a qualified ecologist to develop targeted control measures suitable to the location and feral cat threat prior to initiating each feral cat control event.

8.3.8. Changes to surface water

8.3.8.1. Description of impact

Carpentarian Antechinus live in dry rocky environs with little or no surface water. While they may take advantage of temporary water, they do not need surface water for their survival. Changes to surface water hydrology are unlikely to affect the species.

8.3.8.2. Environmental management measures

No further mitigation of this impact is considered necessary.

8.3.9. Erosion and sedimentation

8.3.9.1. Description of impact

Habitat in which Carpentarian Antechinus occurs is largely situated on steep rocky slopes with massive rock boulders. These areas are heavily weathered through natural processes and increased erosion or sedimentation in these areas from mining activities is not expected. Furthermore, the Dugald River Mine has existing measures to control erosion and sedimentation including commitments to:

- minimise the extent and duration of land disturbance;
- stabilise land promptly;
- install sediment retention measures in potential water flow locations around land disturbance areas; and
- monitor and maintain erosion and sediment control structures.

These are considered sufficient to reduce erosion and sedimentation risk and impacts.

8.3.9.2. Environmental management measures

No further mitigation is considered necessary.

8.3.10. Contamination of habitat

8.3.10.1. Description of impact

Land contamination has the potential to have localised impacts on Carpentarian Antechinus habitats. The risk of impacts are most relevant where the tailings line crosses habitat areas. The TSF and associated pipeline infrastructure is the most likely source of potential contamination to Carpentarian Antechinus habitat.

8.3.10.2. Environmental management measures

Environmental Management Activities, Controls and Performance Targets

A number of mitigation measures will be used to reduce the risk of spill or breach of the TSF pipeline. These measures will be detailed in future TSF designs, but as a minimum will include those measures outlined in Table 11.

Table 11. Control measures to mitigate contamination

Control Measure	Timing	Performance Target
Low and High pressure alarms interlocked to an automated staged shutdown of tailings delivery system	Operational	Spills detected within 5 minutes of breach
Emergency spill response	Within 1 hour of breach	Spill contained within 2 hours of breach; spill cleaned within 1 week of breach
Preventative maintenance schedule for the tailings delivery system	As required by OEM for individual components	No significant equipment breakdowns during LoM
Maintain and test standby mainline pump	Operational	Standby pump activates during testing or operational conditions
Pipeline inspections	Once per shift	No significant pipeline failures during LoM
Pipeline thickness testing	Biannually	No significant pipeline failures during LoM
Corridor, access road and pipeline alignment and design will include bunds and/or other design features to contain spills.	Throughout construction of TSF pipelines and associated infrastructure.	All spills to be contained within easement until spill response measures are implemented.

Environmental Management Maps and Diagrams

N/A

Environmental monitoring

As per targets outlined in Table 11.

Corrective actions

Maintenance and repair as required by individual components.

8.3.11. Disruption of connectivity

8.3.11.1. Description of impact

Connectivity of habitat may be disrupted where new infrastructure or activities prevent movement of the Carpentarian Antechinus.

Most activities and infrastructure associated with the Dugald River Mine are located in areas of habitat unsuitable for the species. Activities which occur in the Knapdale Range include the construction, operation and decommissioning of the TSF and accommodation camp. These activities will occur in discrete locations, and are surrounded by areas of suitable habitat through which movement for the species will be maintained. Linear infrastructure connecting these sites including TSF access roads and pipelines has the potential to permanently isolate areas of habitat. Structures can impede the species movement by forming a physical barrier or by introducing a surface which is too wide and dissimilar to the species' natural habitat.

The access roads will comprise single lane, dirt tracks. The operational width of the access road and pipeline corridor will be 8 m. Information on the species' dispersal behaviour and movement between areas of consolidated rock is limited. The results of the targeted surveys within the mine tenement suggest that individuals may traverse as much as 200m of rocky but unsuitable habitat between areas of consolidated rock. An 8 m wide dirt road surrounded by suitable rocky habitat is not expected to disrupt movement of the species.

8.3.11.2. Environmental management measures

Environmental Management Activities, Controls and Performance Targets

Linear infrastructure including access roads and the TSF pipelines have the potential to affect movement of individuals in the area and reduce habitat connectivity. Measures to avoid and manage this potential impact relate to design and monitoring.

The relatively narrow access roads have a dirt surface and are not anticipated to substantially disrupt the species' movement.

Pipelines laid flush to the ground may present a barrier to Carpentarian Antechinus. The TSF pipelines will be constructed above ground on concrete sleepers with clearance under the steel line to maintain the species movement.

Further detail on mitigation measures in the design of this infrastructure is given in Table 12.

Table 12.Control measures to maintain habitat connectivity.

Control Measure	Timing	Performance Target
Single-lane dirt roads used as access to TSF and associated infrastructure	Construction	Single-lane dirt road.
Raised sections, crossing uneven ground, or overpass opportunities created approximately every 10m along the pipeline length	Construction	Movement passage possible approximately every 10m along length of pipeline.

Environmental Management Maps and Diagrams

An indicative layout of proposed access roads and pipelines is shown in Figure 1.

Environmental monitoring

Crossing locations checked annually to ensure erosion/siltation does not reduce structure efficiency.

Corrective actions

Crossing opportunities recreated/maintained as required on a case-by-case basis.

8.3.12. Changes to the fire regime

8.3.12.1. Description of impact

Construction and operation activities have the potential to increase the risk of fire to adjoining vegetation and habitat areas, reducing the availability of food resources. The sensitivity of Carpentarian Antechinus to fire is not known, but severe fires are known to impact the similar Sandstone Antechinus (Begg et al 1981). It is reasonable to assume that potential impacts associated with an increased risk of fire are relevant to the Carpentarian Antechinus.

Fuel load in Carpentarian Antechinus habitat at Dugald River Mine is low which reduces the likelihood of severe fires. MMG implement systems and processes to minimise the potential of bushfires as a result of construction and operation activities. These measures are outlined in MMG's Bushfire Management Plan. Key elements of the plan include:

- use of fire breaks;
- identification of ignition sources;
- identification of fire risk areas; and
- training.

Implementation of the Bushfire Management Plan is considered adequate to manage this potential risk to the species.

8.3.12.2. Environmental management measures

No further mitigation is considered necessary.

9. Residual risk assessment

This section provides a risk assessment for the impacts and management measures described in Section 8.3.

Risks have been assessed according to the framework set out in the Department of Environment's Environmental Management Plan Guidelines. Risks are categorised by qualitative measures of likelihood and the severity of their consequences. These qualitative measures are used to assign a risk rating to each risk before and after mitigation.

A description of each qualitative measure of likelihood category and consequences is given in Table 13 and Table 14. Table 15 gives a breakdown of risk ratings.

Table 13: Qualitative measures of likelihood.

Qualitative measure of likelihood (how likely is it that this event/issue will occur after control strategies have been put in place)	
Highly likely	***Is expected to occur in most circumstances***
Likely	***Will probably occur during the life of the project***
Possible	***Might occur during the life of the project***
Unlikely	***Could occur but considered unlikely or doubtful***
Rare	***May occur in exceptional circumstances***

Table 14: Qualitative measures of consequences.

Qualitative measure of consequences (what will be the consequence/result if this issue does occur rating)	
Highly likely	Minor incident of environmental damage that can be reversed
Likely	Isolated but substantial instances of environmental damage that could be reversed with intensive efforts
Possible	Substantial instances of environmental damage that could be reversed with intensive efforts
Unlikely	Major loss of environmental amenity and real danger of continuing
Rare	Severe widespread loss of environmental amenity and irrecoverable environmental damage

Table 15: Risk ratings.

	Consequence				
	Minor	***Moderate***	***High***	***Major***	***Critical***
Highly Likely	***Medium***	***High***	***High***	***Severe***	***Severe***
Likely	***Low***	***Medium***	***High***	***High***	***Severe***
Possible	***Low***	***Medium***	***Medium***	***High***	***Severe***
Unlikely	***Low***	***Low***	***Medium***	***High***	***High***
Rare	***Low***	***Low***	***Low***	***Medium***	***High***

9.1. RISK ASSESSMENT RESULTS

The likelihood categories assigned in the initial risk ratings in Table 16 reflect the risks to the Carpentarian Antechinus from the expansion and operation of a mine which is already implementing a range of environmental management measures. The effects of these existing measures have been included in this assessment of initial risk. Residual risk likelihoods consider these initial risks after the introduction of the new mitigation measures set out in Section 8.

The key residual risk identified in this assessment is the proliferation of feral predators. Without mitigation, this presents a high risk to the species in the Dugald River Mine tenement. Mitigation measures will be important for ensuring the minimisation of this potential impact.

Table 16: Risk assessment results

Potential impact	***Description***	***Initial Risk (likelihood x consequence)***	***Proposed Measures***	***Residual Risk (likelihood x consequence)***
Loss of habitat	Over-clearing of Carpentarian Antechinus habitat as a result of: • direct clearing during construction of the TSF; • direct clearing during construction of access roads and pipelines; • direct clearing during construction of the accommodation camp; and • gradual inundation as a result of operation of the TSF.	***Possible x Moderate = Medium***	Undertake ground truthing to map Carpentarian Antechinus habitat in the disturbance areas. Micro-alignment of access roads, TSF pipelines, the power line and drilling lanes to minimise clearing of suitable Areas requiring mechanical clearing will be clearly identified and demarcated prior to clearing, with the area (ha) and type of habitat to be cleared recorded in the Carpentarian Antechinus Habitat Loss Register. Rehabilitation of areas not required for life-of-mine operation (i.e., temporarily cleared areas). Rehabilitation of operational areas (mine-closure).	***Unlikely x Minor =Low***
Mortality	Mortality of Carpentarian Antechinus through the direct loss of habitat during construction and gradual flooding of the TSF.	***Likely x Minor = Low***	Undertake ground truthing to map Carpentarian Antechinus habitat in the disturbance areas. Micro-alignment of access roads, TSF pipelines, the power line and drilling lanes to minimise clearing of suitable	***Likely x Minor = Low***
Human disturbance	Reduction in foraging efficiency, or disruption of breeding behaviour of Carpentarian Antechinus	***Unlikely x Minor = Low***	N/A. Existing measures considered sufficient.	
Noise & vibration	Temporary avoidance behaviour of individual Carpentarian Antechinus in affected areas	***Unlikely x Minor = Low***	N/A. Existing measures considered sufficient.	

Potential impact	Description	Initial Risk (likelihood x consequence)	Proposed Measures	Residual Risk (likelihood x consequence)
Lighting	Temporary avoidance behaviour of individual Carpentarian Antechinus exhibited in well-lit areas as a function of perceived predatory risk.	***Likely x Moderate = Medium***	No night lighting used along access roads to, or around the TSF facility No night lighting along the accommodation camp road Low-use areas which are not subject to frequent visitation but require lighting will be lit with uni-directional (or use light guards), low-intensity (wattage) long wavelength (orange) light. Light guards or uni-direction lights used where lighting is needed around the periphery of the accommodation camp (as required) to prevent spill into surrounding 'natural' habitats.	***Unlikely x Low = Low***
Introduction and spread of weeds	Loss of Carpentarian Antechinus habitat quality as a result of the introduction and spread of declared weed species.	***Possible x High = Medium***	Buffel Grass (*Cenchrus* ciliaris) will be added to the list of weed species of concern (Table 2), making it subject to control actions and monitoring. Existing Weed Management Plan to be updated with trigger values for control of all weed species: • No new outbreaks within 500m of mining related disturbance • Existing outbreaks within 500m of mining disturbance/activities not to increase by >10% Existing Buffel Grass infestations within 500m of mining activities will be subject to monitoring and control. No-go-zones will be established around existing Buffel Grass infestations Areas subject to weed control measures (all species) will be monitored every second month for six months to ensure the control measures are successful.	***Unlikely x Minor = Low***
Proliferation of feral predators	Increased predatory pressure on Carpentarian Antechinus as a result of introduction and proliferation of feral cats.	***Likely x Major = High***	Implementation of the existing Feral Animal Control Program A feral cat register will be established to document all cat observations. Staff will be advised of MMG obligations to monitor and control cats through inductions and communications outlined in the existing Feral Animal Control program. Feeding or encouraging feral cats around infrastructure will not be tolerated. Feral cat monitoring using IR cameras established at strategic locations around infrastructure (particularly in areas where food is	***Likely x Moderate = Medium***

Potential impact	Description	Initial Risk (likelihood x consequence)	Proposed Measures	Residual Risk (likelihood x consequence)
			kept or feral cats may shelter) and baited with a specialised cat attractant (e.g., cat nip/cat urine). Feral cat presence will be recorded in the feral cat register if detected during Rock-wallaby monitoring. This will monitor Feral cats across the broader Knapdale Range.	
Changes to surface water	Decrease in surface water quality affecting Carpentarian Antechinus water resource	*Possible x Minor = Low*	N/A. Existing measures considered sufficient.	
Erosion and sedimentation	Decrease in Carpentarian Antechinus habitat as a result of erosion and sedimentation	*Unlikely x Minor = Low*	N/A. Existing measures considered sufficient.	
Contamination	Contamination and degradation of Carpentarian Antechinus habitat as a result of leakage of tailings from the TSF pipeline infrastructure.	*Possible x Moderate =Medium*	Low and High pressure alarms interlocked to an automated staged shutdown of tailings delivery system Emergency spill response Preventative maintenance schedule for the tailings delivery system Maintain and test standby mainline pump Pipeline inspections Pipeline thickness testing Corridor, access road and pipeline alignment and design will include bunds and/or other design features to contain spills	*Unlikely x Minor = Low*
Disruption of habitat connectivity	Disruption of habitat connectivity as a result of new infrastructure or activities prevent movement of Carpentarian Antechinus.	*Likely x Moderate = Medium*	Single-lane dirt roads used as access to TSF and associated infrastructure Raised sections, crossing uneven ground, or overpass opportunities created approximately every 10m along the pipeline length	*Possible x Minor = Low*
Changes to fire regime	Increased risk of fire to adjoining vegetation and Carpentarian Antechinus habitat areas, reducing the availability of food resources.	*Unlikely x Moderate = Low*	N/A. Existing measures considered sufficient.	

10. Audit and review

10.1. AUDITING

The SHEC Superintendent will be required to undertake an annual audit of the Carpentarian Antechinus Management Plan during the construction phase of the project. The audit will assess the outcomes of the mine's activities against the performance targets set out in this Plan. Results of the audit will be provided annually to the Senior Site Executive as part of the annual environmental report as detailed in Section 4.1.3.

Following completion of construction activities for the mine (i.e. during the operation and rehabilitation phases), an audit of the Carpentarian Antechinus Management Plan will be undertaken every 3 years. The audit will again assess the outcomes of the mine's activities against the performance targets set out in this Plan. Results of the audit will be provided to the Senior Site Executive as part of the relevant annual environmental report as detailed in Section 4.1.3.

10.2. REVIEW

10.2.1. Standard review requirements

Review of the Carpentarian Antechinus Management Plan will be undertaken annually during the construction phase, and every 6 years (in parallel with auditing) during the operation and rehabilitation phases.

The review will be undertaken by the SHEC Superintendent and results of the review will be provided to the Senior Site Executive. Specifically, the review will assess whether the plan is achieving its objectives. The review will consider results of:

- Monthly environmental reports;
- Bi-annual environmental reports;
- Annual environmental reports;
- Carpentarian Antechinus monitoring program report;
- Incident reports.

The review will make recommendations where improvements or changes are deemed necessary.

10.2.2. Environmental incident review requirements

Review of the Carpentarian Antechinus Management Plan will also be required following significant environmental incidents reported as per 'Incident Reporting' (refer to Section 4.1.4). The review will be undertaken as described in Section 10.2.1 above.

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Appendix M

Purple-necked Rock-wallaby Monitoring Program



MMG DUGALD RIVER MINE

PURPLE-NECKED ROCK-WALLABY MONITORING PROGRAM



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Figure 2: Generic Motion Detection Camera Set Up (© DEHP, 2012). 9

1 PURPOSE

The purpose of this Purple-Necked Rock-Wallaby (PNRW) monitoring program is to collect consistent data on a regular (and ongoing) basis so that long term trends/comparisons in population densities and distribution can be observed. MMG will be able to quantitatively monitor and record any positive or negative effects Project mining activities have on the PNRW populations surrounding the mining area.

The original monitoring program was prepared for MMG by Australasian Resource Consultants in September 2012 (AARC, 2012). As per Condition A7 of the Environmental Authority, this monitoring program was reviewed for effectiveness by third party experts, Ecosmart, in April 2014. All amendments to the original document are a result of expert advice.

2 SCOPE

The monitoring program applies to all monitoring activities undertaken for this species within the Dugald River Mine area and surrounding habitats. Requirements relating to the PNRW are defined in the Project's Environmental Authority and are listed below.

Purple-necked Rock-wallaby Monitoring Program (Petrogale purpureicollis)

I9 *The holder of this environmental authority must take all reasonable and practicable measures to avoid, minimise and mitigate impacts on the Purple-necked Rock-wallaby (Petrogale purpureicollis).*

I10 *A purple-necked rock-wallaby monitoring program must be maintained and implemented by an appropriately qualified person to monitor and record the effects of the mining activity on the purple-necked rock wallaby population. A copy of the monitoring program must be provided to the administering authority prior to its implementation.*

I11 *The purple-necked rock-wallaby monitoring program required by condition I10 must be conducted annually in each wet and dry season and must include the following at a minimum:*

- *(a) an estimation of the number of purple-necked rock-wallabies inhabiting the licensed place;*
- *(b) continuation of data collection on suitable purple-necked rock-wallaby shelter sites and foraging areas;*
- *(c) details of the person that undertook the monitoring program and the methods used;*
- *(d) details of when (both date and time of day) and the climatic conditions at the time that the monitoring program was undertaken;*
- *(e) an estimation of the number and type of pest species occurring along the Knapdale Range within the licensed place that may impact on the population of the purple-necked rock-wallaby;*
- *(f) consideration and comparison to previous similar monitoring programs;*
- *(g) support for findings as follows:*
  - (i) *site photos showing monitoring equipment placement and habitat structure;*
  - (ii) *photos/records of the purple-necked rock-wallaby, scats or other trace material; and*
  - (iii) *summary tables with measurements and diagnostic observations from captures.*

(h) procedures for notification to the administering authority and contingency plans in the event that any significant decline in the purple-necked rock-wallaby population is detected.

I12 A report detailing the results of the purple-necked rock-wallaby monitoring program carried out in accordance with conditions I12 and I13 must be provided to the administering authority, before 1 November each year.

3 SPECIES INFORMATION

3.1 ECOLOGY

Rock-wallabies form the most diverse genus of extant macropods, with 16 species found in Australia. They are widespread throughout Australia but suitable habitat is sporadically distributed within their range. The patchy distribution and significant distances between habitat areas leads to populations becoming isolated and increases the likelihood of speciation among the genus (Flannery, 2004).

Menkhorst and Knight (2010) describe Purple-necked Rock-wallaby distribution as locally common in rocky areas of central western Queensland from Kajabbi south to Dajarra and from west of Mt Isa to the eastern end of Selwyn Range (Figure 1 provides the current known distribution of the PNRW).

As the name suggests, Rock-wallabies favour habitat with cliffs, rocky slopes and outcrops or boulder piles. They are often found in outcrop formations, in association with dry Eucalypt (Eucalyptus spp.) and Wattle (*Acacia spp*.) woodlands and Spinifex (*Triodia spp*.) grasslands. Large successful populations generally have access to permanent freshwater and populations may wither without it during extended droughts. However, PNRW are highly adapted to dry conditions and can obtain their water from dew and by extracting it from herbage (Van Dyck and Strahan, 2008). Rock-wallabies exhibit strong fidelity to home ranges and their movements between roosting sites and feeding areas are typically predictable (Horsup, 1994). Prior to the commencement of this monitoring program in 2013, a previous survey within the area demonstrated average foraging distances to be 65 – 120 metres (m) from the outcrop (AARC, 2003). Since then, the local populations of PNRW have been found to primarily comprise small groups, scattered throughout the suitable habitat with some potential overlap in home ranges.

Purple-necked Rock-wallabies reach sexual maturity at 21.8 months and 18 months for males and females, respectively. They have a pouch life of 178–197 days and are weaned 92–171 days after emerging permanently from the pouch (Johnson and Delean, 2002). While the life span of this species is still relatively unknown, they are considered to be similar to several other Petrogale species in this respect. Some Black-flanked Rock-wallabies (*Petrogale lateralis*) have been reported living for at least 12 years while other species have been recorded living for at least 10 to 12 years (Delaney and Marsh, 1995).

Rocky habitat used by Rock-wallabies provides protection from predation by species such as Dingos (*Canis lupus dingo*), Foxes (*Vulpes vulpes*) and Wedge-tailed Eagles (*Aquila audax*) as well as temperature extremes during the day. At night they move over larger areas to feed on plants growing in deeper soils (Law and Dickman, 1988). Caves within rocky outcrops provide a micro environment that buffers temperatures and maintain higher levels of humidity than outside the rocks (Short, 1982). Pest species identified within the Project site during baseline surveys include Dingo, Feral Cat (*Felis catus*), Cane Toad (*Bufo marinus*) and Feral Pig (*Sus scrofa*). The Feral Pig and Cane Toad are considered to be of little direct threat to the PNRW, however feral cats and dingos are a known threat to this species.

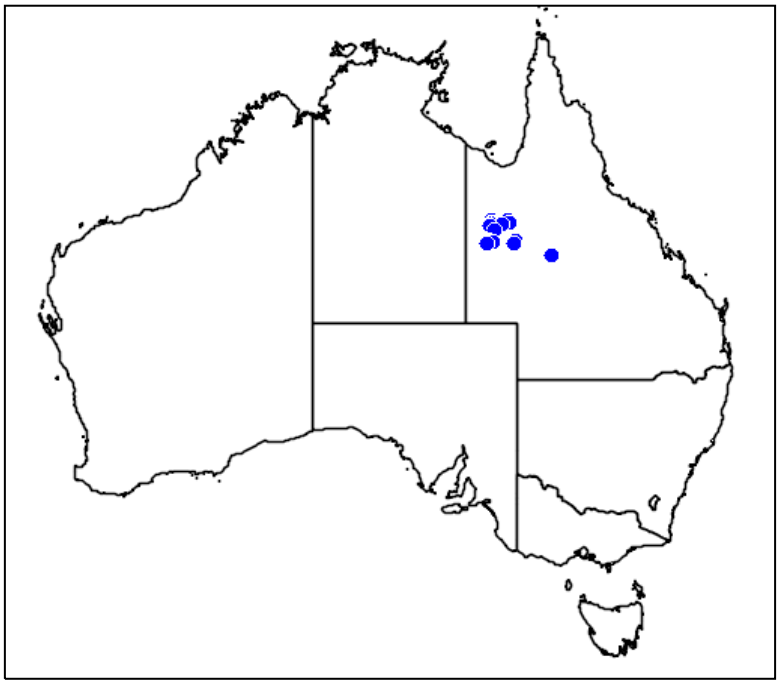


Figure 1: Known Distribution of the PNRW (Atlas of Living Australia, 2012).

3.2 CONSERVATION STATUS

The PNRW is listed as Near Threatened[1] under the *Queensland Nature Conservation Act 1992* (NC Act). Species listed under the NC Act are published in the associated *Nature Conservation (Wildlife) Regulation 2006* (NCWR).

The PNRW is not listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The International Union for Conservation of Nature (IUCN) Red List lists the PNRW as 'Least Concern', in view of its wide distribution, presumed large population, and because it is unlikely to be declining at nearly the rate required to qualify for listing in a threatened category.

4 MONITORING METHODOLOGY

The monitoring program will address the PNRW's presence or absence, estimation of population size and relative abundance within the licensed place. Field techniques will be employed to derive population indices of abundance which provide valuable information in threatened species management (Norton et al, 2011).

A survey of pest species will also be conducted as part of this monitoring program. The species of pest animals present in the area, and the relative abundance of these species will have a bearing on the interpretation of the PNRW data. This information will also be useful in directing any future control programs, as targeting management practices to more than one pest species is important as the control of one pest species may benefit another (e.g. control of dingoes may benefit the European rabbit) (NSW DEC, 2005). The pest survey will be targeted to locations where benefits will be greatest, such as cleared areas facilitating movement, near known pest residences and alongside PRNW habitats.

Current scientific literature documenting other rock-wallaby species' monitoring and mitigation plans was consulted prior to creating the original PNRW monitoring program. Methods deemed successful and appropriate for this Project were adopted, and after three rounds of sampling were reviewed for efficacy. Some changes to the methodology were considered beneficial and are discussed below. A number of monitoring methods will continue to be employed, as methods the chosen methods are complementary rather than alternative techniques and will improve the accuracy of the data (Bluff et. al., 2011).

[1] Near Threatened under the NC Act in this instance is defined as the population size or distribution of the wildlife is small and may become smaller; or the population size of the wildlife has declined, or is likely to decline, at a rate higher than the usual rate for population changes for the wildlife; or the survival of the wildlife in the wild is affected to an extent that the wildlife is in danger of becoming vulnerable.

Qualified scientists or consultants who are familiar with the species, its faecal pellets and the Project will conduct the monitoring program.

The proformas to be used during the biannual surveys (Appendix B) address all types of data collection to be carried out at each sample site.

4.1 MONITORING SITE SELECTION

The initial monitoring sites were selected prior to the commencement of monitoring in 2013. These sites will continue to be monitored, along with additional sites identified in April 2014. In order to assess potential impacts, areas which are both in (impact site) and outside (control site) of the Project impact zone will be evaluated. This will enable MMG to assess whether there are any changes to the PNRW populations and comment on whether it is likely to be a natural change (if all locations exhibit the change) or a specific mine-related change (if only impact sites exhibit the change).

4.1.1 Control Sites

Control sites are defined as areas not impacted by the Project (DEHP, 2012). Control and impact sites, if possible, should be located within the same RE (DEHP, 2012) (RE 1.11.2a). Within the Project site, RE 1.11.2a holds all potential PNRW habitat. Control sites will be located within Dugald River MLs, as far as practicable from Project infrastructure. Potential control areas are those outside of a 1 km buffer surrounding the Project mine infrastructure.

4.1.2 Impact Sites

The Department of Environment and Heritage Protection (2012) define impact sites as those that will eventually be affected directly or indirectly by the proposed development. Impact sites will be focused along the proposed Tailings Storage Facility, accommodation camp and powerline, as the process plant area and water / road corridors are not located near any potential PNRW habitat.

Potential impact areas are considered all those areas of habitat within a 1 km buffer surrounding the Project mine infrastructure.

4.2 MONITORING FREQUENCY

As defined in condition I11 of the Project EA, The PNRW monitoring program will be conducted annually in each wet and dry season. This frequency of monitoring will enable any short term changes in PNRW populations to be detected with sufficient time to implement effective management strategies.

The DEHP 2012 Terrestrial Vertebrate Fauna Survey Guidelines for Queensland define optimal survey timeframes in the Northwest Highlands being wet season or immediately following (December to May) and early dry season before temperatures become too high (August to October).

4.3 POPULATION DETECTION METHOD

The flush transect method will be utilised as a non-intrusive method to determine the presence or absence of the species, as well as provide data on estimated populations and relative abundance. Rock-wallabies are generally crepuscular mammals, foraging during sunrise and sunset and remaining within their shelters for the rest of the day (Menkhorst and Knight, 2010). As such, the opportunities for non-invasive observation are limited and restrict the number of observations that can be carried out during a monitoring event. Flush transects can be carried out during a larger time period, although this method may still be influenced by weather conditions, so although more observations may be made, care will still need to be taken to avoid the hottest parts of the day, when individuals are more likely to remain in their shelters.

Flush transects shall be carried out by one observer remaining stationary at a suitable vantage point, and the other moving through the site disturbing any resident wallabies into movement. The observer notes the number of wallabies detected during the transect. This will be done once per site, per survey.

4.4 MOTION DETECTOR CAMERA TRAPPING

Camera trapping will be utilised as a non-invasive survey technique to detect PNRW and pest species as they pass. Camera traps have many advantages over traditional trapping techniques including the ability to be deployed for extended periods of time and the fact that capturing and handling animals are not required.

One motion detector camera will be set up to detect PNRWs, and will be positioned at each monitoring site for a period of four nights, as per DEHP's (2012) Terrestrial Vertebrate Fauna Survey Guidelines for Queensland. A further four cameras will be positioned for the optimal detection of pest species.

Each motion detector camera will be positioned approximately 1 – 1.5 m from the ground, at an angle of approximately 20° looking down on the bait (refer to Figure 2 for generic setup of a motion detector camera). The bait will be about 2.5 m from the camera in the centre of the camera frame. Bait will consist of lucerne in a hay-net or a mixture of rolled oats, peanut butter and vanilla essence, suspended at a height of 50 centimetres (cm) (Bluff et. al., 2008) for PNRW. Bait for the Dingo and Feral Cat will consist of chicken frames stuffed with commercially available tinned sardines or domestic cat food. Bait will be attached to a wooden or steel frame so animals cannot drag the bait out of the camera frame. Commercially available pheromones will also be sprayed near the bait to lure in pest species.

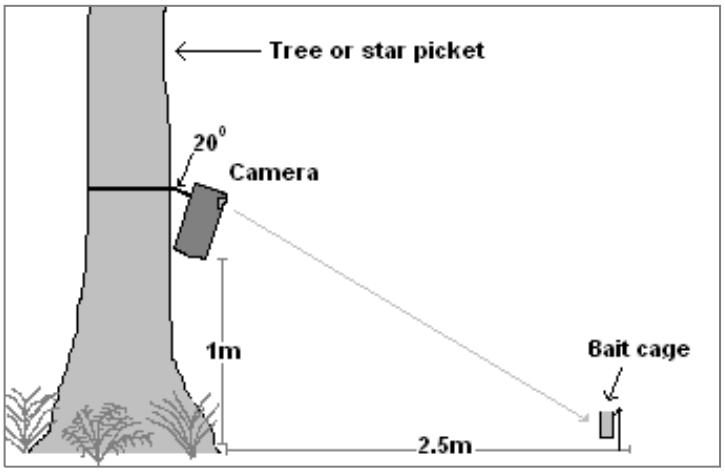


Figure 2: Generic Motion Detection Camera Set Up (© DEHP, 2012).

4.5 FAECAL PELLET DENSITY COUNTS

Secondary signs, such as tracks, faecal pellets (scats) and hair from the PNRW can provide indirect records of the activity at a site. PNRW scats are usually characteristic in size, with an oblong shape, which allows them to easily be identified in the field (Jarman and Capararo, 1997; Triggs, 2004). The presence or absence of scats along transects radiating out from the habitat areas was previously thought to indicate how far PNRW venture during foraging activities, however the durable nature of the scats and the extreme variation in foraging distances depending on conditions made this an unreliable indication. Observer bias and the lack of repeatability also contributed to a review of this method. Faecal pellet quadrats will be used herein as a more accurate and reliable measure of habitat use by PNRW.

Permanent quadrats will be demarcated using survey paint along the entire boundary of each 10x10m plot. The plots are to be located in areas known to be preferentially used by PNRW, and if possible inaccessible to other species of macropods (to minimise observer error in identifying scats correctly). The total number of PNRW scats in the plot will be recorded before the entire plot being cleared of all scats. This will ensure that in the following monitoring event, only new scats will be recorded.

Multiple quadrats will be set up within each existing monitoring site and throughout the previously unsurveyed areas of potential habitat (where evidence of PNRW presence is found). The total number of quadrats will be dependent on time constraints during the initial monitoring periods, and will be confirmed, along with their location, in the 2014 Annual Purple-necked Rock-wallaby Monitoring Report.

4.6 HABITAT VALUE AND VEGETATION ASSESSMENT

Habitat complexity will be assessed by ranking rocky outcrops and shade structures in four classes with respect to the habitat value they provide. This will be assessed by climbing over and walking around the perimeter of each outcrop. This information will assist in describing environmental conditions at each monitoring site. Habitat value and vegetation information will be compared between sites to gauge environmental stability and ecosystem function conditions relative to the Project area. This assessment

need only be done once per monitoring site.

- Class 1 structures are where shade is provided by trees only in close proximity to the main outcrop area.
- Class 2 structures are rocks and ledges in the main outcrop or immediate surroundings that could provide shade for part of the day.
- Class 3 structures include shallow caves and rock overhangs that were shaded for most of the day.
- Class 4 structures are the most complex and included vertical slits, deep caves and tunnels that provided shade and protection throughout the entire day.

Vegetation around each of the sites will be documented in terms of density and species presence, including tree, shrub, grass and forb species richness. Dominant species of canopy, shrub layer and groundcover will be noted. Non-native plant cover will also be documented.

4.7 PHOTOGRAPHIC DOCUMENTATION

At each monitoring event, a series of photographs will be taken from vantage points of each outcrop. The GPS location and bearing will be recorded so that photographs may be replicated. Photographs may document vegetative health, overall habitat structure, rocky outcrop stability, environmental conditions, PNRW sightings and presence or absence of grazing impacts. Over time, these photographs will provide visual documentation of environmental conditions at both control and impact sites. Photographic documentation of monitoring efforts will be included in each annual monitoring report.

4.8 RADIO TRACKING

It has been determined that faecal transects are not an effective indicator of foraging distance or habitat utilisation for the PNRW populations at the licenced place. A more accurate and valuable source of this information is radio tracking. Subject to logistical constraints, radio tracking will be undertaken when appropriate, to contribute to the data on PNRW movements and habitat utilisation. PNRW individuals will be trapped using cage traps, and fitted with radio tracking devices most suitable to the species and the length of the survey (eg. light-weight, self-release devices).

4.9 SUMMARY OF MONITORING METHODOLOGY

Table 2 below summarises the monitoring techniques to be used, the aim and survey effort for each. This survey matrix applies to both control and impact sites.

Table 1: Summary of monitoring methodology

Monitoring Method	Aim of Method	Survey Effort
Flush Transects	Indicate presence / absence and relative abundance of PNRW	One transect, 30 person minutes, per site.
Motion Detector Camera Trapping	Indicate presence / absence of PRNW and pest species	4 nights for PNRW. 12 nights for pest species.
Faecal Pellet Counting	Determining PNRW densities	At least one quadrat per site.
Habitat Value and Vegetation Assessment	Indicator of relative environmental health and habitat value.	One assessment per site.
Photographic Documentation	Provides visual comparison of environmental conditions	One series of photographs per site, per survey.
Radio Tracking	Indicator of habitat use and home range.	When possible.

5 QUALITY ASSURANCE AND REPORTING

5.1 QUALITY ASSURANCE

5.1.1 Monitoring Personnel

All fieldwork required under this PNRW monitoring program will be conducted in a professional manner with the highest attention paid to quality assurance procedures.

The collection of specimens and samples, and the visual observations required will be undertaken by an environmental professional who is appropriately qualified and experienced. All field testing and sampling will be conducted according to manufacturer's instructions (where applicable) and in accordance with the Administering Authority's most recent applicable guidelines and procedures. MMG will remain informed of the latest best practice techniques with regard to the conduct of field works in order to ensure the highest quality assurance.

5.1.2 Monitoring Methods

A source of uncertainty which becomes inherent in biodiversity sampling is species detection (Wintle et al. 2004). This monitoring program will mostly rely on the use of relative abundance indices or presence-absence as the main indicators for impact assessment purposes. These measurements assume that the probability of detecting the species of interest is equal to 1, or that the species will be detected if present. In reality, detection probabilities are much less than 1, which means that even though an individual is present, it may go undetected (DEHP, 2012). This is due to a number of variables that influence detection, which can include observer bias, prevailing climatic conditions, seasonal conditions, equipment bias, habitat types and inherent PNRW species ecology.

PNRW presence at a site is confirmed through direct observation or indirect identification (ie. presence of faecal matter). However, it is virtually impossible to confirm that the PRNW is truly absent from a rocky outcrop site. False-absence rates (recording a species is absent when in fact it is present but undetected) are an important source of variation during analyses of the data, particularly when they are low (MacKenzie et al. 2002; Tyre et al. 2003; Wintle et al. 2004).

To improve the probability of detecting the species, fauna survey methods must be based on multiple visits (where a 'visit' incorporates an active search at a distance from the outcrop) within a survey period, and there needs to be at least one repeat survey conducted in a different season, which is a mandatory requirement of the Project EA. Generally, it is recommended that a site be visited at least three times (within a survey period) in order to minimise the probability of a false absence (Field et al. 2005; MacKenzie and Royle, 2005) and/or, that more sites are sampled. The revised methodology will allow more sites to be sampled, and more repeat visits to all sites, thus reducing the probability of false negative records.

For camera trapping, the same model camera will be utilised throughout each individual survey. It is noted that cameras may not be the same model throughout the life of this monitoring program, as technology will advance and up to date camera models will be sourced for conducting this work. Cameras will be set up in a consistent manner so the detection area is relatively unbiased and uniform. Camera sensitivity settings, numbers of photos per trigger, time interval between photos and image size will all be equivalent at each camera site. GPS coordinates will be recorded so that the camera trap is set up in the same location each monitoring event, to allow for direct comparison.

5.1.3 Interpretation of Results

The interpretation of all results required under this PNRW monitoring program will be conducted in a professional manner to ensure accuracy of interpretation and quality assurance (QA).

All interpretations will be undertaken by the appropriately qualified and experienced environmental supervisor conducting the survey. Additional interpretation and comments will be provided by independent environmental consultants and site personnel when required.

As per condition C32 of the Project EA, a report outlining results and findings will be submitted to the administering authority by 1 November each year. The Annual PNRW Monitoring Report will address at a minimum:

- A description of the monitoring methods used;
- Climatic conditions at the time that the monitoring program was undertaken;
- An estimation of the number of PNRW present at each monitoring site;

- An estimation of the relative abundance of pest species which may impact upon the PNRW inhabiting the licensed place;
- Site photos showing monitoring equipment placement and habitat structure at each site;
- Summary tables with measurements and diagnostic observations from captures;
- Procedures for notification to the administering authority and contingency plans in the event that any significant decline in the PNRW population is detected; and
- Details of the persons that undertook the monitoring program.

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APPENDIX A: LIST OF ABBREVIATIONS

Term	Definition
AARC	Australasian Resource Consultants
cm	centimetre
DEHP	Department of Environment and Heritage Protection
EA	Environmental Authority
EIS	Environmental Impact Statement
EPBC Act	*Environmental Protection and Biodiversity Conservation Act 1999*
GPS	Global Positioning System
ha	hectare
IUCN	International Union for the Conservation of Nature
km	kilometre
m	metre
m^2	square metre
MMG	Minerals and Metals Group
NC Act	*Nature Conservation Act 1994*
NCWR	*Nature Conservation (Wildlife Regulation) 2006*
PNRW	Purple-necked Rock-wallaby
RE	Regional Ecosystem

APPENDIX B: FIELD SURVEY PROFORMAS

Purple-necked Rock-wallaby Biannual Survey – Site Description Data Sheets

LOCATION □ Impact site □ Control site

GPS Coordinates of Site Photographs taken □

_____

Altitude _____m Aspect of Site (*use compass)* _____°

Site Name _____

Date _____

Recorded by _____

Please circle: Wet / Dry Season Year: _____

WEATHER Please circle

Weather: sunny fine but cloudy overcast rain clearing showers storm

Rain in the last 24 hours?: Yes / No

SITE DESCRIPTION

Landform _____

Soil (top soil) _____

Outcrop: *quartz / limestone / sandstone / other:*_____

Number of:

Overhangs	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15+
Shallow caves	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15+
Crevices	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15+
Rock Ledges	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15+
Smoothed areas (wallaby jump sites)	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15+

☐ Fire minimal / moderate / severe _____

☐ Clearing minimal / moderate / severe _____

☐ Grazing minimal / moderate / severe _____

☐ Erosion minimal / moderate / severe _____

☐ Weeds minimal / moderate / severe _____

☐ Storm minimal / moderate / severe _____

☐ Other: _____ minimal / moderate / severe _____

PERCENTAGE OF SHADE COVER (estimate along the transect) ***Note: for wallaby shelter***																					
Tree	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
Cave	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
Rock/Ledge	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
Other	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
Other	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100

SURVEY EFFORT AT SITE:

☐ Flush Transect – 30 person minutes

☐ Faecal count quadrat – No. quadrats _____

☐ Observation point – 30 person minutes

☐ Camera Trapping – targeting Purple-necked Rock-wallabies

☐ Camera Trapping – targeting pest species

☐ Photographs taken Photograph numbers _____

☐ Scats collected No. of samples _____

☐ Tracks and other traces recorded _____

Purple-necked Rock-wallaby Biannual Survey – Camera Trapping Data Sheet

CAMERA TRAPPING

Date Traps Open: ___/___/___

Date Traps Close: ___/___/___

Camera Number: Camera Brand:

GPS Coordinates of Camera:

Direction Camera is facing (use compass):

Species	No. Individuals	On/Off/Near	Other Information

Purple-necked Rock-wallaby Biannual Survey – Habitat and Vegetation Assessment Data Sheet

GROUND COVER (assess at a minimum of 10 quadrats – total for each quadrat should equal 100%) Quadrat Number										
Cover Type	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Native Grass										
Native forbs										
Native shrubs (<1m height)										
Non-native grass										
Non-native forbs and shrubs										
Litter										
Rock										
Bare Ground										

SPECIES STEM COVER – determine species dominance			
SPECIES	**DOMINANCE (D, CD, O, A)**	**LAYER (E, T1, T2, T3, S1, S2, G)**	**Number of Stems**

Purple-necked Rock-wallaby Biannual Survey – Faecal Pellet Count Data Sheet

FAECAL PELLET COUNT SURVEY – *refer to scat information sheet for reference images*			
Survey: DRY / WET		Year:	
Site Number	**Quadrat Number**	**No. Scats**	**Notes**
Opportunistic Scat Collection			
Sample No.		**GPS Location:**	
Sample No.		**GPS Location:**	
Sample No.		**GPS Location:**	
Sample No.		**GPS Location:**	

Purple-necked Rock-wallaby Biannual Survey – Flush Transect and Observational Data Sheet

FLUSH TRANSECT / Observational Data		
Site: Date: Time: am/pm Observers: Please circle: binoculars / telescope / naked eye		
SPECIES	**NUMBER SEEN (TALLY)**	**HEARD ☑**
Purple-necked Rock-wallaby		
Other macropods:		
→		
→		
→		
→		
Feral pig		
Feral cat		
Dingo		
Goat		
Other		
→		
→		
→		
Notes:		

Purple-necked Rock-wallaby Biannual Survey – Scat Identification Leaflet



Purple-necked rock wallaby



Common Wallaroo



Feral Pig



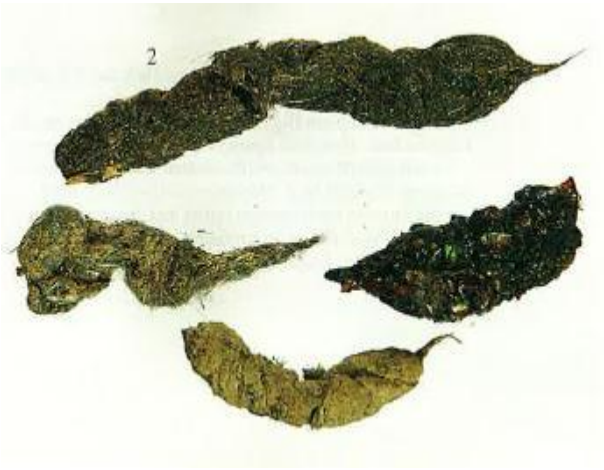
Feral Cat



Goat



Dingo



Fox

Process of Collecting Scats:

1. Wear gloves;
2. Place scats in a brown paper bag;
3. Label with these details:

Site: _____

Quadrat No. (if applicable) _____

Description of Shape and Condition:

_____

Date collected:

_____

Appendix N

MMG Dugald River Mine Demolition Capital Cost Estimate



WorleyParsons
resources & energy

MMG

MMG

MMG Dugald River Mine Demolition

Capital Cost Estimate

201010-00678 – 0016-PLN-0000-PM-0009

11 July 2016

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In formal reports, the synopsis text should be no more than about ten lines. It can contain paragraph breaks if desired.

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PROJECT 201010-00678 - MMG DUGALD RIVER MINE DEMOLITION

REV	DESCRIPTION	ORIG	REVIEW	WORLEY-PARSONS APPROVAL	DATE	CLIENT APPROVAL	DATE
0	Issued for use	N Petherbridge	S Martin	SMartin	3-July 2017	N/A	
1	Revised	N.Petherbridge	S Martin	S Martin	11-July 2017		

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1 EXECUTIVE SUMMARY

MMG are a currently constructing a new zinc mine and processing plant at Dugald River in north central Queensland. Construction is scheduled to be completed late in 2017 and in order to meet financial reporting requirements, MMG are required to determine an updated site closure and demolition cost.

WorleyParsons have been engaged to determine the cost of demolition for all plant and other service infrastructure, which constitutes a major element of the total closure costs for the site. The accuracy of this estimate is +/-50%.

A budget for the demolition has been determined based material quantities as defined in selected drawings, Equipment Lists and Material Take Off information provided to WorleyParsons for this purpose. The estimate is based on the demolition activity being conducted in 2017 at current rates and utilising current demolition best practices methods.

Following the completion of the works herein described, the site will be free of all structures, and power infrastructure, but will require re-profiling of items such as the ROM pad and turkey nest dams to return the site to its previous topography. The Tailings Storage Facility will remain however pumping systems will have been removed. The access road to site from the Burke Development Road, including the concrete bridge over the Dugald River will have been removed and the 65km HV power feed from Chumvale will be disconnected and the poles and conductors completely removed.

In determining the cost, it has been assumed that the mine can be utilised as a waste dump for low value waste, so transport to offsite waste disposal facilities has not been considered. Similarly the retrieval and disposal of any underground equipment in the mine is excluded as is retrieval of buried services throughout the site.

The estimate for the demolition of the site, as defined in this report is $21.7m. The demolition of the site is expected to be completed with 15 month of commencement, with a further 3 months required to remove the bridge, the access road and the 220kV power line.

2 INTRODUCTION

MMG Limited are a global producer of base metals, with operations in Africa, South America, Asia and Australia. MMG are currently constructing the Dugald River Mine in central north Queensland which contains one of the worlds highest-grade zinc deposits. Once completed, it will rank among the world's top ten zinc mines, annually producing around 170,000 tonnes of zinc in zinc concentrate. The mine is estimated to operate for 25 years.

Legislative approval to operate a mine requires closure and site remediation activities to be undertaken once the mine reaches the end of its life. Closure activities cover decontamination and removal of equipment and facilities, site decontamination and rehabilitation. In order to meet MMGs corporate financial reporting requirements, an estimate of the cost of site closure in required.

Currently, the estimate for demolition has been factored from the costs calculated for the demolition of the Century Zinc mine infrastructure some 230km to the North West of Dugald River. Century was closed after final processing was completed in January 2016, so provided a suitable basis on which to estimate the closure costs of the Dugald River mine to date.

With construction of the Dugald River Process Plant due for completion in late 2017, it is now appropriate to generate a new estimate for infrastructure demolition, based on the actual design and construction of the Dugald River site.

2.1 Site Information

The MMG Dugald River Mine (DRM) is located approximately 85 km north-east of Mt Isa and 65 km northwest of Cloncurry, within the Mount Isa Mineral Province. The underground mine has been under construction for several years. The process plant is currently under construction, following the approval of an updated development plan in 2015.

The site consists of an underground mine accessed by two declines providing vehicle access, supported by an administration area and accommodation camp. To the east of the mine entry, a new process plant is under construction for completion late in 2017. This plant will expand the operations at Dugald River and increase staffing requirements. The plant consists of Crushing and Stockpiling areas to feed ore into Grinding Mills. Once ground, the ore is concentrated via a flotation process. Product is produced from a Filtration plant with a Concentrate Storage area for the final product, with waste going to tails.

To support this Process Plant, site facilities have been upgraded with a new accommodation camp constructed to house 350 workers, additional administration buildings, laboratories and maintenance facilities. A 220kV transmission line from Cloncurry has been constructed to power the mine and a new access road including a bridge over the Dugald River to provide all weather site access. A series of sedimentation and run off dams have been constructed and a large Tailings Storage Facility (TSF) constructed north of the mine site.

The layout of the site can be seen in Figure 2-1 Site Layout

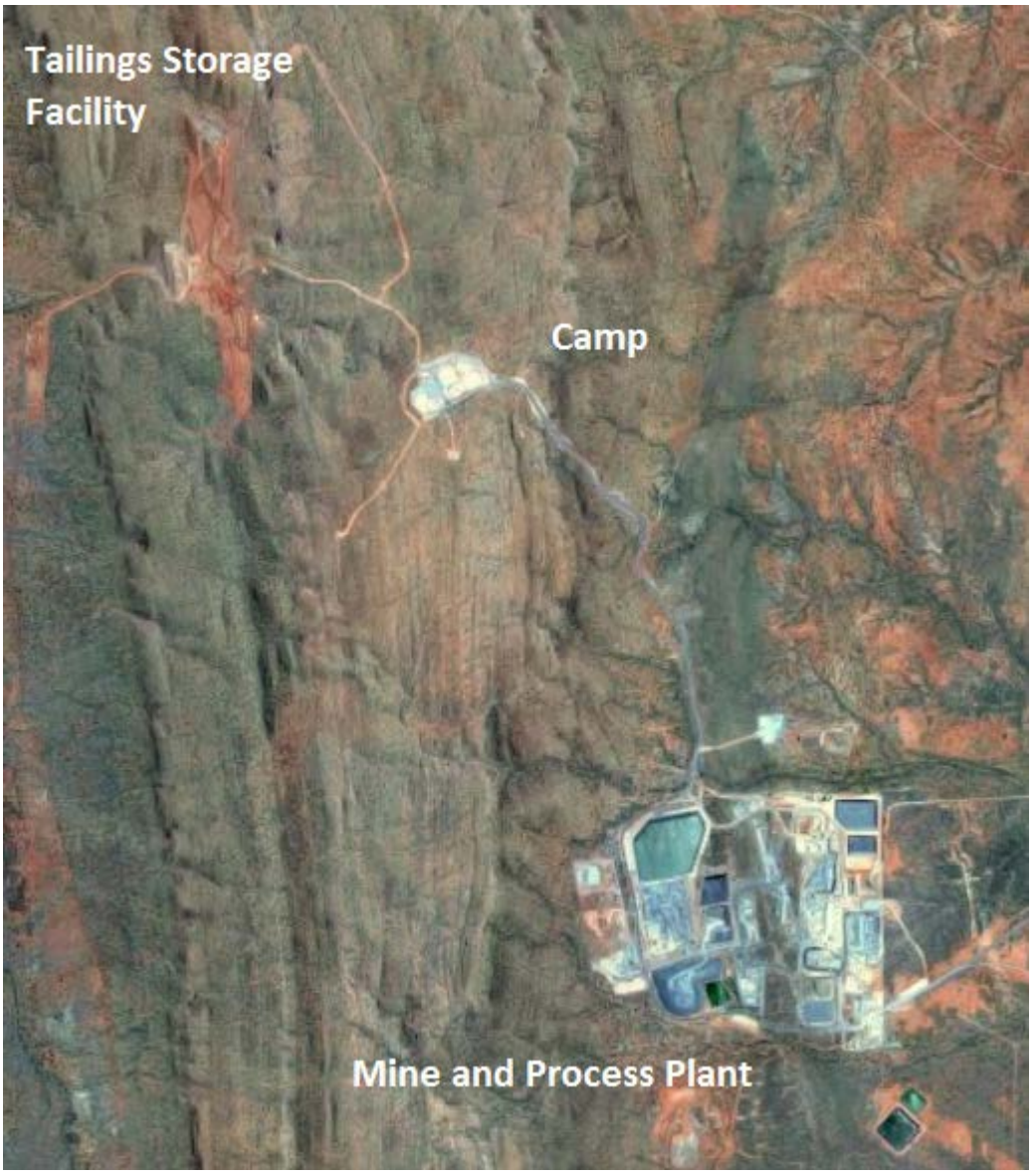


Figure 2-1 Site Layout

2.2 Site Facilities and Material Inventories

This estimate focuses on removal of the above ground infrastructure of the mine and supporting facilities, which must be removed when the mine reaches the end of its productive life. Items included in this estimate include:

Mining Infrastructure and services

- Ventilation fans; 2 fans for the South decline and 1 fan for the North decline.
- All other underground infrastructure is assumed to be decommissioned and made safe but will remain within the mine for disposal and is excluded from this estimate.

Process Plant Scope of work for includes;

- Crushing Plant
- Conveyors from Jaw crusher to Ball Mill
- Grinding & Classification
- Flotation
- Regrind
- Lead Thickening
- Zinc Thickening
- Filtration
- Zinc Concentrate Bulk Storage.
- Lead Concentrate storage containers.
- Tailings Recovery
- Decant return from tailings storage
- Reagents storage facility
- Vehicle wash bay
- Paste Fill Plant

On Site Services & Utilities

- Plant Site Development – removal of dam liners and pipework only
    - Process Plant Run Off Dam
    - Containment Dam
    - Sedimentation Dam A
    - ROM Run Off Dam
    - Sedimentation Dam F
    - Sedimentation Dam G
    - Sedimentation Dam D
    - Pumping & Piping
- Plant Roads & Fences
    - Road sealing & drainage
    - Road works and drainage for processing facility
- Raw & Potable Water
    - Raw water pipeline
    - Storage Dam
    - Surface Distribution
- Gland Water for process area pumps.
- Fire Water
    - Storage
    - Pumping (FMG Compliance)
    - Site Distribution
- Process Water reticulation in process area from dams and tailings storage facility.
- Water Treatment – plant reticulation for safety showers and offices
- Sewerage Treatment
    - Plant Reticulation
    - Evaporation Dam
    - Effluent Pipeline
- Compressed Air Systems (process area)

    - Compressed Air Station
    - Piping Distribution
- 65 km power line from Chumvale substation to the mine site
- HV Switchyard; 220kV HV switchyard on site
- HV Power Distribution
    - Primary 11kV Power Distribution
    - Secondary 11kV Power Distribution
    - Secondary 11kV Power Distribution - Ventilation
- Fuel/Oil Distribution
- Fire Detection/Protection Systems
- IT & Comms
    - Surface Telecoms
    - Network Services
    - Workplace Services
    - Operations Systems Integration
    - Entertainment System
- Control Systems; PLC based control system that services the following
    - Crushing
    - Paste Plant
    - Mine Interface
    - Emergency Power

Plant Infrastructure

- Plant Workshop
- Plant Warehouse
- Administration Building
- Laboratory
- Crib & Ablution Building
- Weighbridge
- Bus Stand & Walkways

Permanent Village

- 350 person camp. Including;
- Village Roads & Siteworks
- Village Services & Utilities
    - Water Treatment Plant
    - Sewage Treatment Plant
- Site Services; water, power, sewer, stormwater, fire detection/protection
- Village Buildings that include;
    - 3 person accommodation modules
    - Laundry units
    - Gym and recreation area.

Site Access

- Site access road from Burke Developmental Road turn off to site boundary
- Road bridge over Dugald River

The estimate covers disposal of waste generated by the demolition activities. This is either transported to a recycler or dumped on site, within the mine. The estimate does not cover material inventories in the form of ore and mine waste stockpiles. Relocation of these materials shall be included in the bulk earthworks required to restore site topography and so are outside the scope of this demolition estimate.

2.3 Scope of Demolition Estimate

This demolition estimate has been prepared in order to assist with site closure accounting provisions and financial reporting. The estimate covers the indicative demolition and removal costs for the redundant, above ground plant, facilities and structures as defined in Section 2.2, to an accuracy of +/-50%.

The estimate details the costs to remove plant and structures including slabs, plinths, retaining walls and foundations (in and above ground level), including the costs to:

- Demolish all fixed structures and infrastructure;
- Remove all concrete footings, foundations and piles (to a depth of 1 metre);
- Concrete breaking/pulverisation and disposal onsite;
- Backfill of all foundation excavations, disturbed land and voids in keeping with site topography using stockpiled fill material in preparation for reuse activities;
- Disposal of all hazardous demolition waste materials at a designated landfill;
- Disposal of all Construction and Demolition wastes at a designated landfill above or underground within the site lease.

This estimate excludes:

- Removal of mine related underground infrastructure such as recovery of refrigeration, shotcrete plant and refuge chambers, or any underground piping or electrical reticulation;
- De-energising and basic decontamination/cleaning of infrastructure. This will include power and service disconnections and decontamination of equipment by flushing with water and the removal of fuels and oils by pumping. This activity will be conducted by MMG;
- Removal off site of any radiation sources or other hazardous wastes;
- Bulk earthworks required restore the site to its original topography;
- Earthworks associated with TSF capping, waste rock haulage underground, topsoil rehandling;
- Revegetation works;
- Treatment of contaminated soils.

The estimate is based on common demolition methods and practices that are currently used for such facilities. In determining the appropriate disposal methods for waste generated, current legislative requirements for recycling of materials have been considered. In determining the best waste disposal strategy for each type of waste, the current scrap value of the waste generated along with current transport logistics costs resulting from the remote location have been considered.

3 DEMOLITION STRATEGY

Demolition methods proposed in this estimate represent the current best practice methods used in Australia for industrial site demolition and are based on WorleyParsons experience in planning and managing demolition projects. Where required WorleyParsons have engaged a major demolition contractor to review proposed methods and confirm their suitability, especially with regard to methods specific to remote area demolition and the complexity of long distance transport logistics.

Methods proposed are highly mechanised and reflect the philosophy of replacing people with machines wherever possible, to reduce the in risk of injury to demolition operators.

3.1 Methods and Equipment

A range of demolition methods are commonly used in the Australian market. These range from extreme methods such as explosive demolition, down to mechanical dismantling piece by piece. Selection of methods is influenced by the type of structure, environmental constraints, and the area in which the demolition occurs.

With the isolation of Dugald River, constraints imposed by the proximity to neighbours such as control of noise and generation dust are reduced, but both of these concerns still impact the site operators, so in order to provide a safe worksite, are still considered important when selecting methods.

As the structures to be demolished at Dugald River are predominantly steel structures and equipment with a maximum height of approximately 25m, the preferred method is usually to eat away at the structure using a mechanical shear, allowing cut sections to fall to grade, for collection and transport to a material processing area. In this area, the large pieces will be processed into trafficable sizes for efficient transport to a recycling facility, or dumping on site.

The primary tool for undertaking this operation is a large, long reach demolition excavator. The demolition excavator is specifically prepared for this type of operation with air filtration systems for the operator and protected/reinforced cab for the health and safety of the operator. The machine selected would be in the 85T to 125T size range and fitted with a long reach boom, onto which is installed hydraulic shears. Such a machine is able to reach up to 25m so be able to access even the tallest structures on site. The long reach boom also permits the excavator to park distant from the workface and outside the material fall zone for improved safety and removed the need to topple structures using cutting charges (or other types of pyrotechnic means) for access, is removed.

3.1.1 Removal of Structures

The Flotation area presents a good example of the sequence of events required to remove the structure. The Flotation area consists of a structure 140m long and up to 18m high, containing 39

pumps, 45 vessels along with hoppers and a central pipe rack for connection to services. The expected demolition method for such a structure would as follows;

- Separation and fencing off of work area
- Complete disconnection of all power and confirmation of electrical isolation.
- Removal of ground level tanks, fixtures and equipment to provide clear access for equipment. Tanks would be cut using shears into large pieces suitable for transport by a dump truck.
- Once the area was clear, working from the top, the long reach excavator shears would progressively cut the structure into large pieces, allowing each piece to fall to ground.
- Fallen material is then collected and placed in a dump truck for removal.
- The dump truck will transport the waste material to a processing area, when further shearing is undertaken to separate different materials (where required), and to process scrap to "in size" for efficient transport to a recycling depot or on-site waste dump.

While this method is expected to be the primary method of demolition, for smaller structures such as the Lime Silo or Reclaim Stacker conveyor support tower, selective cutting of legs may be undertaken to permit the structure to be toppled for easier access.

3.1.2 Removal of Equipment Containing Hardened Elements

For items containing hardened materials such as motor shafts, the motor would be removed from its mounts and craned onto a truck for transport, without processing on site. For large items containing hardened elements, such as the Ball Bill and SAG Mill, the hardened material presents issues for the longevity of the shear attachment so methods such as flame cutting would be required to cut the mill into transportable sized pieces. For areas where hardened wear plates ate fitted, these would generally be removed prior to shear cutting of the supporting structure.

3.1.3 Earthworks

For areas such as Crushing and Stockpiling, earthworks are required to recover equipment such as ROM Bin tie-ins within the ROM Pad and the apron feeders under the Reclaim pile. In these areas, extensive earthworks are required to expose the equipment and these specific earthworks have been included in the estimate.

A dedicated earthworks crew would be mobilized for these works to expose the equipment prior to the demolition crew commencing work. Earthworks would be undertaken using conventional earth moving equipment such as excavators and dump trucks with the recovered earth transported to the mine for disposal.

3.1.4 Buried Services

Extensive use of underground tunnels and conduits are used for the reticulation of power and services throughout the mine and camp areas. These underground service ducts are generally more than 600mm below grade and are intended to remain buried at the completion of demolition. Pipes

and cabling will be terminated where they leave the service ducts. Pipe ends are grouted over to prevent seal in residues and prevent ingress by native fauna.

3.1.5 Dams

For the turkey next dams constructed on site, demolition is restricted to removal of the dam liner, with removal of earth bunds undertaken later during the overall site re-profiling, which is outside the scope of this estimate. Liners are to be removed and deposited in the mine as waste.

The dam liners are anchored around the perimeter by burying the free edge in a trench approximately 500mm wide and 500mm deep. The liner would be cut where it enters the trench, leaving the buried portion intact, removing more than 97.5% of the liner material. This buried edge of the liner would then be left for removal later during the dam wall removal undertaken as part of the site re-profiling. The buried edge of the liner would become exposed during these works and could then be collected for disposal.

3.1.6 Overland Pipelines

Overland pipelines, mounted on footings or within a swale will be lifted and removed. The pipes will be cut into trafficable pieces using a shear and stockpiled for later transfer to the dump created within the mine.

3.1.7 Concrete

Concrete footings and paths will be removed down to at least 1m below grade and stockpiled on site for later processing. Where concrete extends well below this level, rock breaking techniques will be used to break free the upper layer for removal. A stockpiled concrete will then be processed in a mobile crusher and deposited in the mine. To minimize the duration of the crusher mobilization, this activity will be conducted late in the demolition period, when sufficient concrete has been stockpiled to permit the crusher to work continuously until all material is processed.

3.1.8 Overhead Power Lines

Overhead power line conductors, poles and footings will be removed and disposed of as waste. Unlike in built up areas, where power line removal requires careful management of cable tension to prevent the tension causing power poles to collapse, this methods would be used to simplify removal. Once the line is confirmed isolated and critical points such as road crossings are managed, the cutting of conductors with a long reach shear will result in line the tension causing a section of poles between bracing poles to fail and the section of line to fall. The felled conductor will be recovered progressively and processed to size for transport and recycling. Poles will be removed by excavators and transported to a processing site for recycling and waste disposal.

3.1.9 Road Bridge Removal

The road bridge over the Dugald River is constructed from pre-stressed concrete deck units of approximate length 18m, with lateral ties and an upper capping layer. The bridge is supported by four reinforced concrete pylons and headstocks mounted on fifteen cast in place bored piles. The deck is located approximately 8 m above the river bed. In order to remove the bridge, the most cost effective method is to break up the bridge and abutments in-situ, and then excavate the rubble from the river bed. Pile stubs can then be severed at 1m below the river bed level with a rock breaker and removed.

Removal of the deck is achieved, panel by panel, by hammering each section with a rock breaker attachment on a long reach excavator so that pretension tendons are progressively severed, eventually allowing the deck panel to collapse.

Alternatively, the bridge could be deconstructed and removed in sections; however this method would need an engineering investigation to confirm the feasibility, and so has not been considered in this demolition budget. Removal of each deck panel in one piece is not practical due to size and weight, but as the structure consists of multiple, parallel, precast beams, fixed at the ends to the pylons and then laterally tied to make each span a solid structure, it may be possible to sever these lateral ties and remove each beam independently. To achieve this, the upper capping layer would need to be demolished using rock breaking techniques to expose the interfaces between the beams, or else multiple cuts made with a road saw above each interface. If the lateral ties can then be removed, or at least severed between each beam, lifting points could be installed using chemset anchors. Breaking away the fixings of each beam at the pylons would then enable each beam to be freed from the remaining structure and lifted away to a truck for disposal.

This method would be more complex and is contingent on the type of lateral ties installed and the ability to sever these ties successfully to remove each beam independently, but would result in minimal debris falling into the river bed.

This activity would be undertaken in the dry season, when there is no flow in the river, and following completion of site works and demobilisation of the concrete crusher, so material from the bridge must be transferred off site for disposal, at additional cost.

3.2 SHEC Requirements

In preparing this estimate, it was assumed that the contractor engaged to undertake the demolition will be a respected expert in the field of plant demolition and operate to standards of safety that exceed all applicable current legal requirements relating to this type of work.

The contractor would be expected to:

- Design all work to align with nominated MMG safety standards, as a minimum
- Demonstrate a strong focus on engineering work to ensure all activities are planned and sequenced to minimise risk, eliminate hazards and minimise reliance on PPE and administrative controls

- Ensure all work on site is designed in such a way that the focus is places on the utilizing the hierarchy of controls to wherever possible eliminate or substitute identified tasks.
- Provide a systematic method of managing hazards according to the degree of risk, such that risks to personnel, assets and the environment are reduced to a level that is as low as reasonable practical (ALARP)
- Provide plant and equipment which is fit for purpose and well maintained

3.3 Waste management – salvage, recycling, disposal

It is proposed that a variety of waste management alternatives be employed in the demolition of Dugald River as a result of the remote location of the site and associated transport costs. While recycling of all materials may be possible, the practicalities of transporting low value materials long distances to waste recycling deport, is not considered economic.

It is current, normal practice that all steel be recycled by an approved waste processor. In this estimate it is assumed that Sims Metal in Townsville would be the closest recycler. Scrap rates currently paid by Sims Metal and costs for transport of waste to Townsville, have been used in this estimate.

For lower value materials, an alternative strategy has been determined, where the abandoned mine will be used as a waste dump.

The site contains a large quantity of HDPE piping and while recyclable, the cost of recycling is not economic. The estimate assumes that all HDPE piping is recovered and deposited in the abandoned mine.

Concrete used for footings, slabs, paths, etc,(with the exception of the road bridge) will be removed and processed prior to disposal. A crushing plant will be mobilized to site to pulverise the concrete into small pieces (less than 50mm?) prior to depositing in the mine.

Lining material from the turkey nest dams will be collected and deposited in the mine.

Where earthworks are required to expose equipment for removal, such as the Reclaim Apron Feeders, the earth removed is deposited in the mine.

Roads will be scarified and the bitumen collected and deposited in the mine.

Hazardous demolition waste will be identified, classified and segregated from other forms of demolition waste and recyclables. All hazardous waste will be disposed of at Regulatory approved waste depots.

3.4 Assumptions and Exclusions

In the preparation of this estimate it is assumed that:

- Decontamination of equipment undertaken by MMG will be sufficient to remove all heavy metal contamination so that no special handling or disposal requirements are necessary.
- The use of the mine as a waste depository for inert materials, as proposed by MMG does not contravene any existing operational approvals relevant to the site.
- Removal of the entrance road bridge over the Dugald River by breaking the structure in–situ and then recovering the fallen materials from the river bed complies with environmental undertakings required for the issuance of a demolition licence.

3.5 Limitations

The development of methods has been restricted by the information available in drawings and Navisworks model as listed in Appendix 1.

Where mass data did not exist, an estimate was made based on equipment size.

4 HIGH LEVEL DEMOLITION SCHEDULE

A high level demolition estimate has been prepared to demonstrate the sequence of events likely in the demolition of the Dugald River mine, process plant, and support facilities.

In preparing this schedule it has been assumed that works should be executed in a manner with is both time and cost effective. Demolition projects are usually broken up in a number of smaller worksites, and these work sites are fenced off and isolated to prevent the entry of non-essential personnel. As a result demolition projects are executed progressively and acceleration of schedule is only achieved by operating multiple work sites simultaneously; however execution in one work site may prevent entry to a second work site, so correct sequencing of events is essential to efficiency.

For Dugald River, it is proposed that the site be segregated in demolition zones, marked A to Q as allocated below:

A	Crushing
B	Reclaim
C	Grinding and Classification, and Flotation
D	Lead Thickening, Filtration, Concentrate Storage and Fire, Process and Gland Water
E	Reagent Storage, Compressed Air, Grinding Substation and associated piperacks
F	Regrind, Zinc Thickening, Tailings recovery, Tailings Substation and associated piperacks
G	Paste Plant, Fuel Storage and HV Maintenance Area
H	Plant Workshop, Warehouse and Laboratories
J	Administration Area, Temporary Camp and Sewage Treatment
K	Village and Village Site Services
L	Tailings Storage Area
M	Power Infrastructure
N	Roads
P	Water Storage Dams
Q	Mine Infrastructure

A map showing the demolition zones in the Process Plant area is presented in Appendix 2

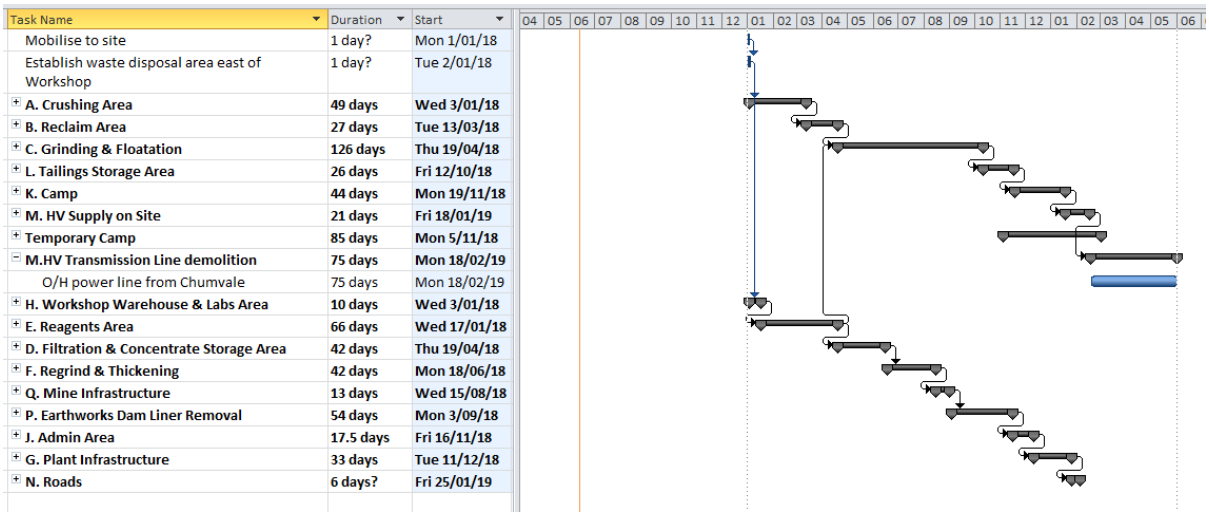
In sequencing the activities in these zones, the following requirements were considered:

- The power supply to the site should be maintained for as long as possible and disconnected from each zone just prior to demolition. (Note: the ability to achieve these "just in time" isolations will be compromised by any undocumented electrical alterations to the site during the life of the mine. This is an issue with many demolition projects on aging industrial sites and can require extensive electrical inspection to ensure supplementary back feeds to switchboards are not present.)
- Demolition of the permanent camp should be removed as late as possible to maximize usage of the camp to house the demolition crews.
- Administration office and heavy vehicle service areas similarly should be demolished as late as possible so that they can be used by demolition crews, reducing the need for temporary site offices.
- Demolition of the access road and bridge are the final scheduled site events, following the completion of all other activities. (Note: as this schedule does not include the follow up earthworks to re-profile the ground following equipment removal, the timing of these events is for reference only.)
- The final activity of removal of the 220kV power line can commence once all power is removed. This activity is expected to be performed by a mobile crew and does not utilize any site facilities, so may be undertaken at any time following the removal of the last site power consumer.
- Consider equipment mobilisation costs in determining the most appropriate number of work fronts to operate simultaneously, and the number of workers on site, due to the cost of transport and accommodation.
- Ensure that work fronts are controlled and well separated to prevent conflicts between the operations of each work front.
- A single processing and transport area should be created to operate for the duration of the project.

Based on these requirements, it is proposed that only two active work fronts are operated simultaneously. Work shall commence with demolition of Zone H so that the area can be cleared for use as the processing and transport area. The second work front will initially undertake the earthworks required to expose buried structures within Zone A – Crushing and Zone B - Reclaim. This will permit sufficient time for the clear out of Zone H and the establishment of the processing area, before large quantities of waste have been generated.

The result is the schedule shown in Figure 4-1 Proposed Demolition Schedule and in Appendix 3. This schedule indicates a total duration of approximately 15 months, followed by the total removal of the 220kV transmission line over a period of approximately 3 months commencing at the completion of site works.

Mobilisation of a temporary camp and administration area will be required from the beginning of the eleventh month, prior to permanent camp demolition, for a period of approximately 5 months.



Task Name	Duration	Start
Mobilise to site	1 day?	Mon 1/01/18
Establish waste disposal area east of Workshop	1 day?	Tue 2/01/18
A. Crushing Area	49 days	Wed 3/01/18
B. Reclaim Area	27 days	Tue 13/03/18
C. Grinding & Floatation	126 days	Thu 19/04/18
L. Tailings Storage Area	26 days	Fri 12/10/18
K. Camp	44 days	Mon 19/11/18
M. HV Supply on Site	21 days	Fri 18/01/19
Temporary Camp	85 days	Mon 5/11/18
M.HV Transmission Line demolition	75 days	Mon 18/02/19
O/H power line from Chumvale	75 days	Mon 18/02/19
H. Workshop Warehouse & Labs Area	10 days	Wed 3/01/18
E. Reagents Area	66 days	Wed 17/01/18
D. Filtration & Concentrate Storage Area	42 days	Thu 19/04/18
F. Regrind & Thickening	42 days	Mon 18/06/18
Q. Mine Infrastructure	13 days	Wed 15/08/18
P. Earthworks Dam Liner Removal	54 days	Mon 3/09/18
J. Admin Area	17.5 days	Fri 16/11/18
G. Plant Infrastructure	33 days	Tue 11/12/18
N. Roads	6 days?	Fri 25/01/19

Figure 4-1 Proposed Demolition Schedule

4.1 Schedule Contingency and Risk

The schedule has been prepared by demolition zone, with the duration of each zone demolition determined by the materials quantities residing in that zone. As a result the schedule has an assumed level of complexity and labour requirement per tonne of material (or equipment) removed and is largely constant throughout the site.

This schedule has been prepared to demonstrate the logic applied to demolition sequence.

It is assumed that all tasks can be progressed and are not delayed by other required closure or remediation activities which are outside the scope of this estimate.

No weather contingency has been included in the schedule.

5 BASIS OF ESTIMATE

This section presents the methodology, qualifications and assumptions used in compiling the capital cost estimate to achieve a target accuracy of +/-50%.

5.1 Estimate Summary

The P50 estimated Total Installed Cost (TIC) for the estimate is shown below. This amount is based on Q2 CY2017 Australian dollars at a 50/50 probability of overrun/underrun (excludes market forces, escalation and currency hedging).

	SCOPE	COST (AUD)	% TIC
A	Crushing	$541,726	2%
B	Reclaim	$571,540	3%
C	Grinding and Classification, and Flotation	$2,457,001	11%
D	Lead Thickening, Filtration, Concentrate Storage and Fire, Process and Gland Water	$655,805	3%
E	Reagent Storage, Compressed Air, Grinding Substation and associated piperacks	$1,027,246	5%
F	Regrind, Zinc Thickening, Tailings recovery, Tailings Substation and associated piperacks	$1,022,167	5%
G	Paste Plant, Fuel Storage and HV Maintenance Area	$555,138	3%
H	Plant Workshop, Warehouse and Laboratories	$166,826	1%
J	Administration Area, Temporary Camp and Sewage Treatment	$205,356	1%
K	Village and Village Site Services	$515,976	2%
L	Tailings Storage Area	$135,948	1%
M	Power Infrastructure	$1,556,927	7%
N	Roads	$431,111	2%

P	Water Storage Dams	$670,870	3%
Q	Mine Infrastructure	$113,312	1%
R	Waste Processing	$(306,924)	-1%
	Design Allowance	$1,548,004	7%
	TOTAL DIRECT COSTS	**$11,868,028**	**55%**
	Common Distributables	$3,401,082	16%
	EPCM	$1,780,204	8%
	Owners Costs	Excl.	0%
	Contingency	$4,650,393	21%
	TOTAL INDIRECTS	$9,831,679	45%
	TOTAL INSTALLED COSTS (P50)	$21,699,707	100%

A total gross credit of $889,705 for salvageable materials (approximately 7,000 tonnes) is estimated based on scrap metal pricing of the day. Disposal costs for non-recyclable materials including concrete, bitumen and HDPE pipe is estimated at $580,781. This gives a total net credit for waste recycling is $306,924.

5.2 Extent of Estimate

The capital cost estimate is based scope information provided by MMG. The estimating building blocks such as labour rates, productivity and contractor distributables are developed from historical information. Demolition hours are generally based on hours per tonne, cubic metres, lineal metres, and per unit (each) approach.

5.3 Qualifications, Assumptions and Exclusions

- The work week at the job-site is assumed to be 70 hours per week.
- The direct work force is 80% non-local.
- The site has been de-energised by others.
- Work has been assessed as Brownfields.
- Underground piping and/or cabling is to remain in place.
- Site remediation costs are excluded.

- All equipment to be rendered functionless prior to leaving site and not sold on in operating condition (i.e. sold as scrap for recycling).
- A recovery factor of 100% by weight for structural steel, piping and vessels was applied. This assumes removal of hazardous materials and contamination by MMG prior to demolition works.
- A recovery factor of 85% for concrete was applied. This assumes concrete more than 1m below the surface remains in place.
- MMG to decommission and clean all tanks, piping and equipment free of contaminants and residue, suitable for handover and demolition. Costs associated with decommissioning and cleaning are excluded.
- No allowance has been made for disposal of contaminated materials.
- It is assumed that all salvageable materials will be cut into suitable sizes for dimension loads by the demolition contractor.
- Salvage rates for Carbon Steel and Wire Cable were provided by a local scrap merchant.
- Concrete crushed, reinforcement removed and stored in the underground mine.
- Disposal of HDPE piping and bitumen from roads to be stored in underground mine.
- An average cycle time for trucks dumping material in the mine is assumed 30 minutes.
- Taxes and duties are excluded.
- Forward escalation beyond the base date of the estimate is excluded.
- Sunk costs are excluded.
- GST is excluded.

5.4 Quantity Derivation

The majority of quantities have been developed based on material take-offs and drawings provided by MMG.

5.5 Salvage of Material

Scrap prices for Carbon Steel, Stainless Steel and Copper Cables were provided by local scrap merchants based on current market pricing. Pricing includes limited site processing and transport offsite.

Commodity	$/tonne
Carbon Steel	130
Copper Cable	2,000
Bare Copper	6,000

5.6 Manual Labour Rates

Labour rate is based on recent historical labour rates for the region. This estimate is based on a 70 work week (7 days by 10 hours per day). The rotation is based on a 21 days on, then 7 days off roster.

The labour rate is $90/hr with an average all-in labour rate of $190/hr.

5.7 Productivity

- Demolition hours are based on hours per tonne, cubic metres, lineal metres, and per unit (each). An average productivity of 1.4 has been applied to the base unit hours to account for the site location and the nature of works.

5.8 Sub-contractors Indirects

Contractor distributables is based on recent historical values for the region. Construction equipment has been assessed specifically for the project. The following scope is included;

- Mobilisation and demobilisation
- Temporary site facilities
- Construction equipment
- Construction equipment spare parts
- Scaffolding
- General/sundry expenses
- Small tools and consumables
- R&R travel costs
- Diesel and fuels
- Frontline supervision
- Field support hours (Constructor non-manual management and administration employees)
- Overhead, contractor risk & profit

5.9 Common Distributables

Common distributable costs include:

- Temporary construction facilities
- Cranes greater than 50t
- Dust control

- Construction support
- Accommodation (temporary camp post demolition of the permanent camp)
- R&R flights

5.10 Engineering, Procurement and Construction Services

EPCM services cost of 15% of Direct Costs has been used based on historical norms for similar projects.

5.11 Forward Escalation

Forward escalation has been excluded from this estimate.

5.12 Contingency

Contingency has been included at 30% of the base estimate less design allowances.

5.13 Owners Costs

Owners Costs have been excluded

Appendix 1 Engineering Source Documents

The following documents were used to derive information used to prepare this estimate:

- Navisworks Model:
  - 2017-07-17_P016-DugaldRiver-GA_0923.nwd

- Material Take Offs:
  - DUG-MTO-2100-ES-5001_R0 Structural Steel MTO
  - DUG-MTO-2100-EP-5001_R0 Piping MTO
  - DUG-MTO-2100-EM-5001_R0 Platework MTO
  - DUG-MTO-2100-EG-5001_R0 Concrete, Platework and Structural MTO
  - DUG-MTO-2100-EE-5001_R0 Electrical Material MTO
  - DUG-MTO-2100-EC-5002_R0 Concrete MTO
  - DUG-MTO-2100-EC-5001_R0 Earthworks MTO

- Equipment Lists:
  - DUG-LIS-0000-EE-5005_R7 Electrical Equipment List
  - DUG-LIS-0000-EM-5001_R3 Mechanical Equipment List

- Drawings:

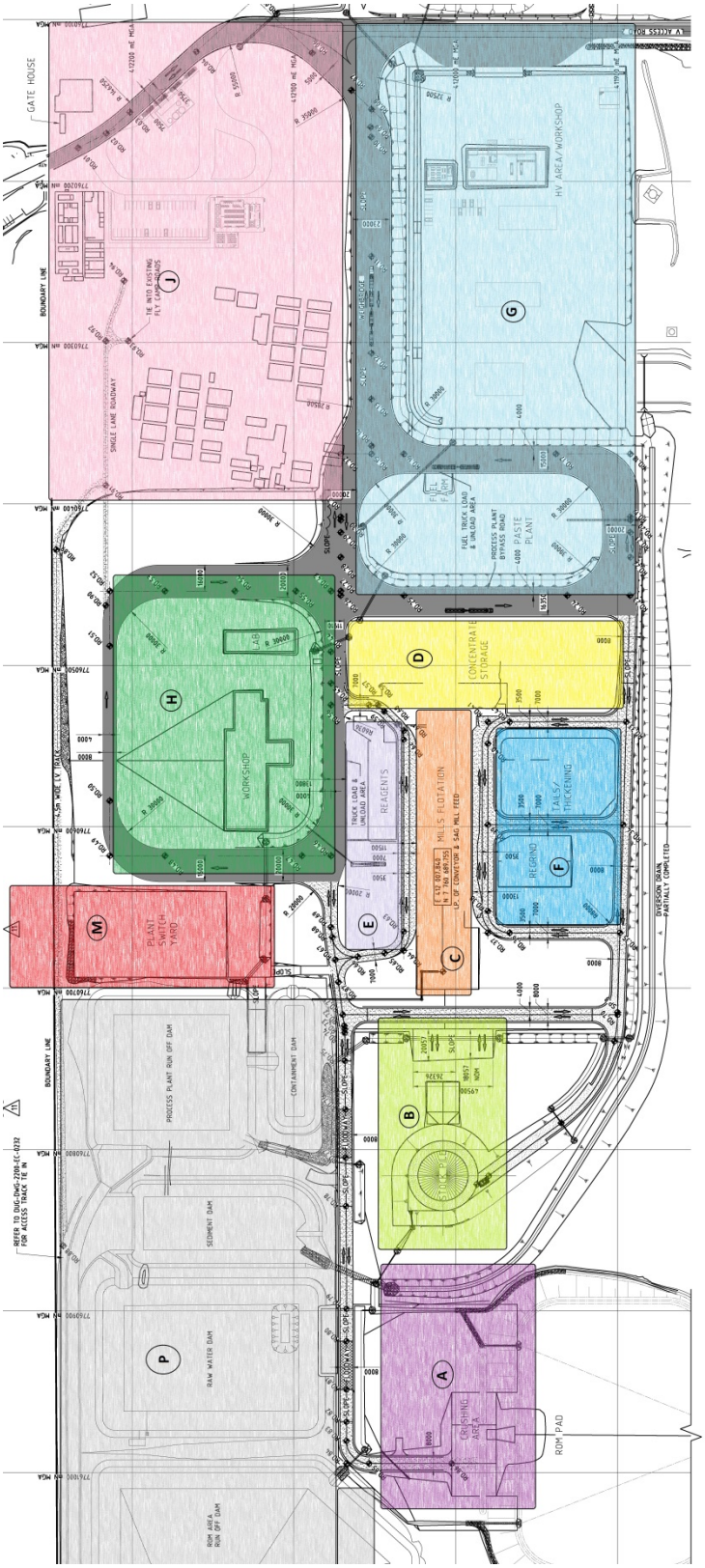
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0016-DWG-2100-P-0002 - AREA 2100 - PROCESS PLANT - BURIED SERVICES - OVERALL PLANT GENERAL ARRANGEMENT SHEET 2.pdf
0016-DWG-2100-P-0003 - AREA 2100 - PROCESS PLANT - BURIED SERVICES - SECTIONS SHEET 1.pdf
0016-DWG-2100-P-0004 - AREA 2100 - PROCESS PLANT - BURIED SERVICES - SECTIONS SHEET 2.pdf
0016-DWG-2100-P-0005 - AREA 2100 - PROCESS PLANT - BURIED SERVICES - SECTIONS SHEET 3.pdf
0016-DWG-2100-P-0006 - AREA 2100 - PROCESS PLANT - BURIED SERVICES - SECTIONS SHEET 4.pdf
0016-DWG-2100-P-0007 - 2100 - PROCESS PLANT - BURIED SERVICES - OVERALL PLANT GENERAL ARRANGEMENT SHEET 3.pdf
0016-DWG-2111-M-0002 - AREA 2111 - PRIMARY CRUSHING AREA - GENERAL ARRANGMENT - SHEET 1 OF 3.PDF
0016-DWG-2111-M-0003 - AREA 2111 - PRIMARY CRUSHING AREA - GENERAL ARRANGMENT - SHEET 2 OF 3.PDF
0016-DWG-2111-M-0004 - AREA 2111 - PRIMARY CRUSHING AREA - GENERAL ARRANGMENT - SHEET 3 OF 3.PDF
0016-DWG-2111-M-0011_-_AREA_2111_-_CRUSHING_-_111-CV-001_-_GENERAL_ARRANGMENT.pdf
0016-DWG-2111-M-0017 - AREA 2111 - CRUSHING - 111-CV-002 - GENERAL ARRANGMENT SHEET 1 OF 2.pdf
0016-DWG-2111-M-0018 - AREA 2111 - CRUSHING - 111-CV-002 - GENERAL ARRANGEMENT SHEET 2 OF 2.pdf
0016-DWG-2112-M-0002 - AREA 2112 - RECLAIM AREA - STOCKPILE RECLAIM - GENERAL ARRANGMENT SHEET 1 OF 2.pdf
0016-DWG-2112-M-0003 - AREA 2112 - RECLAIM AREA - RECLAIM STOCKPILE - GENERAL ARRANGMENT SHEET 2 OF 2.pdf
0016-DWG-2112-M-0007 - AREA 2112 - RECLAIM - 112-CV-003 - GENERAL ARRANGMENT SHEET 1 OF 2.PDF
0016-DWG-2112-M-0008 - AREA 2112 - RECLAIM - 112-CV-003 - GENERAL ARRANGMENT SHEET 2 OF 2.pdf
0016-DWG-2112-M-0012 - AREA 2112 - RECLAIM - 112-CV-003 HEAD CHUTE - ARRANGEMENT AND DETAILS.PDF
0016-DWG-2120-M-0002 - AREA 2120-GRINDING-GRINDING AND CLASSIFICATION PLAN SHEET 1.pdf
0016-DWG-2120-M-0003 - AREA 2120-GRINDING-GRINDING AND CLASSIFICATION PLAN SHEET 2.pdf
0016-DWG-2120-M-0004 - AREA 2120-GRINDING-GRINDING AND CLASSIFICATION PLAN SHEET 3.pdf
0016-DWG-2120-M-0005 - AREA 2120-GRINDING-GRINDING AND CLASSIFICATION PLAN SHEET 4.pdf
0016-DWG-2120-M-0008 - AREA 2120 - GRINDING - MILL DISCHARGE HOPPER ARRANGEMENT AND DETAILS.pdf
0016-DWG-2120-M-0012 - AREA 2120 - GRINDING - SAG MILL TROMMEL COVER & DISHARGE CHUTE - ARRANGEMENT & DETAILS.pdf


0016-DWG-2120-M-0014 - AREA 2120-GRINDING-MILL GUARDS ARRANGEMENT PLAN.pdf
0016-DWG-2131-M-0002 - AREA 2131 - FLOTATION AREA - GENERAL ARRANGEMENT - OVERALL PLAN.pdf
0016-DWG-2131-M-0003 - AREA 2131 - FLOTATION AREA - GENERAL ARRANGEMENT - OVERALL SECTION A (SHEET 1 OF 2).pdf
0016-DWG-2131-M-0004 - AREA 2131 - FLOTATION AREA - GENERAL ARRANGEMENT - OVERALL SECTION A (SHEET 2 OF 2).pdf
0016-DWG-2131-M-0005 - AREA 2131 - FLOTATION AREA - GENERAL ARRANGEMENT - OVERALL SECTION B (SHEET 1 OF 2).pdf
0016-DWG-2131-M-0006 - AREA 2131 - FLOTATION AREA - GENERAL ARRANGEMENT - OVERALL SECTION B (SHEET 2 OF 2).pdf
0016-DWG-2131-M-0007 - AREA 2131 - FLOTATION - GENERAL ARRANGEMENT - OVERALL SECTIONS C AND D.pdf
0016-DWG-2131-M-0008 - AREA 2131 - FLOTATION - GENERAL ARRANGEMENT - OVERALL SECTIONS E AND F.pdf
0016-DWG-2131-M-0047 - AREA 2131 - FLOTATION - PRE-FLOAT CLEANER CONCENTRATE HOPPER - ARRANGEMENT AND DETAILS.pdf
0016-DWG-2132-M-0002 - AREA 2132 - REGRIND AREA GENERAL ARRANGEMENT PLAN - SHEET 1 OF 2.pdf
0016-DWG-2132-M-0003 - AREA 2132 - REGRIND AREA GENERAL ARRANGEMENT PLAN - SHEET 2 OF 2.pdf
0016-DWG-2132-M-0004 - AREA 2132 - REGRIND AREA GENERAL ARRANGEMENT ELEVATION - SHEET 1 OF 4.pdf
0016-DWG-2132-M-0005 - AREA 2132 - REGRIND AREA GENERAL ARRANGEMENT ELEVATION - SHEET 2 OF 4.pdf
0016-DWG-2132-M-0006 - AREA 2132 - REGRIND AREA GENERAL ARRANGEMENT ELEVATION - SHEET 3 OF 4.pdf
0016-DWG-2132-M-0006 - AREA 2132 - REGRIND AREA GENERAL ARRANGEMENT ELEVATION - SHEET 4 OF 4.pdf
0016-DWG-2141-M-0002 - AREA 2141-LEAD THICKENING-GENERAL ARRANGEMENT PLAN.pdf
0016-DWG-2141-M-0003 - AREA 2141-LEAD THICKENING-GENERAL ARRANGEMENT ELEVATION SHEET 1 OF 2.pdf
0016-DWG-2141-M-0004 - AREA 2141-LEAD THICKENING-GENERAL ARRANGEMENT ELEVATION SHEET 2 OF 2.pdf
0016-DWG-2142-M-0002 - AREA 2142-ZINC THICKENING-GENERAL ARRANGEMENT PLAN.pdf
0016-DWG-2142-M-0003 - Area 2142 - Zinc Thickening Area General Arrangement Elevations Sheet 1 of 2.pdf
0016-DWG-2142-M-0004 - Area 2142 - Zinc Thickening Area General Arrangement Elevations Sheet 2 of 2.pdf
0016-DWG-2143-M-0002 - AREA 2143-FILTRATION AREA-GENERAL ARRANGEMENT OVERALL PLAN.pdf
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0016-DWG-2150-M-0002 - AREA 2150 - TAILINGS - TAILINGS AREA - GENERAL ARRANGEMENT PLAN.PDF
0016-DWG-2150-M-0003 - AREA 2150 - TAILINGS - TAILINGS AREA - GENERAL ARRANGEMENT ELEVATION SHEET 1 OF 2.PDF
0016-DWG-2150-M-0004 - AREA 2150 - TAILINGS - TAILINGS AREA - GENERAL ARRANGEMENT ELEVATION SHEET 2 OF 2.PDF
0016-DWG-2160-C-0021 - ATC Williams - STAGE 1 TAILINGS STORAGE FACILITY-CIVIL WORKS - SITE PLAN.pdf
0016-DWG-2160-C-0023 - ATC Williams -STAGE 1 TAILINGS STORAGE FACILITY-CIVIL WORKS - TSF EMBANKMENT AREA-FOUNDATION EXCAVATION PLAN.pdf
0016-DWG-2160-C-0025 - ATC Williams - STAGE 1 TAILINGS STORAGE FACILITY-CIVIL WORKS-TSF EMBANKMENT AREA-GENERAL LAYOUT.pdf
0016-DWG-2160-C-0026 - ATC Williams - STAGE 1 TAILINGS STORAGE FACILITY-CIVIL WORKS - TSF EMBANKMENT AREA-SECTIONS (SHEET 1 OF 2).pdf
0016-DWG-2160-C-0027 - ATC Williams - STAGE 1 TAILINGS STORAGE FACILITY-CIVIL WORKS - TSF EMBANKMENT AREA-SECTIONS (SHEET 2 OF 2).pdf
0016-DWG-2160-M-0001 - ATC Williams - AREA 2160 - STAGE 1 TAILINGS STORAGE FACILITY - RETURN WATER SYSTEM - GENERAL LAYOUT.pdf
0016-DWG-2170-M-0015 - AREA 2170 - REAGENTS-SODIUM CYANIDE STORAGE TANK-ARRANGEMENT AND DETAILS.pdf
0016-DWG-2200-C-0002 - SED. CONTROL BASIN F SURVEY SETOUT LAYOUT PLAN.pdf
0016-DWG-2200-C-0004 - SED. CONTROL BASIN F TYPICAL SECTIONS.pdf
0016-DWG-2200-C-0005 - SED. CONTROL BASIN G SURVEY SETOUT LAYOUT PLAN.pdf
0016-DWG-2200-C-0007 - SED. CONTROL BASIN G TYPICAL SECTIONS.pdf
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0016-DWG-2200-C-0015 - AREA 2200 - EARTHWORKS - PROCESS PLANT AREA PROCESS DAMS - PROCESS PLANT RUN-OFF AND CONTAIN.pdf
0016-DWG-2200-C-0016 - AREA 2200 - EARTHWORKS - PROCESS PLANT AREA PROCESS DAMS - MINE WORKSHOP RUN-OFF DAM LAYOUT.pdf
0016-DWG-2200-C-0027 - AREA 2200 - EARTHWORKS - PROCESS PLANT AREA PROCESS DAMS - PERIMETER FENCING LAYOUT SHEET 1.pdf
0016-DWG-2200-C-0028 - AREA 2200 - EARTHWORKS - PROCESS PLANT AREA PROCESS DAMS - PERIMETER FENCING LAYOUT SHEET 2.pdf
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0016-DWG-2201-C-0013 - AREA 2201 - PLANT SITE DEVELOPMENT - PLANT SITE SETOUT - ROAD & DRAINAGE SECTIONS SHT 2.pdf
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0016-DWG-2201-C-0022 - AREA 2201 - PLANT SITE DEVELOPMENT - PLANT SITE SETOUT - ROAD & DRAINAGE SECTIONS SHT 3.pdf
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0016-DWG-2201-C-0031 - AREA 2201 - PLANT SITE DEVELOPMENT - PLANT SITE SETOUT - ROAD & DRAINAGE PLAN SHT 5.pdf
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0016-DWG-2201-C-0045 - AREA 2201 - ROM PAD AND HAUL ROAD PLAN.pdf
0016-DWG-2201-C-0046 - AREA 2201 - ROM PAD AND HAUL ROAD - ROM PAD SECTIONS.pdf
0016-DWG-2201-C-0057 - ATC Williams- NAF PAD RUNOFF DAM CAPACITY INCREASE-EXISTING CONFIGURATION.pdf
0016-DWG-2201-C-0058 - ATC Williams-NAF PAD RUNOFF DAM CAPACITY INCREASE-GENERAL LAYOUT.pdf
0016-DWG-2203-M-0001 - AREA 2203 - RAW AND POTABLE WATER- RAW AND CAMP WATER PUMPING STATIONS-GENERAL ARRANGEMENT AND ELEVATIONS.PDF
0016-DWG-2203-M-0002 - AREA 2203 - RAW AND POTABLE WATER-RUN OFF POND PUMPING STATION-GENERAL ARRANGEMENT PLAN AND ELEVATIONS.PDF
0016-DWG-2203-M-0003 - AREA 2203-RAW AND POTABLE WATER-RAW WATER PUMP SUCTION FLOAT DETAILS.PDF
0016-DWG-2205-M-0001 - AREA 2205-FIREWATER TANK AND PUMPING STATION OVERALL GENERAL ARRANGMENET.pdf
0016-DWG-2205-M-0002 - AREA 2205-FIREWATER AND GLAND WATER PUMPING STATION GENERAL ARRANGEMENT.pdf
0016-DWG-2205-M-0004 - AREA 2203 - POTABLE WATER PLANT AND PUMPING STATION-GENERAL ARRANGEMENT.pdf
0016-DWG-2206-M-0001 - AREA 2206 - PROCESS WATER - PROCESS WATER TANK - ARRANGEMENT AND DETAILS.pdf
0016-DWG-2210-M-0002 - AREA 2210-COMPRESSED AIR GENERAL ARRANGEMENT PLAN.pdf
0016-DWG-2210-M-0003 - AREA 2210-COMPRESSED AIR GENERAL ARRANGEMENT SECTIONS.pdf
0016-DWG-2212-M-0001 - AREA 2224-TSF SUBSTATION AND DECANT BOOSTER PUMP-GENERAL ARRANGEMENT-PLAN AND ELEVATIONS.pdf
0016-DWG-2213-M-0002 - AREA 2213 - FUEL OIL STORAGE AND DISTRIBUTION-DIESEL STORAGE AREA-GENERAL ARRANGEMENT - PLANS.pdf
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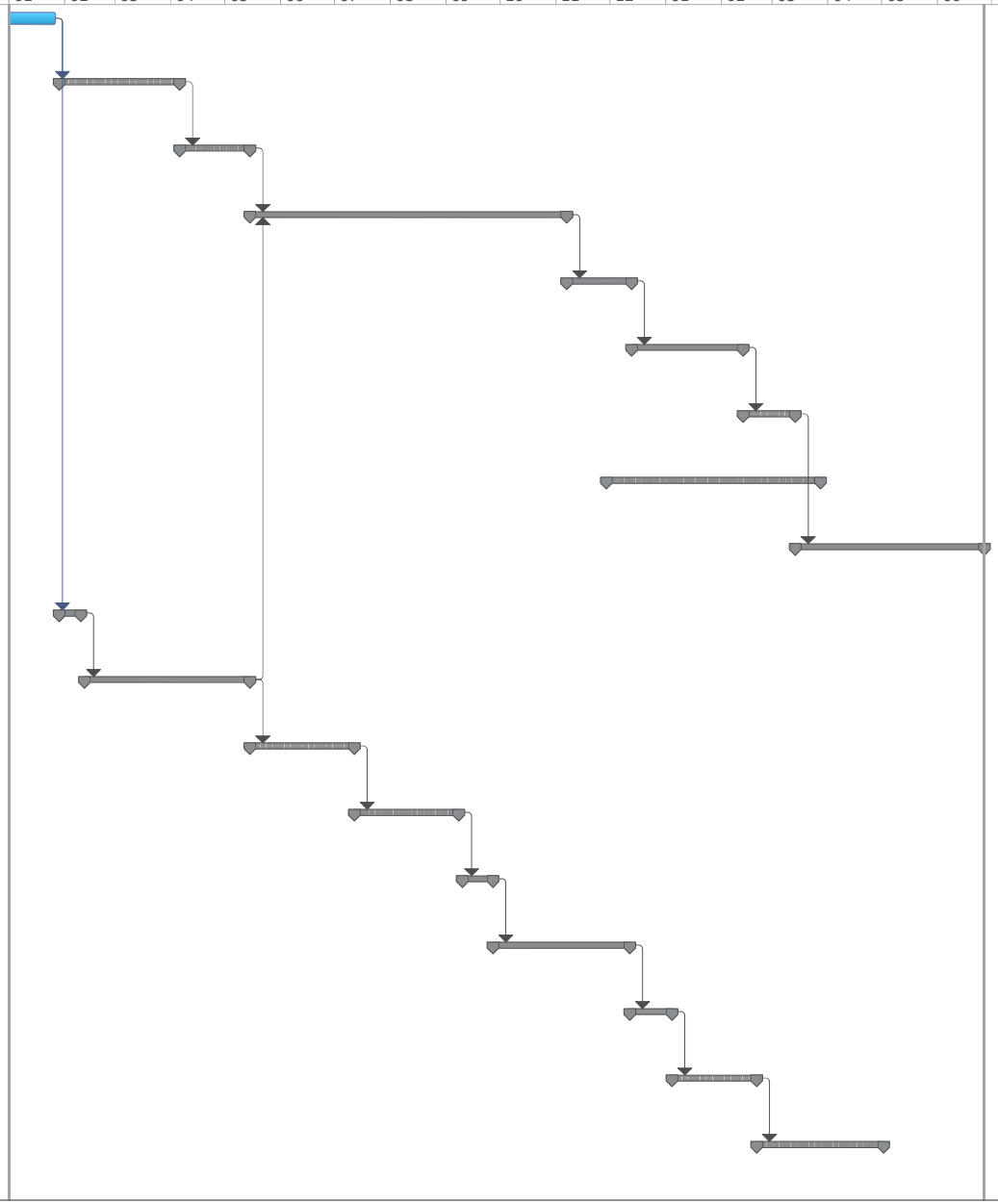
0016-VDR-1802-A-0006-B2501-B02_E_Changehouse Floor Plan.PDF
0016-VDR-1802-A-0007-B2501-B02_F_Changehouse Area Plan.PDF
0016-VDR-1802-A-0013-B2501-B02_A_Changehouse Walkway and Slab.PDF
0016-VDR-1802-A-0027-B2501-B02_F_Changehouse Elevations.PDF
0016-VDR-1803-A-0006-B2501-B02_H_Heavy Vehicle Workshop.PDF
0016-VDR-1806-A-0001-B2501-B02_A_NPI Buildings Plans.PDF
0016-VDR-1806-A-0002-B2501-B02_E_Heavy Vehicle Washbay and Go Area Plan.PDF
0016-VDR-2190-C-0001-B3101-B02_D_Paste Plant General Arrangement.PDF
0016-VDR-2203-P-0001-B3001-B02_A_Fly Camp services.PDF
0016-VDR-2208-C-0001-B3001-B02_A_Village WWTP.PDF
0016-VDR-2301-A-0006-B2501-B02_F_Plant Warehouse Workshop Floor Plan.PDF
0016-VDR-2301-A-0026-B2501-B02_F_Plantwarehouse Workshop elevations.PDF
0016-VDR-2301-A-0217-B2501-B02_E_Reagenst Floor Plan.PDF
0016-VDR-2301-A-0237-B2501-B02_E_Reagents Elevations.PDF
0016-VDR-2305-S-0002-B3001-B02_A_Data Centre.PDF
0016-VDR-2306-A-0006-B2501-B02_E_Laboratory Floor Plan.PDF
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0016-VDR-2306-A-0008-B2501-B02_Laboratory floor plan 2 of 2.PDF
0016-VDR-2306-A-0009-B2501-B02_Laboratory equipment 1 of 2.PDF
0016-VDR-2306-A-0010-B2501-B02_Laboratory equipment 2 of 2.PDF
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0016-VDR-2410-C-0004-B3001-B02_B Village 2 of 2.PDF
0016-VDR-2410-C-0006-B3001-B02_C_Village Typical Modules.PDF
0016-VDR-2410-C-0027-B3001-B02_A_Village Pavement Design.PDF
DUG-SLD-2212-EE-5200_Overall Site HV Distribution.pdf

Appendix 2 Proposed Demolition Zones


GATE HOUSE
BOUNDARY LINE
SINGLE LANE ROADWAY
TIE INTO EXISTING FLY CAMP ROADS
J
HV AREA/ WORKSHOP
G
FUEL TRUCK LOAD & BOILER AREA
PROCESS PLANT BYPASS ROAD
PASTE PLANT
D
CONCENTRATE STORAGE
H
WORKSHOP
REAGENTS
MILLS FLOTATION
TALSX THICKENING
F
REGRIND
E
C
M
PLANT SWITCH YARD
DIVERSION DRAIN PARTIALLY COMPLETED
PROCESS PLANT RUN OFF DAM
CONTAINMENT DAM
B
SEDIMENT DAM
P
RAW WATER DAM
A
CRUSHING AREA
ROM PAD
ROM AREA RUN OFF DAM

Appendix 3 High Level Execution Schedule

ID	Task Name	Duration	Start	Finish	Predecessors
1	Mobilise to site	20 days	Mon 1/01/18	Fri 26/01/18	
2	**A. Crushing Area**	**49 days**	**Mon 29/01/18**	**Thu 5/04/18**	**1**
23	**B. Reclaim Area**	**27 days**	**Fri 6/04/18**	**Mon 14/05/18**	**2**
36	**C. Grinding & Floatation**	**126 days**	**Tue 15/05/18**	**Tue 6/11/18**	**23,98**
54	**L. Tailings Storage Area**	**26 days**	**Wed 7/11/18**	**Wed 12/12/18**	**36**
57	**K. Camp**	**44 days**	**Thu 13/12/18**	**Tue 12/02/19**	**54**
73	**M. HV Supply on Site**	**21 days**	**Wed 13/02/19**	**Wed 13/03/19**	**57**
82	**Temporary Camp**	**85 days**	**Thu 29/11/18**	**Wed 27/03/19**	
85	**M.HV Transmission Line demolition**	**75 days**	**Thu 14/03/19**	**Wed 26/06/19**	**73**
87	**H. Workshop Warehouse & Labs Area**	**10 days**	**Mon 29/01/18**	**Fri 9/02/18**	**1**
98	**E. Reagents Area**	**66 days**	**Mon 12/02/18**	**Mon 14/05/18**	**87**
118	**D. Filtration & Concentrate Storage Area**	**42 days**	**Tue 15/05/18**	**Wed 11/07/18**	**98**
142	**F. Regrind & Thickening**	**42 days**	**Thu 12/07/18**	**Fri 7/09/18**	**118**
158	**Q. Mine Infrastructure**	**13 days**	**Mon 10/09/18**	**Wed 26/09/18**	**142**
165	**P. Earthworks Dam Liner Removal**	**54 days**	**Thu 27/09/18**	**Tue 11/12/18**	**158**
174	**J. Admin Area**	**17.5 days**	**Wed 12/12/18**	**Fri 4/01/19**	**165**
193	**G. Plant Infrastructure**	**33 days**	**Fri 4/01/19**	**Wed 20/02/19**	**174**
214	**N. Roads**	**50.5 days**	**Wed 20/02/19**	**Wed 1/05/19**	**193**



Project: MMG Demolition Schedu
Date: Wed 14/06/17

Task
Split
Milestone
Summary
Project Summary
External Tasks
External Milestone
Inactive Task
Inactive Milestone
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
Deadline
Progress

MMG Demolition Schedule 20170613.mpp

Appendix 4 Demolition Estimate Detail

WorleyParsons
resources & energy

TOTAL PROJECT ESTIMATE - MMG Dugald River Demolition

Department	CAPITAL ESTIMATE				
Project Number	201010-00678				
Project Title	MMG Dugald River Demolition		Date:	16-Jun-17	
Project Engineer/Manager	Steve Martin		Revision:	A	
Class Of Estimate	1		Accuracy	+/-50%	
File Location	\\AUADLWPFIL01V\Data\0MMG\201010-000678 - Dugald River Mine Demolition Estimate\23.0 Estimating\[MMG Demolition Estimate_MASTER.xlsx]ESTIMATE SUMMARY				

CODE (WBS)	Demo Zone	DESCRIPTION	Materials Qty	Materials Unit	Unit Cost Labour	Unit Cost Materials	PF 1.40	Manhours Total	Manhours Rate	Plant & Equipment	Sub Contract & Vendor Support	Bulk Materials DxG	Freight	Direct Labour Cost lxJ	Sub - contract Distribs	TOTAL
		DIRECT COSTS						**59,161**	**90**	**-**	**-**	**- 887,705**	**-**	**5,324,495**	**5,883,234**	**11,868,028**
		PROCUREMENT AND CONSTRUCTION						**59,161**		**-**	**-**	**- 887,705**	**-**	**5,324,495**	**5,883,234**	**10,320,024**
1		**Process Plant Areas**						**33,709**		**-**	**-**	**-**	**-**	**3,033,829**	**3,241,655**	**6,275,484**
							1.40	-	90			-		-	-	-
	A	**2111-Crushing**					1.40	-	90			-		-	-	-
D	A	Structural Steel	120.32	Mt	3		1.40	505.34	90			-		45,481	53,561	99,042
D	A	Platework-Mild Steel	127.5	Mt	3		1.40	535.50	90			-		48,195	56,757	104,952
D1	A	Platework - Bisalloy	220.8	SM	0.5		1.40	154.56	90			-		13,910	16,382	30,292
C	A	Concrete	180.2	CM	0.9		1.40	227.05	90			-		20,435	19,890	40,324
P1	A	Pipes Mild Steel <200mm dia.	32	LM	0.13		1.40	5.82	90			-		524	617	1,141
P2	A	Pipes SS all <50mm dia	229	LM	0.02		1.40	6.41	90			-		577	680	1,257
D2	A	Gridmesh	282.5	SM	0.09		1.40	35.60	90			-		3,204	3,773	6,976
D3	A	Guarding - steel	153	SM	0.09		1.40	19.28	90			-		1,735	2,043	3,778
W1	A	Cable Ladder up to 300mm	207	LM	0.1		1.40	28.98	90			-		2,608	3,072	5,680
W1	A	Cable ladder 300mm to 600mm	119	LM	0.1		1.40	16.66	90			-		1,499	1,766	3,265
W2	A	Light poles 2.4m	41	ea	1		1.40	57.40	90			-		5,166	6,084	11,250
D8	A	Conveyor (900mm)	33	LM	2		1.40	92.40	90			-		8,316	9,793	18,109
D8	A	Conveyor to stacker (900mm)	160	LM	2		1.40	448.00	90			-		40,320	47,483	87,803
D	A	Stacker (already included in structural steel allocation)					1.40	-	90			-		-	-	-
D8	A	Apron feeder ROM bin (Terex Jacques D4 7.5m x 1.7m)	7.5	LM	4		1.40	42.00	90			-		3,780	4,452	8,232
M1	A	Jaw crusher Metso C125 (operating mass)	44	MT	3		1.40	184.80	90			-		16,632	19,587	36,219
U1	A	Transformer 800kVA	1	ea	24		1.40	33.60	90			-		3,024	2,182	5,206
F	A	Switchroom Crushing Area	1	ea	40		1.40	56.00	90			-		5,040	5,935	10,975
	A	Earthworks (to access ROM bin anchors) and dispose in underground mine	1750	CM	0.14		1.40	343.00	90			-		30,870	36,354	67,224
	A						1.40	-	90			-		-	-	-
	B	**2112-Reclaim**					1.40	-	90			-		-	-	-
D	B	Structural Steel	33.16	Mt	3		1.40	139.27	90			-		12,534	14,761	27,296
D	B	Platework-Mild Steel	25	Mt	3		1.40	105.00	90			-		9,450	11,129	20,579
D1	B	Platework - Bisalloy	125.6	SM	0.5		1.40	87.92	90			-		7,913	9,319	17,231
D2	B	Gridmesh	111.56	SM	0.09		1.40	14.06	90			-		1,265	1,490	2,755
C	B	Concrete	197.2	CM	0.9		1.40	248.47	90			-		22,362	21,766	44,129
P1	B	Pipes Mild Steel <200mm dia.	16	LM	0.13		1.40	2.91	90			-		262	309	571
P1	B	Pipes Mild Steel >200mm dia.	0	LM	0.13		1.40	-	90			-		-	-	-
P2	B	Pipes SS all <50mm dia	131	LM	0.02		1.40	3.67	90			-		330	389	719
P3	B	Pipes HDPE <200mm dia.	1104	LM	0.01		1.40	15.46	90			-		1,391	1,638	3,029
P3	B	Pipes HDPE >200mm dia.	0	LM	0.01		1.40	-	90			-		-	-	-
W1	B	Cable Ladder up to 300mm	13	LM	0.1		1.40	1.82	90			-		164	193	357
W1	B	Cable ladder 300mm to 600mm	1210	LM	0.1		1.40	169.40	90			-		15,246	17,955	33,201
W2	B	Light poles 2.4m	14	ea	1		1.40	19.60	90			-		1,764	2,077	3,841
D8	B	Conveyor to mills (900mm)	126	LM	2		1.40	352.80	90			-		31,752	37,393	69,145
D8	B	Apron feeder (Terex Jacques D4, 5.4m x 1.0m)	5.4	LM	2		1.40	15.12	90			-		1,361	1,603	2,963
	B	Earthworks (to access underground apron feeders) and dispose in underground mine	9000	CM	0.14		1.40	1,764.00	90			-		158,760	186,964	345,724
	B						1.40	-	90			-		-	-	-
	C	**2120-Grinding and Classification**					1.40	-	90			-		-	-	-
D	C	Structural Steel	203.26	Mt	3		1.40	853.69	90			-		76,832	90,482	167,314
D	C	Platework-Mild Steel	32	Mt	3		1.40	134.40	90			-		12,096	14,245	26,341
D1	C	Platework - Bisalloy	19.3	SM	0.5		1.40	13.51	90			-		1,216	1,432	2,648
D2	C	Gridmesh	705	SM	0.09		1.40	88.83	90			-		7,995	9,415	17,410
C	C	Concrete	1075.25	CM	0.9		1.40	1,354.82	90			-		121,933	118,682	240,615
D4	C	Bondeck	395	SM	0.15		1.40	82.95	90			-		7,466	8,792	16,257
D5	C	Cladding	177	SM	0.15		1.40	37.17	90			-		3,345	3,940	7,285
D3	C	Guarding - steel	260	SM	0.09		1.40	32.76	90			-		2,948	3,472	6,421
P1	C	Pipes Mild Steel <200mm dia.	248	LM	0.13		1.40	45.14	90			-		4,062	4,784	8,846
P1	C	Pipes Mild Steel >200mm dia.	56	LM	0.13		1.40	10.19	90			-		917	1,080	1,998
P2	C	Pipes SS all <50mm dia	932	LM	0.02		1.40	26.10	90			-		2,349	2,766	5,115
P3	C	Pipes HDPE <200mm dia.	2208	LM	0.01		1.40	30.91	90			-		2,782	3,276	6,058
P3	C	Pipes HDPE >200mm dia.	216	LM	0.01		1.40	3.02	90			-		272	321	593
W1	C	Cable Ladder up to 300mm	263	LM	0.1		1.40	36.82	90			-		3,314	3,903	7,216
W1	C	Cable ladder 300mm to 600mm	1154	LM	0.1		1.40	161.56	90			-		14,540	17,124	31,664
W2	C	Light poles 2.4m	69	ea	1		1.40	96.60	90			-		8,694	10,239	18,933
F	C	SER room (switchroom 2.8m x 7m transportable)	1	ea	40		1.40	56.00	90			-		5,040	5,935	10,975
M2	C	Ball mill D=5.8m, L=8.7m, Polysuis	1	ea	750		1.40	1,050.00	90			-		94,500	68,180	162,680
	C	Ball mill gearbox (Load on truck to scrap)	1	ea			1.40	-	90			-		-	-	-
M2	C	SAG mill D=6.7m, L=3.6m Polysuis	1	ea	500		1.40	700.00	90			-		63,000	45,453	108,453
	C	SAG mill gearbox (Load on truck to scrap)	2	ea			1.40	-	90			-		-	-	-
	C	Ball mill drives 3.2MW (Load on truck to scrap)	2	ea			1.40	-	90			-		-	-	-
	C	SAG mill drive 3.2MW (Load on truck to scrap)	1	ea			1.40	-	90			-		-	-	-
	C						1.40	-	90			-		-	-	-
	C	**2131-Flotation**					1.40	-	90			-		-	-	-
D	C	Structural Steel	312.74	Mt	3		1.40	1,313.51	90			-		118,216	139,217	257,433
D	C	Platework-Mild Steel	138	Mt	3		1.40	579.60	90			-		52,164	61,431	113,595
D2	C	Gridmesh	895	SM	0.09		1.40	112.77	90			-		10,149	11,952	22,102
C	C	Concrete	1255.875	CM	0.9		1.40	1,582.40	90			-		142,416	138,618	281,035
D6	C	Floor plate	33	SM	0.09		1.40	4.16	90			-		374	441	815
D5	C	Cladding	140	SM	0.15		1.40	29.40	90			-		2,646	3,116	5,762
P1	C	Pipes Mild Steel <200mm dia.	1577	LM	0.13		1.40	287.01	90			-		25,831	30,420	56,252
P1	C	Pipes Mild Steel >200mm dia.	321	LM	0.13		1.40	58.42	90			-		5,258	6,192	11,450
P2	C	Pipes SS all <50mm dia	1818	LM	0.02		1.40	50.90	90			-		4,581	5,395	9,977
P3	C	Pipes HDPE <200mm dia.	36780	LM	0.01		1.40	514.92	90			-		46,343	54,576	100,919
P3	C	Pipes HDPE >200mm dia.	11688	LM	0.01		1.40	163.63	90			-		14,727	17,343	32,070
W1	C	Cable Ladder up to 300mm	330	LM	0.1		1.40	46.20	90			-		4,158	4,897	9,055
W1	C	Cable ladder 300mm to 600mm	162	LM	0.1		1.40	22.68	90			-		2,041	2,404	4,445
W2	C	Light poles 2.4m	292	ea	1		1.40	408.80	90			-		36,792	43,328	80,120
	C	Concentrate hoppers (included in platework above)					1.40	-	90			-		-	-	-
D7	C	Cells Large (6.5m dia, h=5) 15 tanks	315	MT	3		1.40	1,323.00	90			-		119,070	140,223	259,293
D7	C	Cells Medium (4.5m dia, h=5) 11 tanks	154	MT	3		1.40	646.80	90			-		58,212	68,554	126,766
D7	C	Cells Small (3.6m dia, h=7), 9 tanks	126	MT	3		1.40	529.20	90			-		47,628	56,089	103,717
D7	C	Cells (2.6 dia, h=3) 10 tanks	36	MT	3		1.40	151.20	90			-		13,608	16,026	29,634
M3	C	Pumps (various)	39	ea	12.5		1.40	682.50	90			-		61,425	44,317	105,742
	C	Piperack (10m incorporated into structure)					1.40	-	90			-		-	-	-
	C	(Large hoppers in platework, small round hoppers to be factored)					1.40	-	90			-		-	-	-
	C						1.40	-	90			-		-	-	-
	D	**2141-Lead Thickening**					1.40	-	90			-		-	-	-
D	D	Structural Steel	24.65	Mt	3		1.40	103.53	90			-		9,318	10,973	20,291
D	D	Platework-Mild Steel	1.4	Mt	3		1.40	5.88	90			-		529	623	1,152
C	D	Concrete	122.4	CM	0.9		1.40	154.22	90			-		13,880	13,510	27,390
D2	D	Gridmesh	65.95	SM	0.09		1.40	8.31	90			-		748	881	1,629
P1	D	Pipes Mild Steel <200mm dia.	110	LM	0.13		1.40	20.02	90			-		1,802	2,122	3,924
P1	D	Pipes Mild Steel >200mm dia.	0	LM	0.13		1.40	-	90			-		-	-	-
P2	D	Pipes SS all <50mm dia	240	LM	0.02		1.40	6.72	90			-		605	712	1,317
P3	D	Pipes HDPE <200mm dia.	5064	LM	0.01		1.40	70.90	90			-		6,381	7,514	13,895
P3	D	Pipes HDPE >200mm dia.	36	LM	0.01		1.40	0.50	90			-		45	53	99
W1	D	Cable Ladder up to 300mm	10	LM	0.1		1.40	1.40	90			-		126	148	274
W1	D	Cable ladder 300mm to 600mm	354	LM	0.1		1.40	49.56	90			-		4,460	5,253	9,713
W2	D	Light poles 2.4m	27	ea	1		1.40	37.80	90			-		3,402	4,006	7,408
D7	D	Thickener (9m dia, h=4m)	1	ea	50		1.40	70.00	90			-		6,300	7,419	13,719
D7	D	Tank Filter feed (6m dia, h=6m, 140m3)	1	ea	20		1.40	28.00	90			-		2,520	2,968	5,488
	D						1.40	-	90			-		-	-	-
	D	**2143-Filtration**					1.40	-	90			-		-	-	-
D	D	Structural Steel	81.29	Mt	3		1.40	341.42	90			-		30,728	36,187	66,914
D	D	Platework-Mild Steel	2.9	Mt	3		1.40	12.18	90			-		1,096	1,291	2,387
D1	D	Platework - Bisalloy	0	CM	0.5		1.40	-	90			-		-	-	-
D	D	Other Steel	0	Mt	3		1.40	-	90			-		-	-	-
C	D	Concrete	303.025	CM	0.9		1.40	381.81	90			-		34,363	33,447	67,810
D2	D	Gridmesh	23	SM	0.09		1.40	2.90	90			-		261	307	568
D4	D	Bondeck	235	SM	0.15		1.40	49.35	90			-		4,442	5,231	9,672
D5	D	Cladding	1237	SM	0.15		1.40	259.77	90			-		23,379	27,533	50,912
P1	D	Pipes Mild Steel <200mm dia.	255	LM	0.13		1.40	46.41	90			-		4,177	4,919	9,096
P1	D	Pipes Mild Steel >200mm dia.	7	LM	0.13		1.40	1.27	90			-		115	135	250
P2	D	Pipes SS all <50mm dia	480	LM	0.02		1.40	13.44	90			-		1,210	1,424	2,634
P3	D	Pipes HDPE <200mm dia.	2840	LM	0.01		1.40	39.76	90			-		3,578	4,214	7,793
P3	D	Pipes HDPE >200mm dia.	144	LM	0.01		1.40	2.02	90			-		181	214	395
W1	D	Cable Ladder up to 300mm	109	LM	0.1		1.40	15.26	90			-		1,373	1,617	2,991
W1	D	Cable ladder 300mm to 600mm	0	LM	0.1		1.40	-	90			-		-	-	-
W2	D	Light poles 2.4m	31	ea	1		1.40	43.40	90			-		3,906	4,600	8,506
D7	D	Tanks 10m dia, h=?	1	ea	12		1.40	16.80	90			-		1,512	1,781	3,293
D7	D	Tanks 3m dia, h=?	2	ea	12		1.40	33.60	90			-		3,024	3,561	6,585
M4	D	Larox filter PF22	15.6	MT	3		1.40	65.52	90			-		5,897	4,254	10,151
M4	D	Larox filter PF144	97	MT	3		1.40	407.40	90			-		36,666	26,454	63,120
M5	D	Gantry crane (16m span 2.5t SWL)	1	ea	26		1.40	36.40	90			-		3,276	2,364	5,640
	D						1.40	-	90			-		-	-	-
	D	**2144-Concentrate Storage**					1.40	-	90			-		-	-	-
D	D	Structural Steel	54.38	Mt	3		1.40	228.40	90			-		20,556	24,207	44,763

CODE (WBS)	Demo Zone	DESCRIPTION	Materials		Unit Cost		PF	Manhours		Plant & Equipment	Sub Contract & Vendor Support	Bulk Materials DxG	Freight	Direct Labour Cost IxJ	Sub - contract Distribs	TOTAL
			Qty	Unit	Labour	Materials	1.40	Total	Rate							
C	D	Concrete	245.225	CM	0.9		1.40	308.98	90			-		27,809	27,067	54,875
D2	D	Gridmesh	65	SM	0.09		1.40	8.19	90			-		737	868	1,605
D5	D	Cladding	1118	SM	0.15		1.40	234.78	90			-		21,130	24,884	46,014
P1	D	Pipes Mild Steel <200mm dia.	0	LM	0.13		1.40	-	90			-		-	-	-
P1	D	Pipes Mild Steel >200mm dia.	0	LM	0.13		1.40	-	90			-		-	-	-
P2	D	Pipes SS all <50mm dia	21	LM	0.02		1.40	0.59	90			-		53	62	115
P3	D	Pipes HDPE <200mm dia.	1560	LM	0.01		1.40	21.84	90			-		1,966	2,315	4,280
P3	D	Pipes HDPE >200mm dia.	0	LM	0.01		1.40	-	90			-		-	-	-
W1	D	Cable Ladder up to 300mm	60	LM	0.1		1.40	8.40	90			-		756	890	1,646
W1	D	Cable ladder 300mm to 600mm	396	LM	0.1		1.40	55.44	90			-		4,990	5,876	10,866
W2	D	Light poles 2.4m	7	ea	1		1.40	9.80	90			-		882	1,039	1,921
M5	D	Extraction fan	1	ea	18		1.40	25.20	90			-		2,268	1,636	3,904
	D	Shed (steel, cladding and concrete included in items listed above)					1.40	-	90			-		-	-	-
	D						1.40	-	90			-		-	-	-
	D	**2204 Gland Water for Process**					1.40	-	90			-		-	-	-
P1	D	Pipes Mild Steel <200mm dia.	362	LM	0.13		1.40	65.88	90			-		5,930	6,983	12,913
P2	D	Pipes SS all <50mm dia	7	LM	0.02		1.40	0.20	90			-		18	21	38
	D						1.40	-	90			-		-	-	-
	D	**2205 Fire Water**					1.40	-	90			-		-	-	-
C	D	Concrete	58.225	CM	0.9		1.40	73.36	90			-		6,603	6,427	13,029
P1	D	Pipes Mild Steel <200mm dia.	135	LM	0.13		1.40	24.57	90			-		2,211	2,604	4,815
P1	D	Pipes Mild Steel >200mm dia.	26	LM	0.13		1.40	4.73	90			-		426	502	927
P2	D	Pipes SS all <50mm dia	26	LM	0.02		1.40	0.73	90			-		66	77	143
W2	D	Light poles 2.4m	4	ea	1		1.40	5.60	90			-		504	594	1,098
D7	D	Tank (14m dia, h=10m) (common to gland water)	1	ea	60		1.40	84.00	90			-		7,560	8,903	16,463
	D	Site distribution included above)					1.40	-	90			-		-	-	-
	D						1.40	-	90			-		-	-	-
	D	**2206 Process Water Reticulation (dam and TSF)**					1.40	-	90			-		-	-	-
P1	D	Pipes Mild Steel <200mm dia.	38	LM	0.13		1.40	6.92	90			-		622	733	1,355
P1	D	Pipes Mild Steel >200mm dia.	25	LM	0.13		1.40	4.55	90			-		410	482	892
P2	D	Pipes SS all <50mm dia	117	LM	0.02		1.40	3.28	90			-		295	347	642
P3	D	Pipes HDPE >200mm dia.	1092	LM	0.01		1.40	15.29	90			-		1,376	1,620	2,996
D7	D	Tank (7m dia, h=6m)	1	ea	20		1.40	28.00	90			-		2,520	2,968	5,488
	D	Effulent pipeline (included above)					1.40	-	90			-		-	-	-
	D	Dam Evaporation (included above)					1.40	-	90			-		-	-	-
	D	Plant reticulation (included above)					1.40	-	90			-		-	-	-
	D						1.40	-	90			-		-	-	-
	E	**2170-Reagent Storage**					1.40	-	90			-		-	-	-
D	E	Structural Steel	25.18	Mt	3		1.40	105.76	90			-		9,518	11,209	20,727
C	E	Concrete	321.3	CM	0.9		1.40	404.84	90			-		36,435	35,464	71,899
D2	E	Gridmesh	179	SM	0.09		1.40	22.55	90			-		2,030	2,390	4,420
P1	E	Pipes Mild Steel <200mm dia.	1100	LM	0.13		1.40	200.20	90			-		18,018	21,219	39,237
P1	E	Pipes Mild Steel <200mm dia.	951	LM	0.13		1.40	173.08	90			-		15,577	18,345	33,922
D3	E	Guarding - steel	67	SM	0.09		1.40	8.44	90			-		760	895	1,655
P2	E	Pipes SS all <50mm dia	3706	LM	0.02		1.40	103.77	90			-		9,339	10,998	20,337
P3	E	Pipes HDPE <200mm dia.	106048	LM	0.01		1.40	1,484.67	90			-		133,620	157,359	290,979
P3	E	Pipes HDPE >200mm dia.	0	LM	0.01		1.40	-	90			-		-	-	-
W1	E	Cable Ladder up to 300mm	84	LM	0.1		1.40	11.76	90			-		1,058	1,246	2,305
W1	E	Cable ladder 300mm to 600mm	24	LM	0.1		1.40	3.36	90			-		302	356	659
W2	E	Light poles 2.4m	48	ea	1		1.40	67.20	90			-		6,048	7,122	13,170
F	E	Building clad (33m x 13m h=10m)	429	SM	0.2		1.40	120.12	90			-		10,811	12,731	23,542
D7	E	Tank cyanide storage (4m dia, h=4m)	10	MT	3		1.40	42.00	90			-		3,780	4,452	8,232
D7	E	Silo lime storage (50m3 capacity)	12	MT	3		1.40	50.40	90			-		4,536	5,342	9,878
D7	E	Tanks various 316SS	106	MT	3		1.40	445.20	90			-		40,068	47,186	87,254
M3	E	Pumps various	64	ea	12		1.40	1,075.20	90			-		96,768	69,816	166,584
	E						1.40	-	90			-		-	-	-
	E	**2221-Gringing Area Sub**					1.40	-	90			-		-	-	-
C	E	Concrete	35.7	CM	0.9		1.40	44.98	90			-		4,048	3,940	7,989
F	E	Substation Grinding area	1	ea	40		1.40	56.00	90			-		5,040	5,935	10,975
U1	E	Transformer Grinding area	1	ea	19.5		1.40	27.30	90			-		2,457	1,773	4,230
F	E	Substation SER	1	ea	40		1.40	56.00	90			-		5,040	5,935	10,975
U1	E	Transformer SAG mill SER	1	ea	19.5		1.40	27.30	90			-		2,457	1,773	4,230
U1	E	Transformer Flotation area 1	2	ea	42		1.40	117.60	90			-		10,584	7,636	18,220
U1	E	Transformer Flotation area 2	3	ea	42		1.40	176.40	90			-		15,876	11,454	27,330
U1	E	Transformer Zinc cleaner	4	ea	33		1.40	184.80	90			-		16,632	12,000	28,632
	E						1.40	-	90			-		-	-	-
	E	**2201-Compressed Air System**					1.40	-	90			-		-	-	-
D	E	Structural Steel	5.4	Mt	3		1.40	22.68	90			-		2,041	2,404	4,445
C	E	Concrete	34.85	CM	0.9		1.40	43.91	90			-		3,952	3,847	7,799
D2	E	Gridmesh	0	SM	0.09		1.40	-	90			-		-	-	-
P1	E	Pipes Mild Steel <200mm dia.	416	LM	0.13		1.40	75.71	90			-		6,814	8,025	14,839
P1	E	Pipes Mild Steel >200mm dia.	155	LM	0.13		1.40	28.21	90			-		2,539	2,990	5,529
P2	E	Pipes SS all <50mm dia	261	LM	0.02		1.40	7.31	90			-		658	775	1,432
W1	E	Cable ladder 300mm to 600mm	52	LM	0.1		1.40	7.28	90			-		655	772	1,427
M5	E	Compressors (Atlas Copco GR200-20 3.8MT each)	4	ea	9		1.40	50.40	90			-		4,536	3,273	7,809
M5	E	Dryers (0.86MT each)	2	ea	4		1.40	11.20	90			-		1,008	727	1,735
M5	E	Receiver 6m3	3	ea	5		1.40	21.00	90			-		1,890	1,364	3,254
M5	E	Receiver 25m3	1	ea	15		1.40	21.00	90			-		1,890	1,364	3,254
	E	Compressed air dustribution (included above)					1.40	-	90			-		-	-	-
	E						1.40	-	90			-		-	-	-
	E	**2180 Piperacks (Area E)**					1.40	-	90			-		-	-	-
	E	**Total length 110m 4m trestles**					1.40	-	90			-		-	-	-
D	E	Structural Steel	59.8	Mt	3		1.40	251.16	90			-		22,604	26,620	49,225
C	E	Concrete	81.175	CM	0.9		1.40	102.28	90			-		9,205	8,960	18,165
D2	E	Gridmesh	38.6	SM	0.09		1.40	4.86	90			-		438	515	953
	E						1.40	-	90			-		-	-	-
	F	**2142-Zinc Thickening**					1.40	-	90			-		-	-	-
D	F	Structural Steel	35.23	Mt	3		1.40	147.97	90			-		13,317	15,683	29,000
D	F	Platework-Mild Steel	3.4	Mt	3		1.40	14.28	90			-		1,285	1,514	2,799
C	F	Concrete	353.6	CM	0.9		1.40	445.54	90			-		40,098	39,029	79,127
D2	F	Gridmesh	73	SM	0.09		1.40	9.20	90			-		828	975	1,803
P1	F	Pipes Mild Steel <200mm dia.	60	LM	0.13		1.40	10.92	90			-		983	1,157	2,140
P1	F	Pipes Mild Steel >200mm dia.	24	LM	0.13		1.40	4.37	90			-		393	463	856
P2	F	Pipes SS all <50mm dia	277	LM	0.02		1.40	7.76	90			-		698	822	1,520
P3	F	Pipes HDPE <200mm dia.	5400	LM	0.01		1.40	75.60	90			-		6,804	8,013	14,817
P3	F	Pipes HDPE >200mm dia.	96	LM	0.01		1.40	1.34	90			-		121	142	263
W1	F	Cable Ladder up to 300mm	37	LM	0.1		1.40	5.18	90			-		466	549	1,015
W1	F	Cable ladder 300mm to 600mm	101	LM	0.1		1.40	14.14	90			-		1,273	1,499	2,771
W2	F	Light poles 2.4m	29	ea	1		1.40	40.60	90			-		3,654	4,303	7,957
F	F	Substation Zinc Cleaner	1	ea	40		1.40	56.00	90			-		5,040	5,935	10,975
U1	F	Transformer 1.6MVA	1	ea	33		1.40	46.20	90			-		4,158	3,000	7,158
D7	F	Thickener (24m dia, h=4m)	1	ea	200		1.40	280.00	90			-		25,200	29,677	54,877
D7	F	Tank Filter feed (6m dia, h=6m, 530m3)	1	ea	20		1.40	28.00	90			-		2,520	2,968	5,488
	F						1.40	-	90			-		-	-	-
	F	**2132-Regrind**					1.40	-	90			-		-	-	-
D	F	Structural Steel	41.05	Mt	3		1.40	172.41	90			-		15,517	18,274	33,790
C	F	Concrete	752.25	CM	0.9		1.40	947.84	90			-		85,305	83,030	168,335
D2	F	Gridmesh	136	SM	0.09		1.40	17.14	90			-		1,542	1,816	3,358
D6	F	Floor Plate	56	SM	0.09		1.40	7.06	90			-		635	748	1,383
P1	F	Pipes Mild Steel <200mm dia.	171	LM	0.13		1.40	31.12	90			-		2,801	3,299	6,100
P1	F	Pipes Mild Steel >200mm dia.	45	LM	0.13		1.40	8.19	90			-		737	868	1,605
P2	F	Pipes SS all <50mm dia	807	LM	0.02		1.40	22.60	90			-		2,034	2,395	4,429
P3	F	Pipes HDPE <200mm dia.	11284	LM	0.01		1.40	157.98	90			-		14,218	16,744	30,962
P3	F	Pipes HDPE >200mm dia.	756	LM	0.01		1.40	10.58	90			-		953	1,122	2,074
W1	F	Cable Ladder up to 300mm	359	LM	0.1		1.40	50.26	90			-		4,523	5,327	9,850
W1	F	Cable ladder 300mm to 600mm	47	LM	0.1		1.40	6.58	90			-		592	697	1,290
W2	F	Light poles 2.4m	63	ea	1		1.40	88.20	90			-		7,938	9,348	17,286
U1	F	Transformer 1.6MVA	1	ea	33		1.40	46.20	90			-		4,158	3,000	7,158
F	F	MCC	1	ea	40		1.40	56.00	90			-		5,040	5,935	10,975
M2	F	Regrind mills	2	ea	40		1.40	112.00	90			-		10,080	7,273	17,353
	F	Mill drives 3MW	2	ea			1.40	-	90			-		-	-	-
	F						1.40	-	90			-		-	-	-
	F	**2150-Tailing Recovery**					1.40	-	90			-		-	-	-
D	F	Structural Steel	28.62	Mt	3		1.40	120.20	90			-		10,818	12,740	23,559
D	F	Platework-Mild Steel	2.4	Mt	3		1.40	10.08	90			-		907	1,068	1,976
C	F	Concrete	198.05	CM	0.9		1.40	249.54	90			-		22,459	21,860	44,319
D2	F	Gridmesh	118	SM	0.09		1.40	14.87	90			-		1,338	1,576	2,914
P1	F	Pipes Mild Steel <200mm dia.	256	LM	0.13		1.40	46.59	90			-		4,193	4,938	9,132
P1	F	Pipes Mild Steel >200mm dia.	3413	LM	0.13		1.40	621.17	90			-		55,905	65,837	121,742
P2	F	Pipes SS all <50mm dia	393	LM	0.02		1.40	11.00	90			-		990	1,166	2,157
P3	F	Pipes HDPE <200mm dia.	10952	LM	0.01		1.40	153.33	90			-		13,800	16,251	30,051
P3	F	Pipes HDPE >200mm dia.	5636	LM	0.01		1.40	78.90	90			-		7,101	8,363	15,464
W1	F	Cable Ladder up to 300mm	109	LM	0.1		1.40	15.26	90			-		1,373	1,617	2,991
W1	F	Cable ladder 300mm to 600mm	0	LM	0.1		1.40	-	90			-		-	-	-
W2	F	Light poles 2.4m	36	ea	1		1.40	50.40	90			-		4,536	5,342	9,878
D7	F	Thickener (18m dia, h=4m)	1	ea	130		1.40	182.00	90			-		16,380	19,290	35,670
D7	F	Tank Floculant storage (4m dia, h=4m)	1	ea	8		1.40	11.20	90			-		1,008	1,187	2,195
	F						1.40	-	90			-		-	-	-
	F	**2218-Tailings 11kV Sub**					1.40	-	90			-		-	-	-
C	F	Concrete	15.3	CM	0.9		1.40	19.28	90			-		1,735	1,689	3,424
F	F	Substation	1	ea	40		1.40	56.00	90			-		5,040	5,935	10,975
	F						1.40	-	90			-		-	-	-
	F	**2223-Tailings Area Sub**					1.40	-	90			-		-	-	-
C	F	Concrete	23.375	CM	0.9		1.40	29.45	90			-		2,651	2,580	5,231
F	F	Substation	1	ea	40		1.40	56.00	90			-		5,040	5,935	10,975
U1	F	Transformers (1.6MVA)	2	ea	33		1.40	92.40	90			-		8,316	6,000	14,316
	F						1.40	-	90			-		-	-	-
	F	**2180 Piperacks (Area F)**					1.40	-	90			-		-	-	-
	F	**Total length 225m 7 to 8m trestles**					1.40	-	90			-		-	-	-
D	F	Structural Steel	119.6	Mt	3		1.40	502.32	90			-		45,209	53,240	98,449
C	F	Concrete	162.35	CM	0.9		1.40	204.56	90			-		18,410	17,920	36,330
D2	F	Gridmesh	77.2	SM	0.09		1.40	9.73	90			-		875	1,031	1,906
	F						1.40	-	90			-		-	-	-

CODE (WBS)	Demo Zone	DESCRIPTION	Materials		Unit Cost		PF	Manhours		Plant & Equipment	Sub Contract & Vendor Support	Bulk Materials DxG	Freight	Direct Labour Cost IxJ	Sub - contract Distribs	TOTAL
			Qty	Unit	Labour	Materials	1.40	Total	Rate							
2		**Plant Services Area**						**3,817**		**-**	**-**	**-**	**-**	**343,569**	**378,395**	**721,964**
	G						1.40	-	90			-		-	-	-
	G	**2190-Paste Plant**					1.40	-	90			-		-	-	-
P3	G	Pipes HDPE <200mm dia.	2916	LM	0.01		1.40	40.82	90			-		3,674	4,327	8,001
D7	G	Tank Tails storage (750kL, 10m dia, h=10)	1	ea	50		1.40	70.00	90			-		6,300	7,419	13,719
D7	G	Silos (6m dia, h=14m)	2	ea	50		1.40	140.00	90			-		12,600	14,838	27,438
M6	G	Belt filter (50m long) incladded building	1	ea	500		1.40	700.00	90			-		63,000	74,192	137,192
M5	G	Paste mixer	1	ea	50		1.40	70.00	90			-		6,300	7,419	13,719
F	G	Switchroom MCC small	1	ea	40		1.40	56.00	90			-		5,040	5,935	10,975
U1	G	Transformer 2MVA	1	ea	37.5		1.40	52.50	90			-		4,725	3,409	8,134
M5	G	Gen set	1	ea	50		1.40	70.00	90			-		6,300	4,545	10,845
D8	G	Conveyor (600mm ??)	33	LM	1.6		1.40	73.92	90			-		6,653	7,835	14,487
	G						1.40	-	90			-		-	-	-
	G	**2213 12-Fuel Oil Distribution**					1.40	-	90			-		-	-	-
C	G	Concrete	59.7975	CM	0.9		1.40	75.34	90			-		6,781	6,600	13,381
D7	G	Tanks diesel (3.3m dia , l=13m, 110kL)	3	ea	8		1.40	33.60	90			-		3,024	3,561	6,585
	G						1.40	-	90			-		-	-	-
	G	**2311-Weighbridge**					1.40	-	90			-		-	-	-
C	G	Concrete	30.6	CM	0.9		1.40	38.56	90			-		3,470	3,378	6,848
M9	G	Weighbridge AWS 54m long	5	MT	3		1.40	21.00	90			-		1,890	2,226	4,116
	G						1.40	-	90			-		-	-	-
	G	**Vehicle Washdown (on surface)**					1.40	-	90			-		-	-	-
C	G	Concrete Apron (30m x 23m)	586.5	SM	0.9		1.40	738.99	90			-		66,509	64,736	131,245
M5	G	Pressure clean and filtration equipment	1	ea	50		1.40	70.00	90			-		6,300	4,545	10,845
	G						1.40	-	90			-		-	-	-
	G	**Heavy Vehicle Workshops**					1.40	-	90			-		-	-	-
D7	G	Tank Oil storage 10CM	2	ea	20		1.40	56.00	90			-		5,040	3,636	8,676
F	G	Workshop (20m x 45m, 672m2) colourbnd clad)	900	SM	0.2		1.40	252.00	90			-		22,680	26,709	49,389
F	G	Crib (12m x 10m 100m2 prefab+D361)	120	SM	0.2		1.40	33.60	90			-		3,024	3,561	6,585
F	G	Oil and Gas farm (12m x 5m)	60	SM	1		1.40	84.00	90			-		7,560	8,903	16,463
	G						1.40	-	90			-		-	-	-
	G	**2203-Raw and Potable Water**					1.40	-	90			-		-	-	-
D	G	Structural Steel	0.36	Mt	3		1.40	1.51	90			-		136	160	296
C	G	Concrete	14.025	CM	0.9		1.40	17.67	90			-		1,590	1,548	3,138
P1	G	Pipes Mild Steel <200mm dia.	17	LM	0.13		1.40	3.09	90			-		278	328	606
P1	G	Pipes Mild Steel >200mm dia.	34	LM	0.13		1.40	6.19	90			-		557	656	1,213
P3	G	Pipes HDPE <200mm dia.	10136	LM	0.01		1.40	141.90	90			-		12,771	15,040	27,812
P3	G	Pipes HDPE >200mm dia.	4728	LM	0.01		1.40	66.19	90			-		5,957	7,016	12,973
W1	G	Cable Ladder up to 300mm	0	LM	0.1		1.40	-	90			-		-	-	-
W1	G	Cable ladder 300mm to 600mm	1	LM	0.1		1.40	0.14	90			-		13	15	27
W2	G	Light poles 2.4m	6	ea	1		1.40	8.40	90			-		756	890	1,646
D7	G	Tank (4m dia, h=2.5)	2	ea	16		1.40	44.80	90			-		4,032	4,748	8,780
	G	Surface distribution included above)					1.40	-	90			-		-	-	-
	G						1.40	-	90			-		-	-	-
	H	**Plant Workshop & Whare House**					1.40	-	90			-		-	-	-
F	H	Building (84m x 24m, 7.5m high)	2016	SM	0.2		1.40	564.48	90			-		50,803	59,829	110,632
F	H	Racking and shelving	170	LM	0.2		1.40	47.60	90			-		4,284	5,045	9,329
	H						1.40	-	90			-		-	-	-
	H	**Laboratory**					1.40	-	90			-		-	-	-
F	H	Metalurgical lab (MLA)					1.40	-	90			-		-	-	-
F	H	Building (38m x 10m, h=5.5m)	380	SM	0.2		1.40	106.40	90			-		9,576	11,277	20,853
F	H	Analytical lab (ALA)					1.40	-	90			-		-	-	-
F	H	Building (33m x 10m, h=5.5m)	330	SM	0.2		1.40	92.40	90			-		8,316	9,793	18,109
	H						1.40	-	90			-		-	-	-
	H	**Crib & Ablution Building**					1.40	-	90			-		-	-	-
F	H	Crib (12m x 12m)	144	SM	0.2		1.40	40.32	90			-		3,629	4,273	7,902
	H						1.40	-	90			-		-	-	-
3		**Administration Area**						**1,068**		**-**	**-**	**-**	**-**	**96,110**	**109,247**	**205,356**
	J						1.40	-	90			-		-	-	-
	J	**2305-Admin Buildings (Mine training, change house and bus stop)**					1.40	-	90			-		-	-	-
F	J	Change house Male (26m x 12m)	312	SM	0.2		1.40	87.36	90			-		7,862	9,259	17,122
F	J	Change house Female (10m x 14m)	140	SM	0.2		1.40	39.20	90			-		3,528	4,155	7,683
F	J	Mine training building (12m x 18m)	216	SM	0.2		1.40	60.48	90			-		5,443	6,410	11,853
C	J	Concrete Bus Stop & Walkways	18.7	CM	0.25		1.40	6.55	90			-		589	694	1,283
	J						1.40	-	90			-		-	-	-
	J	**Temporary Village**					1.40	-	90			-		-	-	-
F	J	Dongas (4 room per) - 55 off	1980	SM	0.2		1.40	554.40	90			-		49,896	58,760	108,656
	J						1.40	-	90			-		-	-	-
	J	**07-Sewage Treatment**					1.40	-	90			-		-	-	-
D7	J	Tanks Steel 3 off	38	MT	3		1.40	159.60	90			-		14,364	16,916	31,280
M5	J	Contanerised plant 20ft (10t)	1	ea	30		1.40	42.00	90			-		3,780	4,452	8,232
P1	J	Pipes Mild Steel <200mm dia.	100	LM	0.13		1.40	18.20	90			-		1,638	1,929	3,567
							1.40	-	90			-		-	-	-
	J						1.40	-	90			-		-	-	-
	J	**Administration Power Supply**					1.40	-	90			-		-	-	-
U1	J	Transformer 1MVA	1	ea	28.5		1.40	39.90	90			-		3,591	2,591	6,182
F	J	Power kiosk	1	ea	40		1.40	56.00	90			-		5,040	3,636	8,676
	J						1.40	-	90			-		-	-	-
	J	**2201-Plant Site development (all old buildings ???)**					1.40	-	90			-		-	-	-
D	J	Structural Steel	0	Mt	3		1.40	-	90			-		-	-	-
D	J	Platework-Mild Steel	0	Mt	3		1.40	-	90			-		-	-	-
D1	J	Platework - Bisalloy	0	CM	0.5		1.40	-	90			-		-	-	-
D	J	Other Steel	0	Mt	3		1.40	-	90			-		-	-	-
C	J	Concrete	0	CM	0.9		1.40	-	90			-		-	-	-
D2	J	Gridmesh	0	SM	0.09		1.40	-	90			-		-	-	-
P1	J	Pipes Mild Steel <200mm dia.	0	LM	0.13		1.40	-	90			-		-	-	-
P1	J	Pipes Mild Steel >200mm dia.	0	LM	0.13		1.40	-	90			-		-	-	-
P2	J	Pipes SS all <50mm dia	0	LM	0.02		1.40	-	90			-		-	-	-
P3	J	Pipes HDPE <200mm dia.	300	LM	0.01		1.40	4.20	90			-		378	445	823
P3	J	Pipes HDPE >200mm dia.	0	LM	0.01		1.40	-	90			-		-	-	-
	J						1.40	-	90			-		-	-	-
4		**Permanent Village & Tailings Storage Area**						**2,642**		**-**	**-**	**-**	**343,148**	**-**	**237,812**	**278,164**	**515,976**
	K	**2420 Village Services & Utilities**					1.40	-	90			-		-	-	-
	K	WTP Camp ??					1.40	-	90			-		-	-	-
	K	STP Camp ??					1.40	-	90			-		-	-	-
F	K	3 person accommodation modules (12m x 3m) - 138 off	4968	SM	0.2		1.40	1,391.04	90			-		125,194	147,435	272,628
F	K	Laundry units - 8 off	288	SM	0.2		1.40	80.64	90			-		7,258	8,547	15,805
F	K	Kitchen, gym and recreation areas	1400	SM	0.2		1.40	392.00	90			-		35,280	41,548	76,828
W3	K	O/H power line conductors (2520m)	7860	LM	0.02		1.40	220.08	90			-		19,807	23,326	43,133
W4	K	Power poles 11m high	32	ea	4		1.40	179.20	90			-		16,128	18,993	35,121
							1.40	-	90			-		-	-	-
	K	**Site Services; water, power, sewer, stormwater, fire detection/protection**					1.40	-	90			-		-	-	-
	K	WWTP					1.40	-	90			-		-	-	-
D7	K	Tanks 26kL (3800 dia)	4	ea	16		1.40	89.60	90			-		8,064	9,497	17,561
D7	K	Tanks 35kL (4500 dia)	3	ea	16		1.40	67.20	90			-		6,048	7,122	13,170
M5	K	Treatmer Container 20'	1	ea	8		1.40	11.20	90			-		1,008	1,187	2,195
M5	K	Treatmer Container 40'	1	ea	8		1.40	11.20	90			-		1,008	1,187	2,195
D7	K	Tank Water 12m dia	2	ea	20		1.40	56.00	90			-		5,040	5,935	10,975
D7	K	Tank Water 9m dia	1	ea	20		1.40	28.00	90			-		2,520	2,968	5,488
M5	K	Gen sets (back up)	1	ea	50		1.40	70.00	90			-		6,300	7,419	13,719
U1	K	Transformer 1600kVA	1	ea	33		1.40	46.20	90			-		4,158	3,000	7,158
	K	Sewage Treatment					1.40	-	90			-		-	-	-
	K						1.40	-	90			-		-	-	-
5		**Tailings Area**						**720**		**-**	**-**	**-**	**-**	**64,766**	**71,182**	**135,948**
	L						1.40	-	90			-		-	-	-
	L	**2224-Tailing Storage Area Sub (booster pump)**					1.40	-	90			-		-	-	-
C	L	Concrete	5.1	CM	0.9		1.40	6.43	90			-		578	563	1,141
F	L	Substation	1	ea	40		1.40	56.00	90			-		5,040	5,935	10,975
U1	L	Transformer 100kVA	1	ea	13.5		1.40	18.90	90			-		1,701	1,227	2,928
	L						1.40	-	90			-		-	-	-
	L	**2160-Tailings Storage**					1.40	-	90			-		-	-	-
C	L	Concrete	0	CM	0.9		1.40	-	90			-		-	-	-
D2	L	Gridmesh	282.5	SM	0.09		1.40	35.60	90			-		3,204	3,773	6,976
P1	L	Pipes Mild Steel <200mm dia.	0	LM	0.13		1.40	-	90			-		-	-	-
P1	L	Pipes Mild Steel >200mm dia.	0	LM	0.13		1.40	-	90			-		-	-	-
P2	L	Pipes SS all <50mm dia	0	LM	0.02		1.40	-	90			-		-	-	-
P3	L	Pipes HDPE <200mm dia.	0	LM	0.01		1.40	-	90			-		-	-	-
P3	L	Pipes HDPE >200mm dia.	0	LM	0.01		1.40	-	90			-		-	-	-
W1	L	Cable Ladder up to 300mm	0	LM	0.1		1.40	-	90			-		-	-	-
W1	L	Cable ladder 300mm to 600mm	1007	LM	0.1		1.40	140.98	90			-		12,688	14,942	27,631
W2	L	Light poles 2.4m	3	ea	1		1.40	4.20	90			-		378	445	823
U1	L	Transformer	1	ea	33		1.40	46.20	90			-		4,158	3,000	7,158
F	L	Kiosk electrical	1	ea	40		1.40	56.00	90			-		5,040	3,636	8,676
D	L	Tailings pump control platform Steel	15	MT	3		1.40	63.00	90			-		5,670	6,677	12,347
	L	Pump positioning cable (15mm cable steel)	3300	LM	0.02		1.40	92.40	90			-		8,316	9,793	18,109
W3	L	Power line from Camp to TSF 1430m (3 phase)	4290	LM	0.02		1.40	120.12	90			-		10,811	12,731	23,542
W4	L	Power poles from camp to TSF (11m high)	19	ea	3		1.40	79.80	90			-		7,182	8,458	15,640
	L						1.40	-	90			-		-	-	-
6		**Infrastructure Power & Roads**						**10,241**		**-**	**-**	**-**	**-**	**921,722**	**1,066,317**	**1,988,038**
	M						1.40	-	90			-		-	-	-
	M	**65km HV Power Line (from Chumvale sub)**					1.40	-	90			-		-	-	-
W4	M	Power poles 12m (min)	182	ea	8.4		1.40	2,140.32	90			-		192,629	226,850	419,479
W5	M	220kV HV transmission line cable	195000	LM	0.02		1.40	5,460.00	90			-		491,400	578,699	1,070,099
	M						1.40	-	90			-		-	-	-
	M	**HV Switchyard (220kV)**					1.40	-	90			-		-	-	-
C	M	Concrete	85	CM	0.9		1.40	107.10	90			-		9,639	9,382	19,021
M8	M	Switchyard Equipment	20	MT	3		1.40	84.00	90			-		7,560	8,903	16,463
	M						1.40	-	90			-		-	-	-
	M	**2217-Main Plant 11kV Sub**					1.40	-	90			-		-	-	-
C	M	Concrete	25.5	CM	0.9		1.40	32.13	90			-		2,892	2,815	5,706
F	M	Substation	1	ea	40		1.40	56.00	90			-		5,040	5,935	10,975
M5	M	Power factor correction	4	ea	5		1.40	28.00	90			-		2,520	1,818	4,338

CODE (WBS)	Demo Zone	DESCRIPTION	Materials		Unit Cost		PF	Manhours		Plant & Equipment	Sub Contract & Vendor Support	Bulk Materials DxG	Freight	Direct Labour Cost IxJ	Sub - contract Distribs	TOTAL
			Qty	Unit	Labour	Materials	1.40	Total	Rate							
M5	M	Standby generators 1250kVA	2	ea	25		1.40	70.00	90			-		6,300	4,545	10,845
	N						1.40	-	90			-		-	-	-
	N	**Village Roads & Siteworks**					1.40	-	90			-		-	-	-
A	N	Rip up spray seal bitumen roads					1.40	-	90			-		-	-	-
A	N	Road from Hwy to Gate (10.1km x 8m)	80800	SM	0.01		1.40	1,131.20	90			-		101,808	118,324	220,132
A	N	Road Gate to Mine North (2km x 8m)	16000	SM	0.01		1.40	224.00	90			-		20,160	23,430	43,590
A	N	Road North Mine to Camp (2.6km x 8m)	20800	SM	0.01		1.40	291.20	90			-		26,208	30,460	56,668
A	N	Carpark (90m x 50m)	4500	SM	0.01		1.40	63.00	90			-		5,670	6,590	12,260
A	N						1.40	-	90			-		-	-	-
	N	**Bridge over Dugald River**					1.40	-	90			-		-	-	-
C	N	Break up with excavator and excavate rubble from the river bed	440	CM	0.9		1.40	554.40	90			-		49,896	48,565	98,461
	N						1.40	-	90			-		-	-	-
7		**Dam Recovery**						**3,423**		-	-	-	-	**308,070**	**362,800**	**670,870**
							1.40	-	90			-		-	-	-
	P	**Water Storage**					1.40	-	90			-		-	-	-
	P	Dam liners to be removed (total for dams below)	193500	SM	0.01		1.40	2,709.00	90			-		243,810	287,124	530,934
	P	Dam Process plant Run Off					1.40	-	90			-		-	-	-
	P	Dam Containment					1.40	-	90			-		-	-	-
	P	Dam Sedimentation A					1.40	-	90			-		-	-	-
	P	Dam ROM Run Off					1.40	-	90			-		-	-	-
	P	Dam Sedimentation F					1.40	-	90			-		-	-	-
	P	Dam Sedimentation G					1.40	-	90			-		-	-	-
	P	Dam Sedimentation D					1.40	-	90			-		-	-	-
	P	Pumping & Piping					1.40	-	90			-		-	-	-
	P	Dam fencing	5100	LM	0.1		1.40	714.00	90			-		64,260	75,676	139,936
	P						1.40	-	90			-		-	-	-
8		**Mine Infrastructure**						**608**		-	-	-	-	**54,747**	**58,565**	**113,312**
	Q						1.40	-	90			-		-	-	-
	Q	**01-Ventilation Fans**					1.40	-	90			-		-	-	-
M7	Q	Fans including drives (5t ea)	15	MT	3		1.40	63.00	90			-		5,670	6,677	12,347
C	Q	Concrete	255	CM	0.9		1.40	321.30	90			-		28,917	28,146	57,063
	Q	**02-Underground Refrigeration**					1.40	-	90			-		-	-	-
	Q	Out of scope					1.40	-	90			-		-	-	-
	Q	**03-Refuge Chambers**					1.40	-	90			-		-	-	-
	Q	Out of scope					1.40	-	90			-		-	-	-
	Q	**04-Paste Reticulation Pipework**					1.40	-	90			-		-	-	-
	Q	Out of scope					1.40	-	90			-		-	-	-
	Q	**05-Dewatering Pumps**					1.40	-	90			-		-	-	-
	Q	Out of scope					1.40	-	90			-		-	-	-
	Q	**06-Dewatering Pipes**					1.40	-	90			-		-	-	-
	Q	Out of scope					1.40	-	90			-		-	-	-
	Q	**07-Underground Power Reticulation**					1.40	-	90			-		-	-	-
	Q	Out of scope					1.40	-	90			-		-	-	-
	Q	**08-Compressed Air Station**					1.40	-	90			-		-	-	-
	Q	Out of scope					1.40	-	90			-		-	-	-
	Q	**09-Compressed Air Reticulation**					1.40	-	90			-		-	-	-
	Q	Out of scope					1.40	-	90			-		-	-	-
	Q	**12-Magazines and Explosives**					1.40	-	90			-		-	-	-
	Q	Out of scope					1.40	-	90			-		-	-	-
	Q	**13-Batch Plant (Shotcreting)**					1.40	-	90			-		-	-	-
	Q	Out of scope					1.40	-	90			-		-	-	-
	Q	**2212-Mines Power**					1.40	-	90			-		-	-	-
F	Q	Switchboard Mine North Portal 11kV C	1	ea	40		1.40	56.00	90			-		5,040	5,935	10,975
F	Q	Switchboard Mine South Portal A 11kV Switchboard	1	ea	40		1.40	56.00	90			-		5,040	5,935	10,975
F	Q	Switchboard Mine South Portal B 11kV Switchboard	1	ea	40		1.40	56.00	90			-		5,040	5,935	10,975
F	Q	Switchboard Tailing area 11kV switchboard	1	ea	40		1.40	56.00	90			-		5,040	5,935	10,975
	Q						1.40	-	90			-		-	-	-
	Q						1.40	-	90			-		-	-	-
	Q						1.40	-	90			-		-	-	-
9		**Tailings Storage Facility**					1.4	-	90	-	-	-	-	-	-	-
		Out of Scope					1.40	-	90			-		-	-	-
							1.40	-	90			-		-	-	-
							1.40	-	90			-		-	-	-
10		**Waste Processing**					1.4	**2,932**	90	-	-	- **887,705**	-	**263,871**	**316,910**	- **306,924**
	R						1.40	-	90			-		-	-	-
	R	Crush concrete and dump in mine	6936	CM	0.1		1.40	971.04	90			-		87,394	101,946	189,340
	R	Recycle Steel - Rebar	694	MT		- 130	1.40	-	90			- 90,168		-	-	- 90,168
	R	Recycle Steel - Structural Steel & Platework	1493	MT		- 130	1.40	-	90			- 194,090		-	-	- 194,090
	R	Recycle Steel - Bisalloy	29	MT		- 130	1.40	-	90			- 3,770		-	-	- 3,770
	R	Recycle Steel - Pipes - CS	424	MT		- 130	1.40	-	90			- 55,120		-	-	- 55,120
	R	Recycle Steel - Pipes - SS	52	MT		- 130	1.40	-	90			- 6,760		-	-	- 6,760
	R	Recycle Steel - Gridmesh	92	MT		- 130	1.40	-	90			- 11,960		-	-	- 11,960
	R	Recycle Steel - Guarding	15	MT		- 130	1.40	-	90			- 1,950		-	-	- 1,950
	R	Recycle Steel - Bondek	7	MT		- 130	1.40	-	90			- 910		-	-	- 910
	R	Recycle Steel - Cladding	14	MT		- 130	1.40	-	90			- 1,820		-	-	- 1,820
	R	Recycle Steel - Floor Plate	8	MT		- 130	1.40	-	90			- 1,040		-	-	- 1,040
	R	Recycle Steel - Tanks	956.4	MT		- 130	1.40	-	90			- 124,332		-	-	- 124,332
	R	Recycle Steel - Conveyors	547.5	MT		- 130	1.40	-	90			- 71,175		-	-	- 71,175
	R						1.40	-	90			-		-	-	-
	R	Mechanical Equipment - Crusher	44	MT		- 130	1.40	-	90			- 5,720		-	-	- 5,720
	R	Mechanical Equipment - Mills	4	EA		- 10,000	1.40	-	90			- 40,000		-	-	- 40,000
	R	Mechanical Equipment - Pumps	103	EA		- 50	1.40	-	90			- 5,150		-	-	- 5,150
	R	Mechanical Equipment - Larox Filters	113	MT		- 130	1.40	-	90			- 14,690		-	-	- 14,690
	R	Mechanical Equipment - Misc	25	EA		- 500	1.40	-	90			- 12,500		-	-	- 12,500
	R	Mechanical Equipment - Filter Building	1	EA		- 20,000	1.40	-	90			- 20,000		-	-	- 20,000
	R	Mechanical Equipment - Fans	15	MT		- 130	1.40	-	90			- 1,950		-	-	- 1,950
	R	Switchyard Equipment	20	MT		- 130	1.40	-	90			- 2,600		-	-	- 2,600
	R	Weighbridge	5	MT		- 130	1.40	-	90			- 650		-	-	- 650
	R	HDPE Pipes - Dispose underground	2343	MT	0.1		1.40	328.02	90			-		29,522	34,438	63,959
	R	Recycle Copper Cabling	32	MT		- 2,000	1.40	-	90			- 64,000		-	-	- 64,000
	R	Recycle Light Poles	670	EA		- 10	1.40	-	90			- 6,700		-	-	- 6,700
	R	Recycle O/H Line	23	MT		- 2,000	1.40	-	90			- 46,000		-	-	- 46,000
	R	Recycle O/H HV Line	48	MT		- 1,500	1.40	-	90			- 72,000		-	-	- 72,000
	R	Recycle Power Poles	233	EA		- 50	1.40	-	90			- 11,650		-	-	- 11,650
	R	Bitumen - dispose in underground mine	6105	CM	0.075		1.40	641.03	90			-		57,692	67,299	124,991
	R	Recycle Transformers	21	EA		- 1,000	1.40	-	90			- 21,000		-	-	- 21,000
	R	Buildings	13683	SM	0.05		1.40	957.81	90			-		86,203	109,346	195,549
	R	Switchrooms	17	EA	1.42857		1.40	34.00	90			-		3,060	3,882	6,942
	R						1.40	-	90			-		-	-	-
	R						1.40	-	90			-		-	-	-
	R						1.40	-	90			-		-	-	-
	R						1.40	-	90			-		-	-	-
	R						1.40	-	90			-		-	-	-
	R						1.40	-	90			-		-	-	-
	1	**Design Growth - calculated on Total Direct Costs**								-	-	-	-	-	-	**1,548,004**
		DESIGN GROWTH														
		Design Growth Allowance @ 15% of Physical Costs	**15%**													1,548,004
		Testing, Commissioning & Training								-	-	-	-	-	-	-
		TESTING, COMMISSIONING & TRAINING						-		-	-	-	-	-	-	-
							1.40	-	90			-		-	-	-
							1.40	-	90			-		-	-	-
							1.40	-	90			-		-	-	-
							1.40	-	90			-		-	-	-
							1.40	-	90			-		-	-	-
		INDIRECT COSTS								-	-	-	-	-	-	**5,181,286**

CODE (WBS)	Demo Zone	DESCRIPTION	Materials		Unit Cost		PF	Manhours		Plant & Equipment	Sub Contract & Vendor Support	Bulk Materials DxG	Freight	Direct Labour Cost IxJ	Sub - contract Distribs	TOTAL
			Qty	Unit	Labour	Materials	1.40	Total	Rate							
		Engineering Procurement and Construction Management	**24%**							-	-	-	-	-	**2,689,000**	**5,181,286**
		EPCM Services								-	-	-	-	-	-	**1,780,204**
		Phase 1: IDENTIFY Engineering												-		
		Phase 2: SELECT Engineering												-		-
		Phase 3: DEFINE Engineering and Procurement Packages														-
																-
		Phase 4: EPCM (to be performed by MMG)	15%											-		1,780,204
		Common Distributables								-	-	-	-	-	**2,689,000**	**3,401,082**
		Common Distributables - site services support and non manual labour	6%													712,082
		Temporary Camp Construction	45	beds		$35,000									1,575,000	1,575,000
		Temporary Camp Operation costs	6300	mandays		$150									945,000	945,000
		R&R Flights (return)	338	flights		$500									169,000	169,000
		Owners Costs								-	-	-	-	-	-	-
		Owners Costs - Excluded														-
																-
		Excluded	0%													-
		Contingency applied @ 30% of costs	30%													**4,650,393**
		Total Expected Cost (Including Costs to date)	21%													**$21,699,707**

Item	Equipment		rate ($/h)	General		Concrete		Equipment		Ripping		Electrical		Concrete Waste		C&D Waste		Recyled Waste	
				Qty	total	Qty	total	Qty	total	Qty	total	Qty	total	Qty	total	Qty	total	Qty	total
Lead				1		1		1		1		1		1		1		1	
Labourer				5		2		3		1		1		4		2		1	
Equipment Operators				3		1		1		1				6		5		1	
Rigger / Dogman								1											
Drivers																			
Total Labour		Dugald River Project	90	9	810	4	360	6	540	3	270	2	180	11	990	8	720	3	270
Excavator	80T		196	1	195.5		0		0		0		0		0		0		0
	Shear		85	1	140		0		0		0		0		0		0		0
	Grapple - Large 50T		64		0		0		0		0		0		0		0		0
	Hammer		34		0		0		0		0		0		0		0		0
Excavator	Komatsu - PC450-8		157	1	157.25	1	157.25		0		0		0		0		0		0
	Shear		85	1	85		0		0		0		0		0		0		0
	Grapple - Large 50T		64	1	63.75	1	63.75		0		0		0		0		0		0
	Hammer		34		0	1	34		0		0		0		0		0		0
	Dozer		157		0		0		0	1	157.25		0		0		0		0
	Ripper		85		0		0		0	1	85		0		0		0		0
	Grader		128		0		0		0				0		0		0		0
	Roller																		
Loader	Komatsu - WA65 Loader		81		0		0		0		0		0	1	80.75	1	80.75	1	80.75
	Grapple - Large 50T		64		0		0		0		0		0	1	63.75	1	63.75	1	63.75
Trucks	Volvo Dump Truck A40		145		0		0		0		0		0	4	578	4	578		0
	Volvo Water Truck		64		0		0		0		0		0		0		0		0
Other	Manato		60	1	59.5		0	1	59.5		0		0		0		0		0
	Boomlift - JLG 660SJ		38	1	38.25		0	1	38.25		0		0		0		0		0
	Crusher	1000t per day	170				0				0		0	1	170		0		0
Crane	50T Crane		149		0		0	1	148.75		0		0		0		0		0
Total Equipment					739.25		255		246.5		242.25		0		892.5		722.5		144.5
					91.27%		70.83%		45.65%		89.72%		0.00%		90.15%		100.35%		53.52%
Other contractor Indirects		based on Dugald River Contracts			26.50%		26.50%		26.50%		26.50%		43.00%		26.50%		26.50%		26.50%
Total Subcontractor Distribs		%		G	118%		97%		72%		116%		43%		117%		127%		80%
		$			105.99		87.60		64.93		104.60		38.70		104.99		114.16		72.02
All-in labour rate		$			195.99		177.60		154.93		194.60		128.70		194.99		204.16		162.02

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SGM Environmental (SGME) is a boutique consulting firm of experienced industry experts working with our clients and their stakeholders to develop and deliver innovative solutions to complicated challenges that create enduring value.

SGM Environmental Pty Limited (SGME) was established to provide services in soil science, geochemistry, mine closure and Environmental management, planning & approvals cost efficiently. When you engage SGME you engage a partner to your business, priding themselves on:

Honest – Straight-up and no nonsense.

Trust – We say what we mean and we will deliver on our promises. We will advocate strongly for you.

Innovation – We will always look for new ways to help and create enduring value because that is what friends do when they work together.

Safety – We do it right so we all go home safely.

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