Environmental Approval & Compliance Solutions

Mt Carbine Void Closure Plan

Mt Carbine Quarries Pty Ltd

Document Control Summary

NRA Environmental Consultants

NRA Filepath:	F:\AAA\380_EQ Resources\380018_PRCP\380018.01_Transistional\rpt\Void Closure Plan\Rpting\Mt Carbine Void Closure Plan_R02.docx		
Status:	R02	**Date of Issue:**	24 April 2025
Project Manager:	John Broughton		
Title:	Mount Carbine Void Closure Plan		
Client:	Mount Carbine Quarries Pty Ltd		
Client Contact:	Kevin MacNeill		
Copies Dispatched:	1 PDF		
Other Info or Requirements:	This report supersedes and replaces all previously prepared versions.		

Report Summary	
Key Words	Void Closure Plan, Open Pit, Void, Progressive Rehabilitation and Closure Plan (PRCP), Mount Carbine, Mount Carbine Quarries Pty Ltd (MCQPL), EQ Resources (EQR)
Abstract	This void closure plan was prepared as part of the Mount Carbine progressive rehabilitation and closure plan, as required by the administering authority, cognisant of relevant statutory guidelines and site history.

Citation
This report should be cited as: NRA 2025, *Mount Carbine Void Closure Plan*, R02, prepared by NRA Environmental Consultants for Mount Carbine Quarries Pty Ltd, 24 April 2025.

Quality Assurance					
Author	**Technical Review**	**Editor**	**Document Version**	**Approved for Issue by QA Manager**	
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1. Introduction

This Void Closure Plan (VCP) integrates relevant information from the Progressive Rehabilitation and Closure Plan (PRCP) (NRA 2023a) and other sources, with Section 3.6.3 of the *Statutory Guideline: Progressive rehabilitation and closure plans* (the PRCP Guideline) (DES 2023). The VCP also includes responses to comments made by DETSI[1,2] on a working copy of the VCP.

For mine sites with voids, DETSI requires the PRCP to include a VCP that includes, but is not limited to, the items identified in Section 3.6.3 of DES (2023) (reproduced in **Text Box 1**).

Text Box 1: VCP items identified in Section 3.6.3 of the PRCP Guideline (DES 2023)

1	Options available for minimising final void area and volume (where a final void is proposed).
2	Proposed final dimensions of the void (*ie* depth, length and width).
3	Pit wall geotechnical and geochemical stability, considering the effects of long-term erosion and weathering of the pit wall and the effects of significant hydrological events.
4	Proposed final slope angles of high wall, low wall and end walls of each final void.
5	Void hydrology, addressing the long-term water balance and water level in the voids, stratification connections to groundwater resources and potential for overflow.
6	Groundwater modelling to determine whether the void is acting as a sink or a source for groundwater.
7	A water balance study including an assessment of void surface and groundwater interactions such as: • groundwater lowering/reduction in hydraulic head (from new voids) (*eg* caves/karst systems) • cones of depression and associated impacts • the drainage and flooding behaviours of surface waters in the vicinity of the void • the potential extent of flooding and implications of interactions with the void • a conceptual model that incorporates all projected inflows, outflows, and recharge rates • water storage and long-term water balance • each of the major water fluxes into and out of the void • the sources of surface water within the mine catchment that are likely to influence the water quality in the void.
8	Predicted water quality in the long-term including potential stratification.
9	A 3D void design plan.
10	Rehabilitation strategies.

The items in **Text Box 1** are addressed in **Section 2**.

DETSI was provided working copies of the VCP for comments on 2 April 2024 and 23 September 2024. A meeting to discuss the VCP and PRCP process was held 8 November 2024. The VCP has been updated to address the feedback provided by DETSI. An updated working copy of the VCP was provided to DETSI (on 19 November 2024) post the 8 November 2024 meeting.

[1] The Department of Environment and Science (DES) became the Department of Environment, Science, and Innovation (DESI) on 18 December 2023, and the Department of Environment, Tourism, Science, and Innovation (DETSI) in early November 2024. For consistency, this report refers to the administering authority as ódETSIô.

[2] *Pers. comm.* Marina Gibson, Senior Environmental Officer, DESI, to Kevin MacNeill, CEO, EQR, and Tim Anderson, Director and Principal Scientist, NRA, email dated 30 April 2024.

Comments made by DETSI on the working copy of the VCP sent 2 April 2024[2], and after a review of the working copy of the VCP provided on 19 November 2024[3], are reproduced in **Text Box 2**.

Text Box 2: DETSI comments

DETSI comments on VCP sent 2 April 2024	
DETSI comment 1	The historical underground mining method
DETSI comment 2	Interactions between the underground mining structures and the current open pit
DETSI comment 3	Information regarding rehabilitation of historical underground infrastructure/structures required to be completed, and if not, information detailing why this would not be required
DETSI comment 4	Appropriately qualified person (AQP) certification regarding geotechnical stability of the final structure
DETSI comments on VCP sent 19 November 2024	
DETSI comment 5	é information, including ability to exclude fauna and humans, erodibility and ability to revegetate, should be provided for the noise bundé

The DETSI comments in **Text Box 2** are addressed in **Section 3**.

The PRCP designates the Mount Carbine void and its bund (collectively) a non-use management area (NUMA).

The Mount Carbine void and its bund is not on a floodplain.

There are three underground mining components that relate to the open pit.

- The historical ôartesianô underground mines that predate the ômodernô (*ie* that which started in the 1970s) mining period. The artesian underground mines were in the material excavated for the modern open pit that was developed in the 1970s and early 1980s. They no longer exist.
- The existing modern underground mining structures, which consist of the partially constructed decline (430 m long) and its portal, which were built *circa* 1987ï 1988.
- The designed, planned and costed modern underground mine, which is undergoing refinement, is included in the VCP and is described in **Section 3.4**.

[3] *Pers. comm*. Marina Gibson, Senior Environmental Officer, DETSI, to Kevin MacNeill, CEO, EQR, and John Broughton, Principal Scientist, NRA, email dated 11 December 2024.

2. PRCP Guideline VCP items

2.1 Minimising final void area and volume

PRCP Guideline VCP item 1: Options available for minimising final void area and volume (where a final void is proposed).

The final void area and volume has been limited to those required to access ore safely and efficiently. The steepness of the void walls is commensurate with host rock stability. For the purposes of this VCP, backfilling of the void with material from the waste rock dump (*ie* non-quarry inventory rock) will not occur.

2.2 Proposed final dimensions

PRCP Guideline VCP item 2: proposed final dimensions of the void (*ie* depth, length and width)

Approximate final dimensions of the open pit[4] are:

- 220 m deep
- 770 m long (longest axis)
- 360 m wide (at widest axis perpendicular to longest axis).

ATCW (2022a, **Appendix A**) reports the spill height for the open pit as 380 mAHD[5].

2.3 Pit wall stability

PRCP Guideline VCP item 3: pit wall geotechnical and geochemical stability, considering the effects of long-term erosion and weathering of the pit wall and the effects of significant hydrological events.

A number of geotechnical assessments and inspections have been undertaken, including GTS (2023a, **Appendix B**; 2023b, **Appendix C**; 2022, **Appendix D**), ATCW (2022b, **Appendix E**), HCOVGlobal (2020, **Appendix F**), Golder (1984, **Appendix G**) and Piteau and Associates (1982, **Appendix H**).

GTS (2022) reports the findings of the geotechnical inspections and reviews undertaken before the open pit was drained (in late 2022/early 2023). With regard to the exposed high north wall of the open pit, GTS (2022) reports the following.

> Key features are that despite the rock being distinctly weathered and fractured and not smooth-blasted the batter is intact despite over 50 years of exposure. This is indicative of high strength rock substance and high strength joints that [are] the result of the silicification and metamorphism of the original fine grained sedimentary rocks. The condition of this batter is representative of much of the rest of the pit giving confidence in the original Piteau (1982) observations and recommendations.

[4] *Pers. comm.* Dean Krak, Geologist, EQR, to John Broughton, Senior Earth Scientist, NRA, email dated 27 September 2022.

[5] Elevation in metres with respect to the Australian Height Datum.

GTS (2023b) reports on geotechnical aspects of the open pit. It builds on the previous sources using information collected since the restart of mining in the open pit (in mid-2023). GTS (2023b) reports the following.

- The pit walls were in excellent condition reflecting the high strength of each of the rock types and the ore-bearing quartz veins.
- Draining of the pit and the subsequent drying of the wall rocks had not resulted in any deterioration of the wall rocks. Notably along the South Wall Fault (SWF) the wall had remained stable despite the cable anchors no longer being effective.
- The exposed *in situ* rock is fractured. The joints were tight and clean with little by way of clay coated geological defects apart from the SWF. Consequently, the undamaged, *in situ* rock was mostly strongly interlocked.
- There is no evidence of groundwater induced instability.
- There had been a possible concern that draining of the pit would generate groundwater pressures behind the pit walls. However, there was almost no visible groundwater seeping through the walls and no evidence of groundwater pressure induced instability. This observation provides confirmation of Laitôs (RLA 2012) groundwater study which inferred:
  - low hydraulic conductivity of the Hodgkinson Formation aquifers; and
  - no conclusive links between groundwater and surface water chemistry at the site.

  As noted in the Lait report [RLA 2012] the pit is [a] hydraulic sink and the absence of any major seepage appears to confirm that the rock is tight.
- Blast damage had loosened the wall rock particularly along bench crests but there had been very little fresh rockfall.
- The pit designs suggested by Piteau and Associates (1982) remain essentially valid and have been incorporated in the current pit shell.

The geochemical stability of the wall rocks is demonstrated by the long-term stability of the excavated material stored in the low-grade stockpiles and the stability of the void walls (GTS 2023b). The low geochemical reactivity of void walls is reflected in the near-neutral pH and low electrical conductivity of the open pit waters (see **Table 1**).

Paul Maconochie (RPEQ 5828), Principal Geotechnical Engineer at GeoTek Solutions Pty Ltd, examined the stability of the open pit design and determined that the overall stability of the pit is high and that the factor of safety for the final void would be greater than 1.5 (GTS 2024, **Appendix I**).

Table 1: Data used in assessment of open pit water quality against surface water reference sites

Site[1]	Analyte	Start	Finish	Count	Minimum	5%ile	20%ile	50%ile	80%ile	95%ile	Maximum
OW1	Aluminium, filtered mg/L	8/02/2011	6/01/2023	70	0.011	0.014	0.02	0.025	0.034	0.057	0.54
SW1	Aluminium, filtered mg/L	8/02/2011	15/08/2024	93	0.022	0.24	0.59	1.3	2.5	3.34	4.7
SW16	Aluminium, filtered mg/L	5/06/2013	4/07/2024	42	0.009	0.021	0.07	0.27	1.07	1.5	1.7
OW1	Aluminium, unfiltered mg/L	25/02/2011	6/01/2023	68	0.01	0.018	0.023	0.032	0.072	0.31	0.52
SW1	Aluminium, unfiltered mg/L	25/02/2011	15/08/2024	90	0.3	1.2	2.76	4.6	6.2	8.1	9.9
SW16	Aluminium, unfiltered mg/L	5/06/2013	4/07/2024	40	0.04	0.119	0.45	1.2	3	5	5.8
OW1	Antimony, filtered mg/L	31/03/2011	6/01/2023	27	<0.002	<0.002	<0.003	<0.003	<0.003	<0.003	0.003
SW1	Antimony, filtered mg/L	31/03/2011	15/08/2024	67	<0.001	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
SW16	Antimony, filtered mg/L	3/06/2014	4/07/2024	38	<0.002	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
OW1	Antimony, unfiltered mg/L	31/03/2011	6/01/2023	27	<0.002	<0.002	<0.003	<0.003	<0.003	<0.003	<0.003
SW1	Antimony, unfiltered mg/L	31/03/2011	15/08/2024	67	<0.001	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
SW16	Antimony, unfiltered mg/L	3/06/2014	4/07/2024	38	<0.002	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
OW1	Arsenic, filtered mg/L	8/02/2011	6/01/2023	70	0.016	0.086	0.1	0.14	0.15	0.16	0.17
SW1	Arsenic, filtered mg/L	8/02/2011	15/08/2024	96	0.001	<0.003	<0.003	<0.003	<0.003	0.004	0.007
SW16	Arsenic, filtered mg/L	5/06/2013	4/07/2024	42	0.004	0.005	0.006	0.007	0.009	0.016	0.019
OW1	Arsenic, unfiltered mg/L	30/05/2002	6/01/2023	75	0.045	0.088	0.11	0.15	0.16	0.16	0.2
SW1	Arsenic, unfiltered mg/L	1/04/2009	15/08/2024	95	0.001	<0.003	<0.003	<0.003	0.003	0.006	0.008
SW16	Arsenic, unfiltered mg/L	5/06/2013	4/07/2024	42	0.005	0.005	0.007	0.008	0.01	0.017	0.019
OW1	Boron, filtered mg/L	4/06/2013	26/08/2021	39	<0.005	0.014	0.023	0.028	0.039	<0.05	<0.05
SW1	Boron, filtered mg/L	4/06/2013	15/03/2023	38	<0.005	<0.005	<0.005	0.007	0.011	0.019	<0.05
SW16	Boron, filtered mg/L	5/06/2013	9/02/2022	16	<0.005	<0.005	<0.005	<0.005	0.008	0.015	0.023
OW1	Boron, unfiltered mg/L	4/06/2013	26/08/2021	39	<0.005	0.013	0.022	0.027	0.04	<0.05	<0.05
SW1	Boron, unfiltered mg/L	4/06/2013	15/03/2023	38	<0.005	<0.005	<0.005	0.009	0.012	0.021	<0.05
SW16	Boron, unfiltered mg/L	5/06/2013	9/02/2022	16	<0.005	<0.005	<0.005	<0.005	0.008	0.015	0.022
OW1	Cadmium, filtered mg/L	8/02/2011	6/01/2023	70	<0.0001	<0.0001	0.0003	0.0007	0.0008	0.0012	0.0013
SW1	Cadmium, filtered mg/L	8/02/2011	15/08/2024	96	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001
SW16	Cadmium, filtered mg/L	5/06/2013	4/07/2024	42	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001
OW1	Cadmium, unfiltered mg/L	30/05/2002	6/01/2023	75	<0.0001	<0.0001	0.0001	0.0007	0.0009	0.0012	0.009
SW1	Cadmium, unfiltered mg/L	1/04/2009	15/08/2024	95	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	0.0002
SW16	Cadmium, unfiltered mg/L	5/06/2013	4/07/2024	42	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0002
OW1	Chloride mg/L	10/11/1992	6/01/2023	60	8	34.9	42	59	62	69	210
SW1	Chloride mg/L	21/01/2013	15/08/2024	83	4	5	6	8	12	14	18
SW16	Chloride mg/L	5/06/2013	26/04/2024	37	6	6	7	8	9	11	13
OW1	Chromium, filtered mg/L	8/02/2011	6/01/2023	70	0.0005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SW1	Chromium, filtered mg/L	8/02/2011	15/08/2024	94	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SW16	Chromium, filtered mg/L	5/06/2013	4/07/2024	41	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
OW1	Chromium, unfiltered mg/L	25/02/2011	6/01/2023	68	0.0005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SW1	Chromium, unfiltered mg/L	25/02/2011	15/08/2024	92	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
SW16	Chromium, unfiltered mg/L	5/06/2013	4/07/2024	41	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.002
OW1	Cobalt, filtered mg/L	8/02/2011	6/01/2023	70	0.0005	<0.001	<0.001	<0.001	<0.001	<0.005	<0.005
SW1	Cobalt, filtered mg/L	8/02/2011	15/08/2024	96	<0.001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.005
SW16	Cobalt, filtered mg/L	5/06/2013	4/07/2024	42	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
OW1	Cobalt, unfiltered mg/L	25/02/2011	6/01/2023	68	0.0005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.005
SW1	Cobalt, unfiltered mg/L	25/02/2011	15/08/2024	94	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.005
SW16	Cobalt, unfiltered mg/L	5/06/2013	4/07/2024	42	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
OW1	Copper, filtered mg/L	8/02/2011	6/01/2023	70	0.0005	<0.001	<0.001	<0.001	<0.001	0.003	0.005
SW1	Copper, filtered mg/L	8/02/2011	15/08/2024	96	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.002
SW16	Copper, filtered mg/L	5/06/2013	4/07/2024	42	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.004
OW1	Copper, unfiltered mg/L	30/05/2002	6/01/2023	75	0.0005	<0.001	<0.001	<0.001	0.002	0.005	0.024
SW1	Copper, unfiltered mg/L	1/04/2009	15/08/2024	95	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.005
SW16	Copper, unfiltered mg/L	5/06/2013	4/07/2024	42	<0.001	<0.001	<0.001	<0.001	0.001	0.002	0.004
OW1	EC ÕS/cm	10/11/1992	6/01/2023	80	550	620	768	820	860	951	2100
SW1	EC ÕS/cm	1/04/2009	4/07/2024	86	38.1	41	49	55	68	73.8	85.1
SW16	EC ÕS/cm	5/06/2013	26/04/2024	33	42.6	49	55	59	75	95	99
OW1	Fluoride mg/L	8/02/2011	6/01/2023	70	6.6	6.7	7.8	8.4	9	10	20
SW1	Fluoride mg/L	8/02/2011	15/08/2024	95	0.07	0.09	0.11	0.13	0.15	0.18	0.37
SW16	Fluoride mg/L	5/06/2013	4/07/2024	42	0.1	0.1	0.13	0.16	0.19	0.23	0.48
OW1	Lead, filtered mg/L	8/02/2011	6/01/2023	66	0.0005	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
SW1	Lead, filtered mg/L	8/02/2011	15/08/2024	93	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
SW16	Lead, filtered mg/L	5/06/2013	4/07/2024	41	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001
OW1	Lead, unfiltered mg/L	25/02/2011	6/01/2023	64	0.0005	<0.001	<0.001	<0.001	<0.001	<0.001	0.002
SW1	Lead, unfiltered mg/L	25/02/2011	15/08/2024	91	<0.001	<0.001	<0.001	<0.001	0.002	0.002	0.004
SW16	Lead, unfiltered mg/L	5/06/2013	4/07/2024	41	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.002
OW1	Manganese, filtered mg/L	8/02/2011	6/01/2023	64	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.006
SW1	Manganese, filtered mg/L	8/02/2011	15/08/2024	95	<0.005	<0.005	<0.005	<0.005	<0.005	0.006	0.014

Site[1]	Analyte	Start	Finish	Count	Minimum	5%ile	20%ile	50%ile	80%ile	95%ile	Maximum
SW16	Manganese, filtered mg/L	5/06/2013	4/07/2024	42	<0.005	<0.005	<0.005	<0.005	<0.005	0.035	0.045
OW1	Manganese, unfiltered mg/L	25/02/2011	6/01/2023	62	<0.005	<0.005	<0.005	<0.005	0.006	0.028	0.038
SW1	Manganese, unfiltered mg/L	25/02/2011	15/08/2024	90	0.0007	0.006	0.008	0.013	0.017	0.026	0.039
SW16	Manganese, unfiltered mg/L	5/06/2013	4/07/2024	40	<0.005	<0.005	<0.005	0.007	0.016	0.038	0.05
OW1	Molybdenum, filtered mg/L	8/02/2011	6/01/2023	64	0.041	0.046	0.051	0.059	0.063	0.065	0.069
SW1	Molybdenum, filtered mg/L	8/02/2011	15/08/2024	95	<0.001	<0.001	<0.001	<0.001	0.002	<0.005	<0.01
SW16	Molybdenum, filtered mg/L	5/06/2013	4/07/2024	42	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.005
OW1	Molybdenum, unfiltered mg/L	25/02/2011	6/01/2023	62	0.041	0.045	0.052	0.059	0.064	0.067	0.07
SW1	Molybdenum, unfiltered mg/L	25/02/2011	15/08/2024	93	<0.001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.01
SW16	Molybdenum, unfiltered mg/L	5/06/2013	4/07/2024	42	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.005
OW1	Nickel, filtered mg/L	31/03/2011	6/01/2023	27	<0.001	<0.001	<0.001	<0.001	0.001	<0.002	0.002
SW1	Nickel, filtered mg/L	31/03/2011	15/08/2024	67	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002
SW16	Nickel, filtered mg/L	3/06/2014	4/07/2024	38	<0.001	<0.001	<0.001	<0.001	<0.001	<0.002	0.002
OW1	Nickel, unfiltered mg/L	31/03/2011	6/01/2023	27	<0.001	<0.001	<0.001	<0.001	0.001	<0.002	0.002
SW1	Nickel, unfiltered mg/L	31/03/2011	15/08/2024	67	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.002
SW16	Nickel, unfiltered mg/L	3/06/2014	4/07/2024	38	<0.001	<0.001	<0.001	<0.001	<0.001	<0.002	0.002
OW1	pH unitless	10/11/1992	6/01/2023	79	7.2	7.6	7.9	8.1	8.2	8.4	8.7
SW1	pH unitless	1/04/2009	4/07/2024	93	6.5	6.7	6.9	7.2	7.58	7.86	8.14
SW16	pH unitless	5/06/2013	4/07/2024	41	6.5	6.6	6.8	7.26	7.38	7.48	7.7
OW1	Selenium, filtered mg/L	27/11/2014	6/01/2023	25	0.002	0.002	<0.003	<0.003	<0.003	<0.003	0.003
SW1	Selenium, filtered mg/L	30/05/2012	15/08/2024	65	<0.001	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
SW16	Selenium, filtered mg/L	3/06/2014	4/07/2024	38	<0.002	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
OW1	Selenium, unfiltered mg/L	27/11/2014	6/01/2023	25	<0.003	<0.003	<0.003	<0.003	<0.003	0.004	0.004
SW1	Selenium, unfiltered mg/L	30/05/2012	15/08/2024	65	<0.001	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
SW16	Selenium, unfiltered mg/L	3/06/2014	4/07/2024	38	<0.002	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
OW1	Sulfate mg/L	10/11/1992	6/01/2023	72	160	190	230	250	260	284	620
SW1	Sulfate mg/L	8/02/2011	15/08/2024	96	<0.5	<0.5	<0.5	<0.5	0.6	0.7	2.3
SW16	Sulfate mg/L	5/06/2013	13/05/2024	40	<0.5	<0.5	0.7	0.9	1.1	1.8	3.3
OW1	Tungsten, filtered mg/L	31/03/2011	6/01/2023	44	<0.0001	0.001	0.024	0.036	0.041	0.047	0.051
SW1	Tungsten, filtered mg/L	31/03/2011	15/08/2024	81	<2e-06	<0.0005	<0.0005	<0.0005	<0.001	<0.001	0.0011
SW16	Tungsten, filtered mg/L	5/06/2013	4/07/2024	42	<0.0005	<0.0005	<0.0005	<0.0005	<0.001	<0.001	0.002
OW1	Tungsten, unfiltered mg/L	31/03/2011	6/01/2023	44	<0.0001	0.0039	0.026	0.036	0.045	0.051	0.077
SW1	Tungsten, unfiltered mg/L	31/03/2011	15/08/2024	78	<1e-06	<0.0005	<0.0005	0.0005	<0.001	0.0015	0.0042
SW16	Tungsten, unfiltered mg/L	5/06/2013	4/07/2024	41	<0.0005	<0.0005	<0.0005	0.0005	<0.001	0.0013	0.0026
OW1	Turbidity NTU	10/11/1992	5/04/1994	2	0.37	0	0	1	1	1	<1.0
SW1	Turbidity NTU	28/03/2022	15/08/2024	9	2.27	4.03	12.41	19.04	25.1	25.5	25.5
SW16	Turbidity NTU	4/01/2017	4/07/2024	20	0.98	1.57	5.2	12.34	15	17.27	22.6
OW1	Uranium, filtered mg/L	4/06/2013	26/08/2021	39	<0.0005	<0.0005	0.0006	0.001	0.001	0.0013	0.0015
SW1	Uranium, filtered mg/L	4/06/2013	15/03/2023	38	<0.0005	<0.0005	<0.0005	<0.0005	<0.001	<0.001	<0.001
SW16	Uranium, filtered mg/L	5/06/2013	9/02/2022	16	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.001	<0.001
OW1	Uranium, unfiltered mg/L	4/06/2013	26/08/2021	39	<0.0005	0.0006	0.0007	0.001	0.001	0.0012	0.0018
SW1	Uranium, unfiltered mg/L	4/06/2013	15/03/2023	38	0.0000008	<0.0005	<0.0005	0.0006	<0.001	0.001	0.0029
SW16	Uranium, unfiltered mg/L	5/06/2013	9/02/2022	16	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.001	<0.001
OW1	Zinc, filtered mg/L	8/02/2011	6/01/2023	65	0.0025	<0.005	<0.005	<0.005	0.007	0.016	0.019
SW1	Zinc, filtered mg/L	8/02/2011	15/08/2024	96	<0.005	<0.005	<0.005	<0.005	<0.005	0.009	0.018
SW16	Zinc, filtered mg/L	5/06/2013	4/07/2024	42	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.006
OW1	Zinc, unfiltered mg/L	30/05/2002	6/01/2023	70	0.0025	<0.005	<0.005	<0.005	0.01	0.037	0.21
SW1	Zinc, unfiltered mg/L	1/04/2009	15/08/2024	95	0.003	<0.005	<0.005	<0.005	0.007	0.015	0.024
SW16	Zinc, unfiltered mg/L	5/06/2013	4/07/2024	42	<0.005	<0.005	<0.005	<0.005	<0.005	0.007	0.011

[1] OW1 is open pit monitoring site; SW1 is Manganese Creek reference site; SW16 is Holmes Creek reference site.

2.4 Proposed final slope angles

PRCP Guideline VCP item 4: proposed final slope angles of high wall, low wall and end walls of each final void.

The typical overall angle of the pit walls will be 54° on the high and low walls[6]. The angle of the upper 20 m of the south low wall is 45° to ensure stability in the softer oxide material in the area[7].

2.5 Void hydrology

PRCP Guideline VCP item 5: void hydrology, addressing the long-term water balance and water level in the voids, stratification connections to groundwater resources and potential for overflow.

ATCW (2022c, **Appendix J**) prepared a final void water balance model that conceptualises the inflows and outflows to the pit and a number of climate scenarios over 650 years. In line with the approach taken for this VCP, the model did not include backfilling of the void and did not include interaction of void water with future underground workings. The water balance modelling indicates that the void is expected to act as a groundwater sink under three modelled climate scenarios. This has been interpreted using the equilibrium water levels from the modelled scenarios and the reported elevation of the inflow/outflow transition point[8,9] (365 mAHD) in the void. The transition point is consistent with the highest groundwater level recorded in proximity to the void by Piteau and Associates (1982) prior to the voidôs expansion between 1982 and 1990 (*ie* to its dimensions up to the re-commencement of mining in 2023).

The equilibrium water levels given by ATCW (2022c) for each climate scenario are:

- for the no-change scenario:
  - oscillating between 357 mRL and 369 mRL (mid-point 363 mRL), indicating the void will swap between inflows and outflows
  - as the mid-point of the oscillation range is below the transition elevation, the void is expected to act as a net groundwater sink
- for the RCP4.5 scenario[10]:
  - oscillating between 355 mRL and 365 mRL, indicating that the void will act as a groundwater sink
- for the RCP8.5 scenario:
  - oscillating between 352 mRL and 364 mRL, indicating that the void will act as a groundwater sink.

[6] This is consistent with the 70° angle for ódiftsô with 8 m berms reported in the bankable feasibility study (EQR 2021).

[7] *Pers. comm.* Tony Bainbridge, Exploration Manager, EQR, to John Broughton, Senior Earth Scientist, NRA, email dated 23 January 2024.

[8] The transition point is where water levels that are higher result in outflows from the void, and void water levels that are lower result in inflows (Diagram 19 of ATCW 2022a).

[9] ATCW (2022c) reports elevations using relative level (RL); ATCW (2022a) reports elevations using RL and AHD. As RL and AHD are used for the same elevations (*eg* spill elevation) they are assumed to be equivalent between the ATCW (2022a, 2022c) reports.

[10] Representative concentration pathways (RCPs) are climate change scenarios to project future greenhouse gas concentrations.

The void acting as a groundwater sink reduces the risk of void water migration and the associated environmental concerns.

ATCW (2022c) also identified that for each of the climate scenarios modelled, there was a very low risk of spill from the final void.

Groundwater flow near the void is expected to be relatively inhibited by the void host rocks. RLA & Hydrogeologist (2022, **Appendix K**) identifies that the hydraulic conductivity of the void host rocks (Hodgkinson Formation hornfels) may be lower than that of the surrounding rock. This suggests that where groundwater flows to or from the void occur, they are likely to be reduced relative to the wider geology.

The void is not significantly hydrogeologically linked to the existing underground workings (*ie* the decline constructed in the late 1980s). This is demonstrated by the water held in the re-opened decline portal (see photographs dated 8 July 2024 in **Figure 1)**, approximately 200 m horizontally and 45 m vertically from the floor of the void, after the void had been empty for approximately 12 months. If a significant hydrogeological link existed between the void and the underground workings, the level of water in the decline would have fallen with the reducing water level in the void.



Figure 1: EQR presentation showing existing decline and underground development

2.6 Groundwater modelling

PRCP Guideline VCP item 6: groundwater modelling to determine whether the void is acting as a sink or a source for groundwater

ATCW (2022c) prepared a final void water balance model that conceptualises the inflows and outflows to the pit and a number of climate scenarios over 650 years. In line with the approach taken for this VCP, the model did not include backfilling of the void and did not include interaction of void water with future underground workings. Piteau and Associates (1982) measured the groundwater levels in 1982 (before the open pit was expanded) at between 359 mAHD and 365 mAHD. Using Piteau and Associates (1982) pre-pit expansion groundwater levels and ATCW (2022c) modelling, the void is expected to act as a groundwater sink under three modelled climate scenarios. This has been interpreted using the equilibrium water levels from the modelled scenarios and the reported elevation of the inflow/outflow transition point[7,8] (365 mAHD) in the void. The equilibrium water levels given by ATCW (2022c) for each climate scenario are:

- for the no-change scenario:
  - oscillating between 357 mRL and 369 mRL (mid-point 363 mRL), indicating the void will swap between inflows and outflows
  - as the mid-point of the oscillation range is below the transition elevation, the void is expected to act as a net groundwater sink
- for the RCP4.5 scenario:
  - oscillating between 355 mRL and 365 mRL, indicating that the void will act as a groundwater sink
- for the RCP8.5 scenario:
  - oscillating between 352 mRL and 364 m RL, indicating that the void will act as a groundwater sink.

The void acting as a groundwater sink reduces the risk of void water migration and the associated environmental concerns.

Groundwater flow near the void is expected to be relatively inhibited by the void host rocks. RLA & Hydrogeologist (2022) identifies that the hydraulic conductivity of the void host rocks (Hodgkinson Formation hornfels) may be lower than of the surrounding rock. This suggests that where groundwater flows to or from the void occur, they are likely to be reduced relative to the wider geology.

The void is not significantly hydrogeologically linked to the existing underground workings (*ie* the decline constructed in the late 1980s). This is demonstrated by the water held in the re-opened decline portal (see photographs dated 8 July 2024 in **Figure 1**), which is approximately 200 m horizontally and 45 m vertically from the floor of the void, after the void had been empty for approximately 12 months. If a significant hydrogeological link existed between the void and the underground workings, the level of water in the decline would have fallen with the reducing water level in the void.

2.7 Water balance study

PRCP Guideline VCP item 7: A water balance study including an assessment of void surface and groundwater interactions such as:

- groundwater lowering/reduction in hydraulic head (from new voids) (*eg* caves/karst systems)
- cones of depression and associated impacts
- the drainage and flooding behaviours of surface waters in the vicinity of the void
- the potential extent of flooding and implications of interactions with the void
- a conceptual model that incorporates all projected inflows, outflows, and recharge rates
- water storage and long-term water balance
- each of the major water fluxes into and out of the void
- the sources of surface water within the mine catchment that are likely to influence the water quality in the void.

2.7.1 Groundwater lowering/reduction in hydraulic head (from new voids) (*eg* caves/karst systems)

There is expected to be a minor lowering of the groundwater level associated with the open pit. This is based on groundwater levels from before the expansion of the open pit in 1982 (Piteau & Associates 1982) and the modelled pit water levels (over 650 years) from the final void water balance model (ATCW 2022c).

Piteau and Associates (1982) measured the groundwater levels in 1982 (before the open pit was expanded) at between 359 mAHD and 365 mAHD. These were compared to the equilibrium open pit water levels from ATCWôs (2022c) modelled scenarios. The equilibrium water levels given by ATCW (2022c) for each climate scenario are:

- for the no-change scenario:
  - oscillating between 357 mRL and 369 mRL (mid-point 363 mRL), indicating the void will swap between inflows and outflows
  - as the mid-point of the oscillation range is below the transition elevation, the void is expected to act as a net groundwater sink, and correspondingly, there will generate a net minor reduction in hydraulic head
- for the RCP4.5 scenario:
  - oscillating between 355 mRL and 365 mRL, indicating that the void will act as a groundwater sink and will generate a minor reduction in hydraulic head
- for the RCP8.5 scenario:
  - oscillating between 352 mRL and 364 mRL, indicating that the void will act as a groundwater sink and will generate a minor reduction in hydraulic head.

2.7.2 Cones of depression and associated impacts

Negligible cones of depression are expected to be associated with the modest differences between the equilibrium void water levels predicted by ATCW (2022c) and the pre-pit expansion groundwater levels identified by Piteau and Associates (1982).

Further, groundwater flow near the void is expected to be relatively inhibited by the void host rocks. RLA & Hydrogeologist (2022) identifies that the hydraulic conductivity of the void host rocks (Hodgkinson Formation hornfels) may be lower than of the surrounding rock. This suggests that where groundwater flows to or from the void occur (and the associated cones of depression), they are likely to be reduced relative to the wider geology.

2.7.3 The drainage and flooding behaviours of surface waters in the vicinity of the void

The Mount Carbine void and its bund is not on a floodplain and is unlikely to interact directly with surface waters beyond its limited catchment.

The catchment of the void was included in the void water balance model by ATCW (2022c). ATCW (2022c) prepared a final void water balance model that conceptualises the inflows and outflows to the pit and a number of climate scenarios over 650 years. In line with the approach taken of this VCP, the model did not include backfilling of the void and did not include interaction of void water with future underground workings. Piteau and Associates (1982) measured the groundwater levels in 1982 (before the open pit was expanded) at between 359 mAHD and 365 mAHD. Using Piteau and Associates (1982) pre-pit expansion groundwater levels and ATCW (2022c) modelling, the void is expected to act as a groundwater sink under three modelled climate scenarios. This has been interpreted using the equilibrium water levels from the modelled scenarios and the reported elevation of the inflow/outflow transition point[11,12] (365 mAHD) in the void.

The equilibrium water levels given by ATCW (2022c) for each climate scenario are:

- for the no-change scenario:
  - oscillating between 357 mRL and 369 mRL (mid-point 363 mRL), indicating the void will swap between inflows and outflows
  - as the mid-point of the oscillation range is below the transition elevation, the void is expected to act as a net groundwater sink
- for the RCP4.5 scenario:
  - oscillating between 355 mRL and 365 mRL, indicating that the void will act as a groundwater sink
- for the RCP8.5 scenario:
  - oscillating between 352 mRL and 364 m RL, indicating that the void will act as a groundwater sink.

The void acting as a groundwater sink reduces the risk of void water migration and the associated environmental concerns.

2.7.4 The potential extent of flooding and implications of interactions with the void

The Mount Carbine void and its bund is not on a floodplain. Flooding of the open pit is not considered a significant risk based on the following modelling. Manganese Creek is the closest watercourse to the void. The lip of the void is some 10 m higher than, and 300 m away from, the channel of Manganese Creek. To flood the void, Manganese Creek would need to flood its valley up to the height of the void lip *ie* approximately 10 m above the local bed of Manganese Creek. Based on this, the cross-section area[13] of Manganese Creek valley at 10 m deep is

[11] The transition point is where water levels that are higher result in outflows from the void, and void water levels that are lower result in inflows (Diagram 19 of ATCW 2022a).

[12] ATCW (2022c) reports elevations using relative level (RL); ATCW (2022a) reports elevations using RL and AHD. As RL and AHD are used for the same elevations (*eg* spill elevation) they are assumed to be equivalent between the ATCW (2022a, 2022c) reports.

[13] Calculated as 300 m (distance from pit edge to Manganese Creek bed) + 300 m (distance from Manganese Creek bed to far side of valley) Ĭ 10 m (depth) õ 2.

3,000 m^2. Conservatively assuming the (flood) water in Manganese Creek has a speed of 1 m/s (*ie* slow), the flow in Manganese Creek would be 3,000 m^3/s. Record rainfall from Cyclone Jasper in December 2023 generated the largest monthly rainfall on record for the Mt Carbine weather station 031180 (BoM 2025). Measured flows in Manganese Creek (NRA 2023c), including those associated with the record rainfall, reported a maximum flow of 19 m^3/s (on 20 December 2023). For Manganese Creek flood waters to reach the lip of the void, approximately 150 times the measured flow in Manganese Creek during the record rainfall would be required (and not considering the noise bund, which is between Manganese Creek and the void); therefore, Manganese Creek flood waters are unlikely to enter the void.

2.7.5 A conceptual model that incorporates all projected inflows, outflows, and recharge rates

ATCW (2022c) prepared a final void water balance model that conceptualises the inflows and outflows to the pit and a number of climate scenarios over 650 years. In line with the approach taken for this VCP, the model did not include backfilling of the void and did not include interaction of void water with future underground workings. The water balance modelling indicates that the void is expected to act as a groundwater sink under three modelled climate scenarios. This has been interpreted using the equilibrium water levels from the modelled scenarios and the reported elevation of the inflow/outflow transition point[11,12] (365 mAHD) in the void. The transition point is consistent with the highest groundwater level recorded in proximity to the void by Piteau and Associates (1982) prior to the voidôs expansion between 1982 and 1990 (*ie* to its dimensions up to the re-commencement of mining in 2023).

The equilibrium water levels given by ATCW (2022c) for each climate scenario are:

- for the no-change scenario:
  - oscillating between 357mRL and 369 mRL (mid-point 363 mRL), indicating the void will swap between inflows and outflows
  - as the mid-point of the oscillation range is below the transition elevation, the void is expected to act as a net groundwater sink
- for the RCP4.5 scenario:
  - oscillating between 355 mRL and 365 mRL, indicating that the void will act as a groundwater sink
- for the RCP8.5 scenario:
  - oscillating between 352mRL and 364 mRL, indicating that the void will act as a groundwater sink.

The void acting as a groundwater sink reduces the risk of void water migration and the associated environmental concerns.

ATCW (2022c) also identified that for each of the climate scenarios modelled, there was a very low risk of spill from the final void.

2.7.6 Water storage and long-term water balance

ATCW (2022c) prepared a final void water balance model that conceptualises the inflows and outflows to the pit and a number of climate scenarios over 650 years. In line with the approach taken for this VCP, the model did not include backfilling of the void and did not include interaction of void water with future underground workings. The water balance modelling indicates that the void is expected to act as a groundwater sink under three modelled climate scenarios. This has been interpreted using the equilibrium water levels from the modelled scenarios and the reported elevation of the inflow/outflow transition point[7,8] (365 m AHD) in

the void. The transition point is consistent with the highest groundwater level recorded in proximity to the void by Piteau and Associates (1982) prior to the voidôs expansion between 1982 and 1990 (*ie* to its dimensions up to the re-commencement of mining in 2023). The equilibrium water levels given by ATCW (2022c) for each climate scenario are:

- for the no-change scenario:
  - oscillating between 357 mRL and 369 mRL (mid-point 363 mRL), indicating the void will swap between inflows and outflows
  - as the mid-point of the oscillation range is below the transition elevation, the void is expected to act as a net groundwater sink
- for the RCP4.5 scenario:
  - oscillating between 355 mRL and 365 mRL, indicating that the void will act as a groundwater sink
- for the RCP8.5 scenario:
  - oscillating between 352 mRL and 364 mRL, indicating that the void will act as a groundwater sink.

ATCW (2022c) also identified that for each of the climate scenarios modelled, there was a very low risk of spill from the final void.

2.7.7 Each of the major water fluxes into and out of the void

Surface water (from the pitôs limited catchment) is expected to be the major source of water to the pit. Input from groundwater is expected to be negligible. Evaporation will be the major output for the pit.

ATCW (2022c) prepared a final void water balance model that conceptualises the inflows and outflows to the pit and a number of climate scenarios over 650 years. In line with the approach taken for this VCP, the model did not include backfilling of the void and did not include interaction of void water with future underground workings. The water balance modelling indicates that the void is expected to act as a groundwater sink under three modelled climate scenarios. This has been interpreted using the equilibrium water levels from the modelled scenarios and the reported elevation of the inflow/outflow transition point[11,12] (365 m AHD) in the void. The transition point is consistent with the highest groundwater level recorded in proximity to the void by Piteau and Associates (1982) prior to the voidôs expansion between 1982 and 1990 (*ie* to its dimensions up to the re-commencement of mining in 2023). The equilibrium water levels given by ATCW (2022c) for each climate scenario are:

- for the no-change scenario:
  - oscillating between 357 mRL and 369 mRL (mid-point 363 mRL), indicating the void will swap between inflows and outflows
  - as the mid-point of the oscillation range is below the transition elevation, the void is expected to act as a net groundwater sink
- for the RCP4.5 scenario:
  - oscillating between 355 mRL and 365 mRL, indicating that the void will act as a groundwater sink
- for the RCP8.5 scenario:
  - oscillating between 352 mRL and 364 mRL, indicating that the void will act as a groundwater sink.

ATCW (2022c) also identified that for each of the climate scenarios modelled, there was a very low risk of spill from the final void.

2.7.8 The sources of surface water within the mine catchment that are likely to influence the water quality in the void

Sources of surface water within the mine catchment that are likely to influence the water quality in the void are expected to be consistent with those that contributed to the documented open pit water quality (*ie* between 1992 and 2023) (see **Appendix A**). The sources are run-off from:

- disturbed and undisturbed areas immediately adjacent to the pit
- the noise/final bund
- the waste rock dump.

2.8 Predicted long-term water quality

Guideline VCP item 8: Predicted water quality in the long-term including potential stratification

The Mount Carbine open pit has contained water since the cessation of open pit operations in 1988. Pit water quality data is available from 1992 to 2023 (when the pit was emptied). This data provides a robust predictor of future pit water quality because the processes and materials that generated the pit water quality will be the same as those after closure (*ie* the excavated rock in the void catchment is from the same rock units previously stored in the voidôs catchment). NRA 2023b (**Appendix L**) provides a summary of the open pit water quality. Salient parts of NRA (2023b) are reproduced below.

2.8.1 Void water quality

Void water quality was examined to inform the environmental risk associated with spills (*ie* the void over-topping) and seepage (loss from the wall and floor). The examination compared all available void water quality data (*ie* from 1992 to 2023) to:

- aquatic ecosystem protection guideline values
- the quality of water previously released from site
- livestock drinking water quality guideline values.

Additionally, DETSI requested on 8 November 2024 that pit water quality be compared to reference surface water quality. Data from surface water reference sites SW1 (on Manganese Creek) and SW16 (on Holmes Creek) were used for the comparison.

Before assessments were undertaken, water quality data for each site-analyte was screened for outliers[14], which were excluded from the assessment. Outliers were nominated as values:

- greater than the 75th percentile plus 1.5 times the interquartile range[15]; or
- less than the 25th percentile minus 1.5 times the interquartile range.

Analytical reliability is reduced as determinations approach the limit of reporting (LOR); therefore, values that were less than 10 times the LOR were not considered outliers. Data summaries and outliers are in **Attachment 1, Appendix L**.

[14] Using the inter-quartile range method described in DES (2021).

[15] 75th quartile ï 25th quartile.

Aquatic ecosystem protection guideline values

Void water quality was assessed against aquatic ecosystem protection guideline values using:

- the Mount Carbine receiving environment monitoring program (REMP), (NRA 2020, **Appendix M**) site-specific guideline values (SSGVs) for Manganese Creek[16] for pH, electrical conductivity (EC), sulfate, fluoride, and filtered concentrations of aluminium, antimony, arsenic, cadmium, chromium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, tungsten, and zinc. Medians are the assessment values used with SSGVs
- toxicant default guideline values (DGVs) for the protection of moderately disturbed aquatic ecosystems (ANZG 2018) for filtered concentrations of aluminium, antimony, arsenic, boron, cadmium, chromium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, uranium, and zinc. The 95th percentiles are the assessment values used with toxicant DGVs.

Assessment values had to be greater than (or less than for pH assessment against lower guideline values) all relevant guideline values (*ie* DGVs and SSGVs) for the analyte to report an exceedance. Exceedances were reported for pH, EC, fluoride, sulfate, filtered arsenic, filtered cadmium, filtered molybdenum, filtered tungsten and filtered uranium.

Release water quality

Void water was compared to water quality of releases[17] from TSF4 that occurred from:

- 24 January ï 12 February 2013
- 15 April ï 8 May 2014
- 3ï 14 February 2022.

Maximum values in void water were compared to maximum values during releases, and the minimum pH value in the void water was compared to the minimum pH recorded during the releases. pH, EC, sulfate, fluoride, sodium, calcium, magnesium, chloride, and filtered and unfiltered concentrations of aluminium, antimony, arsenic, boron, cadmium, chromium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, and uranium were assessed.

The maximum value for void water exceeded the maximum value record during releases for pH, EC, sulfate, fluoride, sodium, calcium, magnesium, chloride, filtered antimony, filtered and unfiltered arsenic, filtered and unfiltered boron, filtered and unfiltered cadmium, filtered and unfiltered cobalt, filtered lead, filtered and unfiltered nickel, filtered and unfiltered selenium, filtered and unfiltered tungsten, filtered and unfiltered uranium, and unfiltered zinc. The minimum void water pH was not lower than the lowest pH recorded during a release.

Livestock drinking water quality guideline values

Void water quality was assessed against livestock (beef cattle) drinking water quality guideline values (ANZG 2018). The assessment compared the maximum, median and minimum of each analyte in the void water to the guideline value. Analytes assessed were EC, sulfate, fluoride, aluminium, arsenic, boron, cadmium, chromium, cobalt, copper, lead, molybdenum, nickel, selenium, uranium and zinc.

[16] If the void were to spill, Manganese Creek is expected to be the receiving water.

[17] Only release events where the REMP reporting has been concluded.

The only reported exceedance was for fluoride. The maximum, median and minimum values all exceed the fluoride guideline value for livestock (beef cattle) drinking water.

Surface water reference water quality

Void water quality was assessed against surface water reference water quality provided by reference sites on Manganese and Holmes creeks (monitoring sites SW1 and SW16, respectively). The assessment compared the median of available data of each analyte in the void water to the 80th percentile (and 20th percentile for analytes with range thresholds) of reference site values[18].

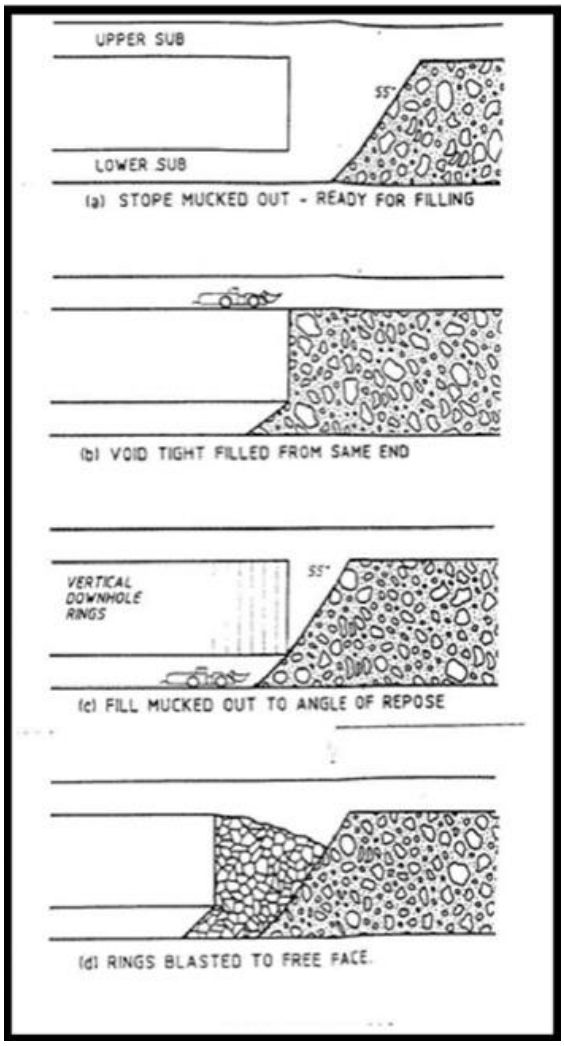
Analytes assessed were pH, EC, turbidity, chloride, fluoride, sulfate, aluminium, antimony, arsenic, boron, cadmium, chromium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, tungsten, uranium and zinc.

Analytes in the pit water that were found to exceed the 80th (or the 20th percentile for range analytes) were: pH, EC, sulfate, fluoride, chloride, arsenic (filtered and unfiltered), boron (filtered and unfiltered), cadmium (filtered and unfiltered), molybdenum (filtered, unfiltered), tungsten (filtered and unfiltered) and uranium (filtered and unfiltered).

2.8.2 Pit water stratification

Two investigations of pit water stratification have been undertaken. The first in January (summer) of 2013 and the second in August (winter) of 2021. The void water stratification is unlikely to be influenced by the existing underground workings (*ie* the partly completed decline started *circa* 1987) as there does not appear to be a significant hydrogeological link between the void and the existing underground workings. Underground mining is expected to be by the Avoca method which includes progressive backfilling (**Figure 2**). Interaction of void water with backfilled underground workings is expected to be negligible. The results of stratification investigation monitoring are in **Table 2** (2013 investigation) and **Table 3** (2021 investigation). The consistency of water quality with depth indicates stratification does not occur.

[18] Where there were eight or more values for the analyte at the reference site.



Source: Deswik 2022

Figure 2: Avoca mining method

Table 2: Open pit (monitoring site OW1) depth sampling results, 11 January 2013

Analyte	Unit	Depth m	Value
Aluminium, filtered	mg/L	1	0.02
		5	0.018
		10	0.018
		15	0.017
		20	0.021
		25	0.022
		30	0.015
Aluminium, unfiltered	mg/L	1	0.02
		5	0.019
		10	0.022
		15	0.018
		20	0.021
		25	0.022
		30	0.016

Analyte	Unit	Depth m	Value
Arsenic, filtered	mg/L	1	0.15
		5	0.15
		10	0.15
		15	0.15
		20	0.15
		25	0.14
		30	0.15
		1	0.15
		5	0.15
		10	0.15
		15	0.15
		20	0.15
		25	0.14
		30	0.15
Cadmium, filtered	mg/L	1	0.0007
		5	0.0007
		10	0.0006
		15	0.0007
		20	0.0007
		25	0.0006
		30	0.0007
Cadmium, unfiltered	mg/L	1	0.0007
		5	0.0007
		10	0.0006
		15	0.0007
		20	0.0007
		25	0.0007
		30	0.0007
Calcium	mg/L	1	95
		5	94
		10	92
		15	93
		20	92
		25	90
		30	94
Chloride	mg/L	1	63
		5	63
		10	63
		15	64
		20	64
		25	59
		30	59
Chromium, filtered	mg/L	1	<0.001
		5	<0.001
		10	<0.001
		15	<0.001
		20	<0.001
		25	<0.001
		30	<0.001
Chromium, unfiltered	mg/L	1	<0.001
		5	<0.001
		10	<0.001
		15	<0.001
		20	<0.001
		25	<0.001
		30	<0.001

Analyte	Unit	Depth m	Value
Cobalt, filtered	mg/L	1	<0.001
		5	<0.001
		10	<0.001
		15	<0.001
		20	<0.001
		25	<0.001
		30	<0.001
Cobalt, unfiltered	mg/L	1	<0.001
		5	<0.001
		10	<0.001
		15	<0.001
		20	<0.001
		25	<0.001
		30	<0.001
Copper, filtered	mg/L	1	<0.001
		5	<0.001
		10	<0.001
		15	<0.001
		20	<0.001
		25	<0.001
		30	<0.001
Copper, unfiltered	mg/L	1	<0.001
		5	<0.001
		10	<0.001
		15	<0.001
		20	<0.001
		25	<0.001
		30	<0.001
EC	ÕS/cm	1	860
		5	860
		10	860
		15	860
		20	870
		25	840
		30	830
Fluoride	mg/L	1	8.7
		5	8.6
		10	8.6
		15	8.7
		20	8.5
		25	8.4
		30	8.5
Lead, filtered	mg/L	1	<0.001
		5	<0.001
		10	<0.001
		15	<0.001
		20	<0.001
		25	<0.001
		30	<0.001
Lead, unfiltered	mg/L	1	<0.001
		5	<0.001
		10	<0.001
		15	<0.001
		20	<0.001
		25	<0.001
		30	<0.001

Analyte	Unit	Depth m	Value
Magnesium	mg/L	1	27
		5	26
		10	26
		15	26
		20	26
		25	25
		30	26
Manganese, filtered	mg/L	1	<0.005
		5	<0.005
		10	<0.005
		15	<0.005
		20	<0.005
		25	<0.005
		30	<0.005
Manganese, unfiltered	mg/L	1	<0.005
		5	<0.005
		10	<0.005
		15	<0.005
		20	<0.005
		25	<0.005
		30	<0.005
Mercury, unfiltered	mg/L	1	<0.00010
		5	<0.00010
		10	<0.00010
		15	<0.00010
		20	<0.00010
		25	<0.00010
		30	<0.00010
Molybdenum, filtered	mg/L	1	0.063
		5	0.064
		10	0.063
		15	0.064
		20	0.064
		25	0.065
		30	0.064
Molybdenum, unfiltered	mg/L	1	0.063
		5	0.064
		10	0.066
		15	0.064
		20	0.067
		25	0.07
		30	0.067
pH	No unit	1	8.3
		5	8.3
		10	8.3
		15	8.3
		20	8.2
		25	8
		30	7.6
Potassium	mg/L	1	2.6
		5	2.7
		10	2.7
		15	2.6
		20	2.6
		25	2.5
		30	2.6

Analyte	Unit	Depth m	Value
Sodium	mg/L	1	42
		5	42
		10	41
		15	41
		20	41
		25	40
		30	41
Sulfate	mg/L	1	260
		5	260
		10	250
		15	250
		20	250
		25	250
		30	250
Zinc, filtered	mg/L	1	<0.005
		5	0.007
		10	<0.005
		15	<0.005
		20	<0.005
		25	0.017
		30	<0.005
Zinc, unfiltered	mg/L	1	0.02
		5	0.008
		10	0.006
		15	0.012
		20	0.009
		25	0.019
		30	0.029

Table 3: Open pit (monitoring site OW1) depth sampling results, 26 August 2021

Analyte	Unit	Depth m	Value
Total alkalinity	mgEqCaCO$_3$/L	1	69
		10	71
		20	73
		30	73
		40	72
Aluminium, filtered	mg/L	1	0.02
		10	0.021
		20	0.019
		30	0.023
		40	0.019
Aluminium, unfiltered	mg/L	1	0.022
		10	0.023
		20	0.041
		30	0.24
		40	0.023
Antimony, filtered	mg/L	1	<0.003
		10	<0.003
		20	<0.003
		30	<0.003
		40	<0.003

Analyte	Unit	Depth m	Value
Antimony, unfiltered	mg/L	1	<0.003
		10	<0.003
		20	<0.003
		30	<0.003
		40	<0.003
Arsenic, filtered	mg/L	1	0.087
		10	0.088
		20	0.089
		30	0.091
		40	0.093
Arsenic, unfiltered	mg/L	1	0.093
		10	0.094
		20	0.097
		30	0.095
		40	0.1
Boron, filtered	mg/L	1	0.024
		10	0.024
		20	0.023
		30	0.023
		40	0.023
Boron, unfiltered	mg/L	1	0.024
		10	0.024
		20	0.023
		30	0.023
		40	0.023
Cadmium, filtered	mg/L	1	<0.0001
		10	<0.0001
		20	<0.0001
		30	<0.0001
		40	<0.0001
Cadmium, unfiltered	mg/L	1	<0.0001
		10	<0.0001
		20	<0.0001
		30	<0.0001
		40	<0.0001
Calcium	mg/L	1	63
		10	63
		20	62
		30	63
		40	62
Chloride	mg/L	1	36
		10	37
		20	36
		30	35
		40	35
Chromium, filtered	mg/L	1	<0.001
		10	<0.001
		20	<0.001
		30	<0.001
		40	<0.001
Chromium, unfiltered	mg/L	1	<0.001
		10	<0.001
		20	<0.001
		30	<0.001
		40	<0.001

Analyte	Unit	Depth m	Value
Cobalt, filtered	mg/L	1	<0.001
		10	<0.001
		20	<0.001
		30	<0.001
		40	<0.001
Cobalt, unfiltered	mg/L	1	<0.001
		10	<0.001
		20	<0.001
		30	<0.001
		40	<0.001
Copper, filtered	mg/L	1	<0.001
		10	<0.001
		20	<0.001
		30	<0.001
		40	<0.001
Copper, unfiltered	mg/L	1	<0.001
		10	<0.001
		20	0.001
		30	0.001
		40	0.001
EC	ÕS/cm	1	650
		10	620
		20	620
		30	620
		40	620
Fluoride	mg/L	1	6.7
		10	6.8
		20	6.7
		30	6.8
		40	6.8
Lead, filtered	mg/L	1	<0.001
		10	<0.001
		20	<0.001
		30	<0.001
		40	<0.001
Lead, unfiltered	mg/L	1	<0.001
		10	<0.001
		20	<0.001
		30	<0.001
		40	<0.001
Magnesium	mg/L	1	19
		10	19
		20	19
		30	19
		40	19
Manganese, filtered	mg/L	1	<0.005
		10	<0.005
		20	<0.005
		30	<0.005
		40	<0.005
Manganese, unfiltered	mg/L	1	0.023
		10	0.025
		20	0.032
		30	0.033
		40	0.038

Analyte	Unit	Depth m	Value
Mercury, unfiltered	mg/L	1	<0.00005
		10	<0.00005
		20	<0.00005
		30	<0.00005
		40	<0.00005
Molybdenum, filtered	mg/L	1	0.05
		10	0.051
		20	0.051
		30	0.053
		40	0.053
Molybdenum, unfiltered	mg/L	1	0.05
		10	0.051
		20	0.051
		30	0.053
		40	0.056
Nickel, filtered	mg/L	1	<0.001
		10	<0.001
		20	0.001
		30	<0.001
		40	0.001
Nickel, unfiltered	mg/L	1	<0.001
		10	0.001
		20	0.001
		30	<0.001
		40	0.001
pH	No unit	1	8.06
		10	7.92
		20	7.79
		30	7.82
		40	7.78
Potassium	mg/L	1	2.7
		10	2.8
		20	2.7
		30	2.7
		40	2.7
Selenium, filtered	mg/L	1	<0.003
		10	<0.003
		20	<0.003
		30	<0.003
		40	<0.003
Selenium, unfiltered	mg/L	1	<0.003
		10	<0.003
		20	<0.003
		30	<0.003
		40	<0.003
Sodium	mg/L	1	27
		10	27
		20	26
		30	27
		40	27
Sulfate	mg/L	1	190
		10	190
		20	190
		30	190
		40	190

Analyte	Unit	Depth m	Value
Tungsten, filtered	mg/L	1	0.023
		10	0.023
		20	0.023
		30	0.025
		40	0.024
Tungsten, unfiltered	mg/L	1	0.024
		10	0.025
		20	0.026
		30	0.026
		40	0.027
Uranium, filtered	mg/L	1	0.0005
		10	0.0005
		20	0.0005
		30	0.0005
		40	0.0005
Uranium, unfiltered	mg/L	1	0.0006
		10	0.0006
		20	0.0006
		30	0.0006
		40	0.0006
Zinc, filtered	mg/L	1	<0.005
		10	<0.005
		20	<0.005
		30	<0.005
		40	<0.005
Zinc, unfiltered	mg/L	1	<0.005
		10	<0.005
		20	<0.005
		30	<0.005
		40	<0.005

2.9 3D void design plan

PRCP Guideline VCP item 9: 3D void design plan

A three-dimensional pit model has been developed by EQR geologists. Diagrammatic outputs of the final void are shown in **Figures 3** and **4**.

2.10 Rehabilitation strategies

PRCP Guideline VCP item 10: Rehabilitation strategies

Section 1.5 of the PRCP details the rehabilitation management approach. Section 1.5.5 deals with the void. Section 1.5.5 of the PRCP is reproduced in **Text Box 3**.

Text Box 3: Section 1.5.5 of the PRCP

Section 1.5.5 Voids

The open pit will provide access to the underground mine workings, subject to renewal of underground mine methods; upon cessation of all mining, the open pit will remain as a residual void.

Contemporary assessment of the void status at end-of-mine life confirms that, apart from the void itself, serious environmental harm is not expected.

Water Quality

The quality of water in the void measured up to early 2023, that includes an extended period of mine closure, is indicative of the water quality that can be expected in the future (refer to PRCP Appendix 3).

Spill risk

It is not expected that the void will overtop following mine closure under current climatic conditions nor projected climate change scenarios (refer to PRCP Appendix 4).

Sink

It is expected that the void will be a groundwater sink (refer to PRCP Appendices 2 and 3).

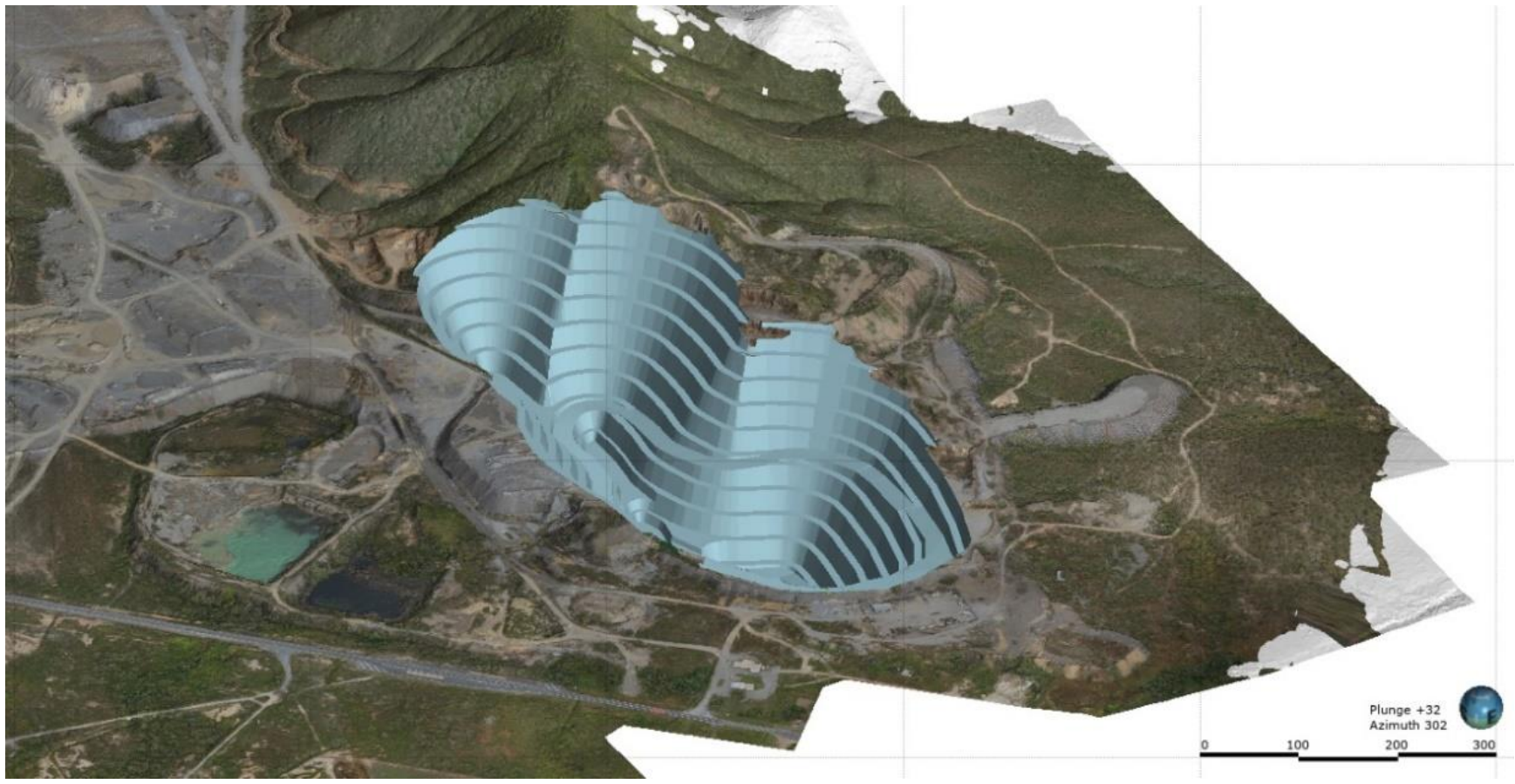


Figure 3: Oblique output of the Mount Carbine 3-dimensional final void design

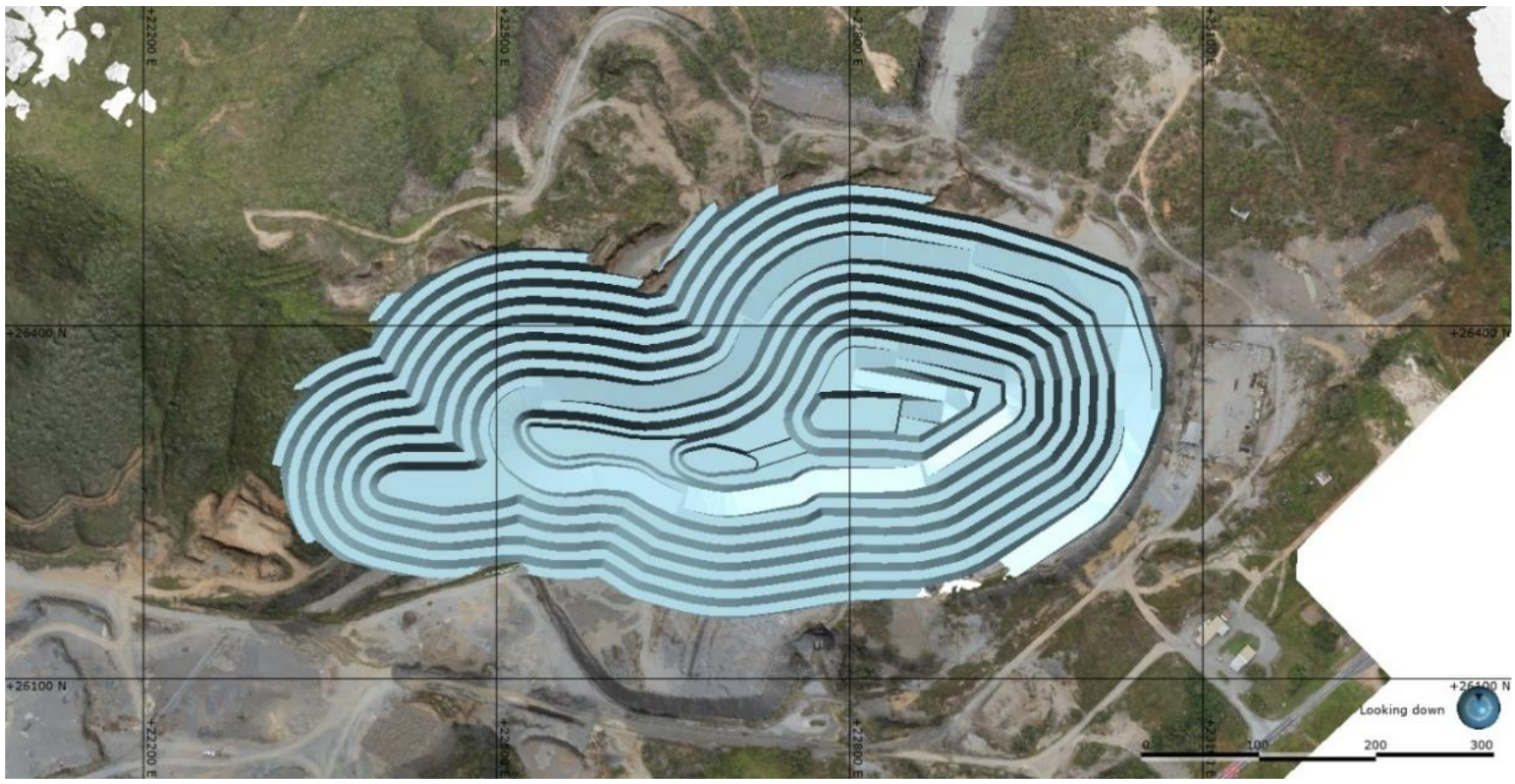


Figure 4: Plan output of the Mount Carbine 3-dimensional final void design

3. DETSI comments

The following section provides information to address comments made by DETSI on a working copy of the VCP.

3.1 Historical underground mining method

DETSI comment 1: Historical underground mining method

The following information is from EQR[19] and edited for context.

The underground mining at Mount Carbine has occurred in two phases.

- Phase 1: Historical artisanal workings:
  - Artisanal workings where small-scale mining occurred down to 60 m depth using hand mining methods. Drives were 1.5 m Ĭ 2.0 m generally and rabbit holed the high-grade veins. None of these workings were outside the pit completed in 1986 by Roche Brothers (previous mine operators) *ie* Roche Brothers mined to 150 m depth, well below any artisanal workings and 200 m either end past the workings. The location of historical workings in relation to the expanded pit is shown in **Figure 5**. The EQR pit extension does not have any old workings in them.
- Phase 2: Decline constructed by Poseidon Minerals 1987ï 1988:
  - A decline was started by Poseidon Minerals *circa* 1987 when open cut mining was completed. A full underground mine was designed, and feasibility completed. The mine included a 2.8 km decline for sub-level block caving with ore extracted on levels and conveyed to the surface via the decline. The mine was planned to take out 7 Mt at 0.22% WO_3 using this method. Poseidon Minerals ran out of money when 430 m of the decline had been developed (**Figure 6**) and the project went into hold in 1988. EQR has reopened the decline portal (**Figures 1** & **7**). This decline was completed at 1:6 grade using modern underground mining equipment (*eg* Jumbos, scoop trams, underground trucks). It was a drill-blast-muck operation.

[19] *Pers. comm.* Tony Bainbridge, Exploration Manager, EQR, to John Broughton, Principal Scientist, NRA, email dated 16 August 2024.

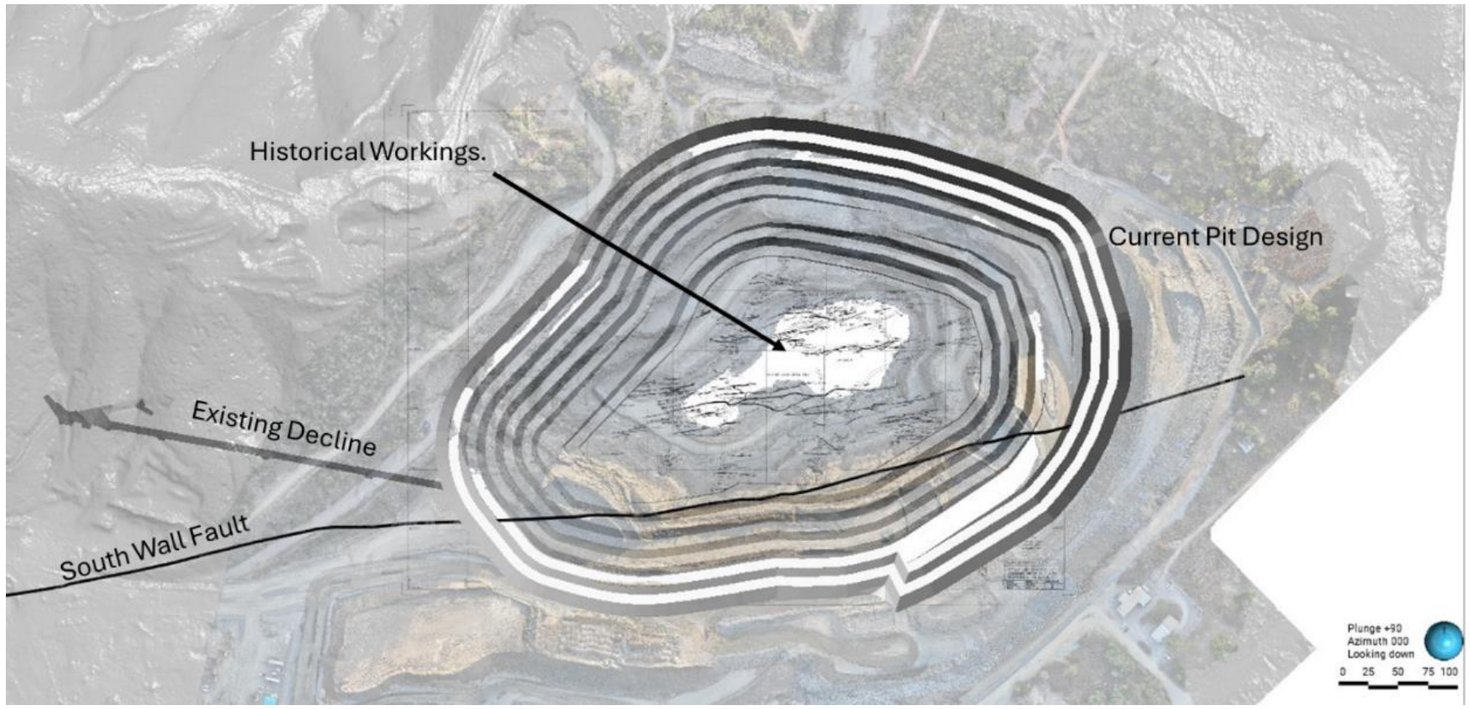


Figure 5: Current pit design showing South Wall Fault and location of 1987 decline

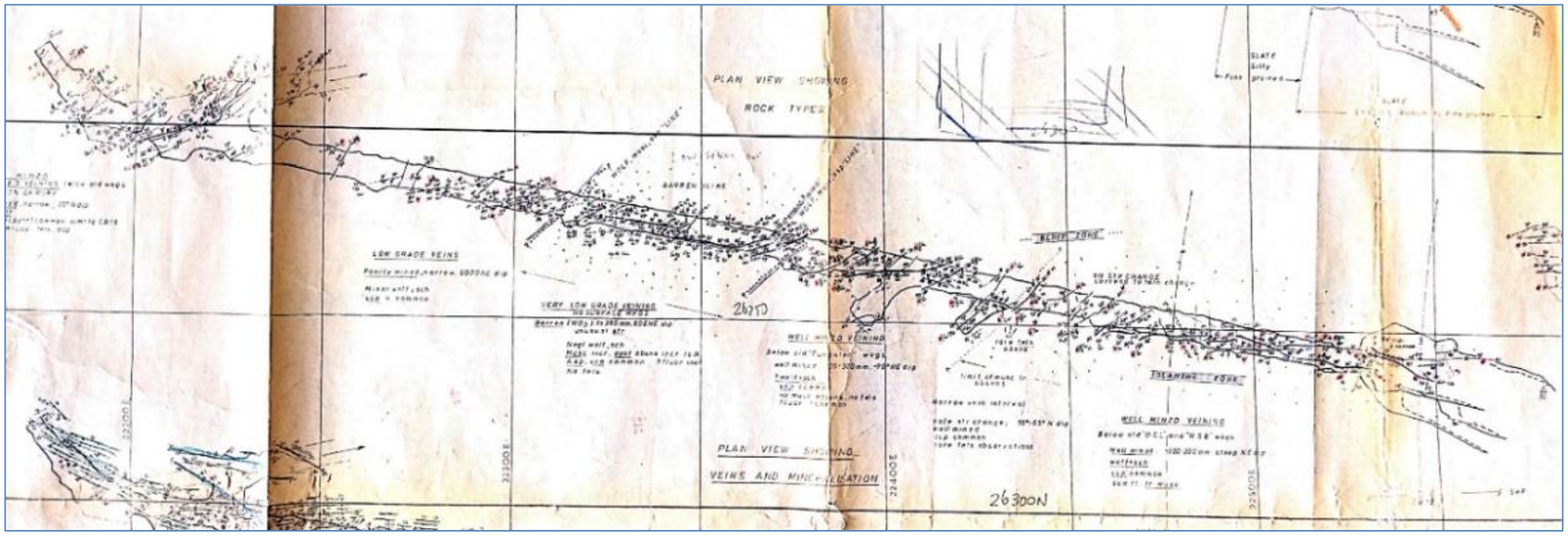


Figure 6: Decline in plan with rock types



Figure 7: Reopened Poseidon Minerals portal in 2024

3.2 Interactions between mining structures and open pit

DETSI comment 2: Assessment of interactions between the underground mining structures and the current open pit

There is no interaction between the void and the existing underground mining structures (*ie* the partially constructed decline started *circa* 1987) other than the portalôs location in the void.

The following information is from EQR[20] and edited for context.

> EQR has reviewed mapping of the decline by Poseidon and over 14 holes in the tunnel area to confirm the geology is correct. There were no major ground condition issues ï in fact no rock bolting was deemed necessary when putting this tunnel in. This would be rectified now by installing rock bolting and meshing over its entire length as per updated

[20] *Pers. comm.* Tony Bainbridge, Exploration Manager, EQR, to John Broughton, Principal Scientist, NRA, emails dated 16 August 2024 and 12 September 2024.

mining laws. The mapping does not show any major structures in this decline and was a dry decline when installed.

Work on the adjacent open cut has shown that the walls are extremely competent with no rock falls *etc*. Following the engineered pit designs has led to a safe working pit environment and the general assessment is that the adjacent underground in the same rocks will be extremely competent provided Geotech design is followed.

The planned underground mine will follow the outline developed by Deswik (2022) (**Figure 8**)[21]. The planned underground mine includes a second portal in the lower parts of the open pit. The proposed underground mining method is based on the Avoca approach (**Figure 2**), which is expected to be suitable for the narrow near-vertical veins that host the mineralisation. An important aspect of the Avoca method is that voids are progressively backfilled as shown in **Figure 2** and this has a benefit of reducing the risk of subsidence. Based on the geotechnical studies of Piteau and Associates (1982) and Golder (1984), open pit geotechnical assessments, and observation of local ground conditions, subsidence due to underground mining that follows Deswik (2022, **Appendix N**) and using the Avoca method is expected to be unlikely.

The void water quality and stratification are unlikely to be influenced by the existing underground workings (*ie* the partly completed decline started *circa* 1987) as there does not appear to be a significant hydrogeological link between the void and the existing underground workings. Planned underground mining is expected to be by Avoca method, which includes progressive backfilling. Interaction of void water with backfilled underground workings is expected to be negligible.

[21] *Pers. comm.* Tony Bainbridge, Exploration Manager, EQR, to John Broughton, Principal Scientist, NRA, email dated 12 September 2024.

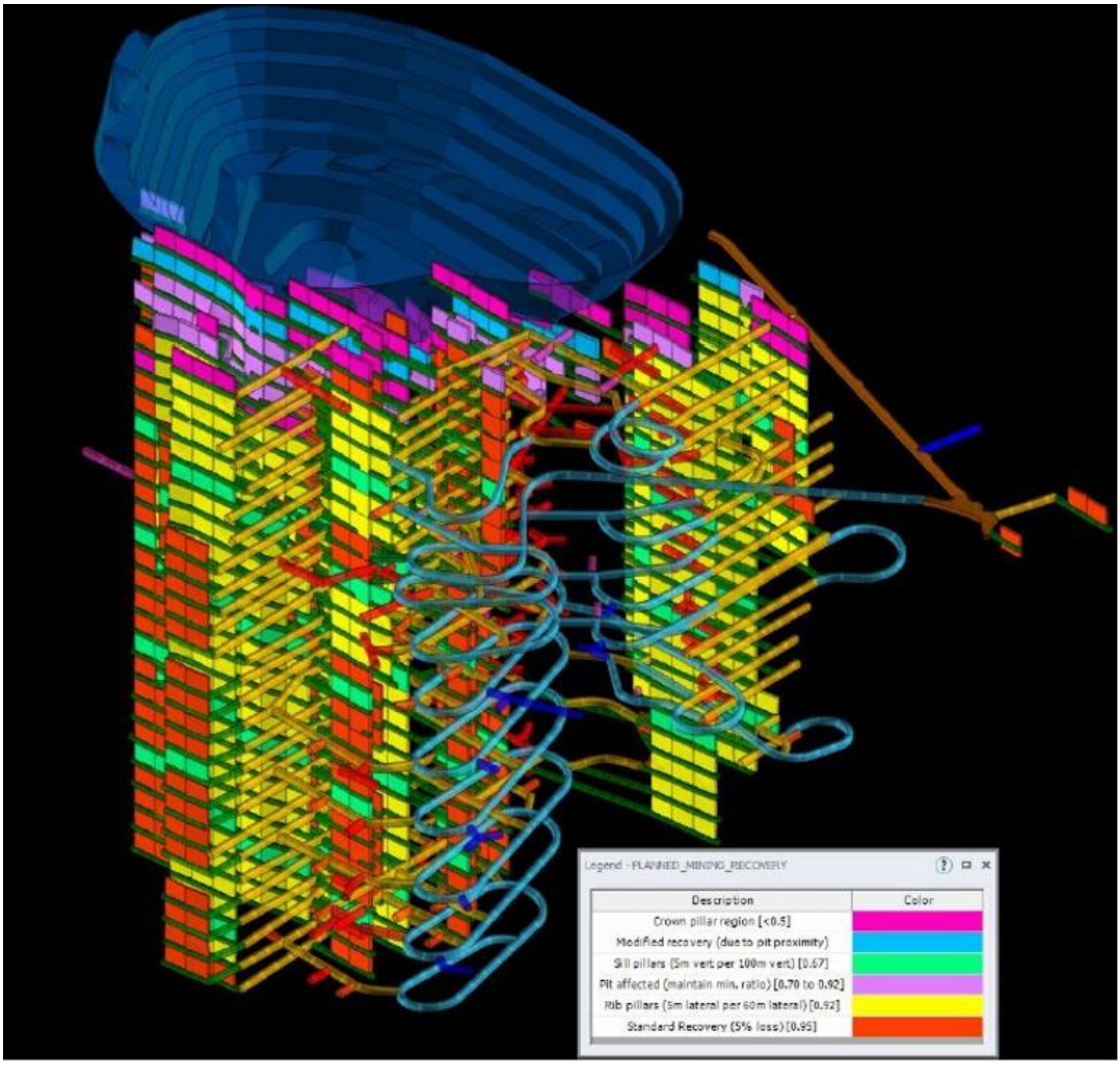


Figure 8: Conceptual underground mine plan (Deswik 2022)

3.3 Rehabilitation of historical infrastructure

DETSI comment 3: rehabilitation of historical underground infrastructure/structures required to be completed

There are no historical workings within the zone where EQR is undertaking mining[22].

Rehabilitation of historical underground infrastructure/structures required to be completed is expected to be minimal; the planned mining method (modified Avoca) involves backfilling of stopes (EQR 2023, **Appendix O**), and any remaining decline will be sealed and made safe as part of closure.

3.4 Stability of the final structure

DETSI comment 4: Geotechnical certification of the stability of the final structure

Paul Maconochie (RPEQ 5828), Principal Geotechnical Engineer at GeoTek Solutions Pty Ltd examined the stability of the open pit design and determined that the overall stability of the pit is high and that the factor of safety for the final void would be greater than 1.5 (GTS 2024). GTS (2024) concludes that based on the Piteau 1982 design considerations, the absence of deterioration of the pit walls in fresh rock over the period that the pit has existed and the adoption of contemporary blasting designs that the walls will remain stable overall in the long term.

EQR plan to undertake underground mining at Mount Carbine using the Avoca mining method. The method uses a cut and fill approach, with space created by mining being filled by waste rock. Consequently, the risk of post-mining subsidence is minimised as the voids created by ore recovery have been substantially backfilled (GTS 2024).

A view of the underground mine development designed by Deswick (2022) is shown in **Figure 8**. In relation to final void subsidence consideration would need to be given to the crown pillar and preventing that from failing and thereby connecting completed underground mining with the open pit. Even if this were to occur it would not necessarily result in subsidence extending outside of the pit footprint.

3.5 Noise bund: exclusion of fauna; erodibility; revegetation

DETSI comment 5: é information, including ability to exclude fauna and humans, erodibility and ability to revegetate, should be provided for the noise bundé

Fauna, including humans, will be excluded from the void by the noise bund (which also acts as the final safety bund) and where it is not practicable to construct the bund (eg the steep areas to the north of the open pit), a fence with warning signs will be installed (GTS 2024).

[22] *Pers. comm.* Tony Bainbridge, Exploration Manager, EQR, to John Broughton, Principal Scientist, NRA, email dated 16 August 2024.

With respect to weathering and erosion of the noise bund, GTS (2024) identifies:

> *The rock in the Safety and Noise Bund is highly resistant to weathering and will not break down significantly over the long term. The blockiness and angularity of the rock results in an inherently high particle to particle contact friction … and, combined with its angularity, is expected to remain tightly interlocked. As a result, weathering and erosion are unlikely to compromise the stability of the noise bund in the long term.*

Revegetation of the noise bund is not planned on account of impracticality; rather, resources will be prioritised for weed management. Revegetation trials on similar material (the low-grade material stockpile) were conducted by NRA in 1994 (**Appendix P**). The revegetation trial demonstrated the predicted poor revegetation outcomes on the rocky low-grade material.

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Appendix A:
Mount Carbine Mining Stage 3 Water Management Plan (ATCW 2022a)

REPORT

Mt Carbine Quarries Pty Ltd
ABN: 52 065 645 650

Mount Carbine Mining
Stage 3 Water Management Plan

119190.04R01_0
NOVEMBER 2022

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Document Control

Project Name:	Mount Carbine Mining
Document Title:	Water Management Plan
File Location:	N:\Synergy\Projects\119\119190 SMI Mt Carbine\04 Stage 3 Water Mgt Plan\Documents\R01\Text\119190-04R01_0.docx
Document Number:	119190-04R01_0

Revision History

Revision	Issue	Issue Date	Prepared by	Reviewed by
A	WORKING DRAFT	08 Nov 2022	Naomi Tyack	Lee Rigley
B	WORKING DRAFT	17/11/2022	Naomi Tyack	Lee Rigley
0	FINAL	30/11/2022	Naomi Tyack	Lee Rigley

Issue Register

Distribution List	Date
Tim Anderson, NRA Environmental Consultants	30 November 2022

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1 INTRODUCTION

1.1 Background

The Mount Carbine Project (the Project) is located approximately 80 km north-west of Cairns, in North Queensland. The Project currently comprises the extraction of tungsten from the mine waste that exists at the site and repurposing the resulting waste material for beneficial reuse. The mine waste is derived from the site waste emplacements formed as part of historical mining activities on the mine leases (MLs). The repurposing of the mine waste is being undertaken as a staged process. Stage 1 was the pilot study to determine the feasibility of the process and to set up the reprocessing plant. Stage 2 of the works allowed for increasing processing rates of the mine waste up to 500,000 t/year, with the plant operating seven days a week. Stage 3 will increase the processing of tungsten ore by the mining of material from the Open Cut Pit. The Stage 1 pilot study and Stage 2 increase in processing rates have been completed and the Stage 3 works are being planned. This report addresses the on-site water management for the Stage 3 works.

The mine waste extraction and screening activity is a licensed extractive activity, that is, a quarry operation that occurs under Environmental Authority (EA) Permit No. EPPR00438313, issued by the Department of Environment and Science (DES), dated 16 March 2021 **[1]**. This quarrying operation is separate to the mining and processing activity.

The development and operation of the ML's, held by Mount Carbine Quarries Pty Ltd (MCQ), is subject to EA Permit No. EPML00956913 **[2]**, issued by DES, and effective from 14 April 2022. This EA relates to the mining and processing of the metal ore for quantities greater than 100,000 t per annum.

The site is located on ML 4867 and ML 4919, and includes the following key features with regards to mining activities:

- Open Cut Pit;
- Crushing Plant (quarry);
- Processing Plant and Workshop;
- Tailings Storage Facility 3 (TSF3);
- Tailings Storage Facility 4 (TSF4); and
- Clean Water Dam.

General layout plans of the Mount Carbine Project showing the location of these features for the existing site layout have been provided in **Appendix A**. The figures were reproduced from the 'Mount Carbine Tungsten Project Estimated Rehabilitation Costs (ERC)' report **[3]** and the project briefing document **[4]**. Layout plans for the proposed changes to the site operations have been included in **Appendix B**. The proposed site layout is based on the designs developed by ATC Williams Pty Ltd (ATCW) to address the requirements to recommence mining from the existing pit **[5]**.

1.2 Purpose of the Water Management Plan

A water management plan (WMP) is required to support the application to DES to amend the EA for the recommencement of mining of the Open Cut Pit. EQ Resources, acting as MCQ, commissioned ATCW to undertake development of a WMP for the Project.

The purposes of this WMP document are to:

- Comply with the likely EA requirements and conditions;
- Outline the control measures to be implemented to prevent detrimental impact on receiving waters; and,
- Provide site personnel with a guide for effective water management.

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The contents of the WMP were prepared to satisfy the conditions in the Department of Environment and Science (DES) guideline 'Preparation of Water Management Plans for Mining Activities' **[6]**. The WMP includes the following elements.

- Discussion of the environmental values impacted by the mining operations
- Contaminant source study
- Water management system
- Site water balance and model
- Emergency and contingency planning
- Monitoring and review

1.3 Report Structure

The structure of this report, to address the above purpose and scope, is as follows:

Section 2.0 Provides a description of the Project in the context of the site climatic and hydrological conditions, the geology and water management features.

Section 3.0 Presents a summary of the environmental values surrounding the Project site.

Section 4.0 Presents an overview of the outcomes of the contaminant source study and the receiving environment water quality requirements.

Section 5.0 Outlines the water management system.

Section 6.0 Presents a summary of the site water balance modelling and reviews the overall hydrological performance based on the adopted water management layout.

Section 7.0 Details site water monitoring and review requirements.

Section 8.0 Provides an overview of the emergency and contingency procedures on-site.

Section 9.0 Provides an overview of the erosion and sediment control plan developed for the site (by others).

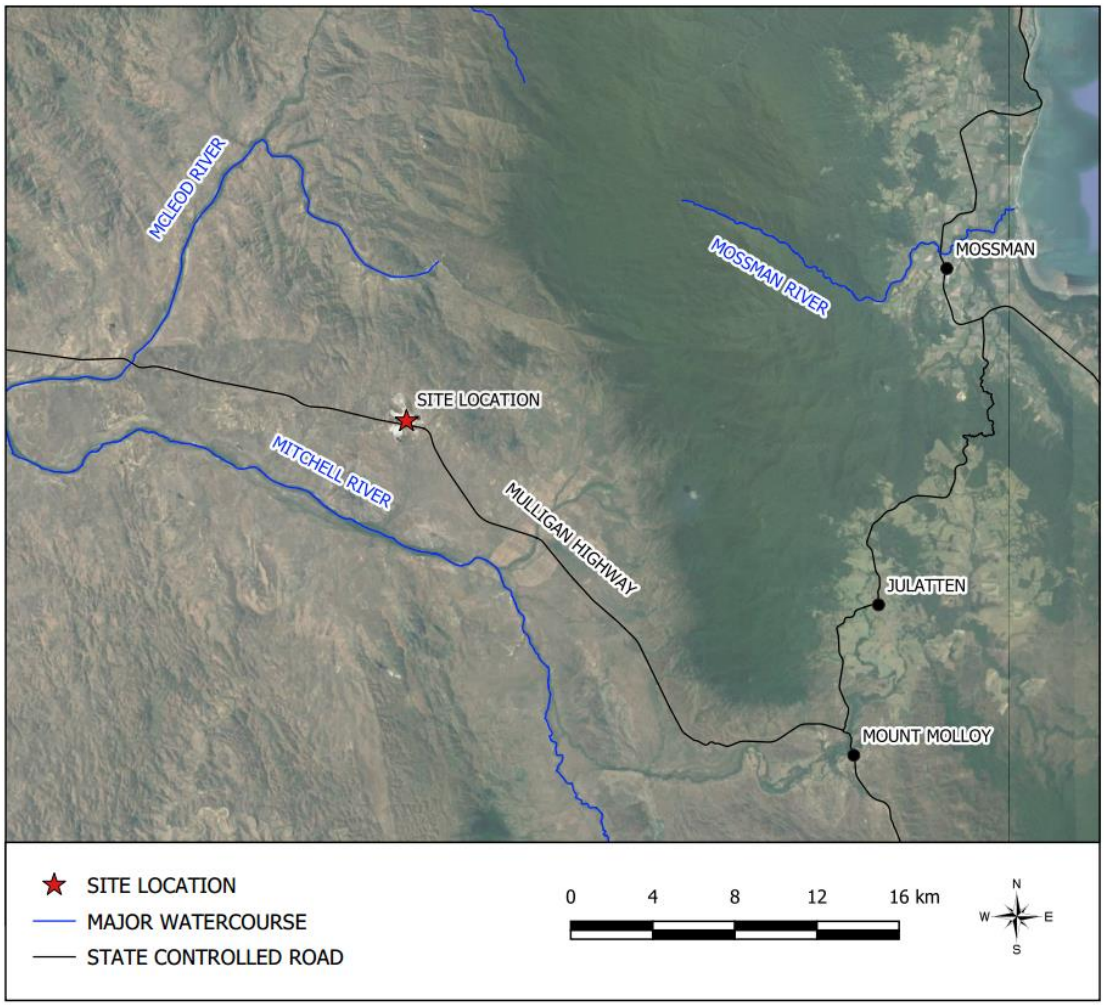
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2 PROJECT SITE

2.1 Site Location

The Mount Carbine Project is located approximately 80 km north-west of Cairns, in North Queensland. The geographical location of the project site is shown on **DIAGRAM 1**.

DIAGRAM 1: SITE LOCATION



The current land use on the site is quarrying/crushing of waste rock and tailings and processing of the crushed rock to obtain tungsten and quarry inventory. The surrounding land use is rural-urban, low-intensity grazing and conservation. The site is located within the Brooklyn Nature Refuge **[7]**.

The Mount Carbine township, comprising some rural residences, a caravan park, a hotel and a roadhouse, are located within 5 km of the mine site. All these features are to the south or east of the site **[7]**.

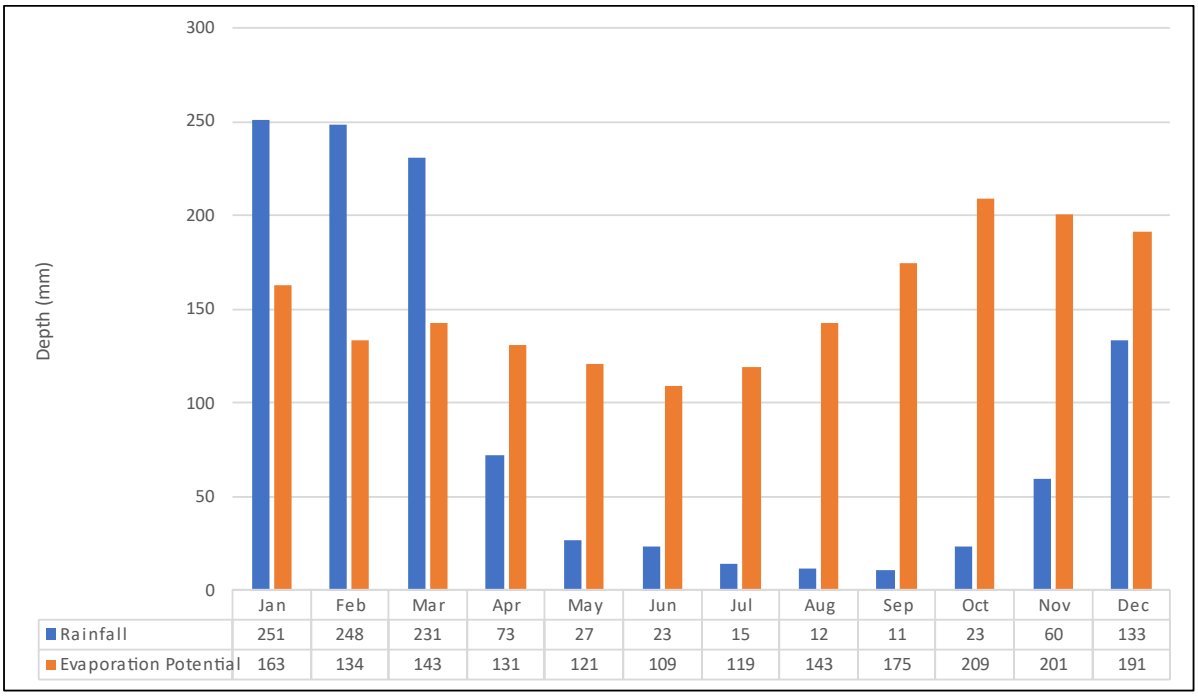
2.2 Climatic Conditions

The Mount Carbine project site is situated in the tropical monsoon belt of northern Queensland and is subject to a tropical climate associated with highly variable rainfall conditions. The closest meteorological station to the site is the Bureau of Meteorology's (BoM) Mount Carbine Township Station (No. 031180), located adjacent to the east of the site. Mount Carbine Township Station does not have a complete rainfall record and has no long term evaporation data, which is a key factor in the assessment of surface water management. Therefore, for the purpose of this assessment, evaporation data has been sourced from a SILO Data Drill **[8]** for Mount Carbine.

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A Patched Data Drill provides an uninterrupted date record for a site, primarily based on real data. Data sourced from the BoM weather stations is utilised with missing/or suspect data supplemented with synthetically generated data based on regionally observed climatic trends. **DIAGRAM 2** summarises the average monthly rainfall and evaporation for the site for the period 1889 to 2022, based on the available period of evaporation pan data from the Patched SILO Data Drill.

DIAGRAM 2: AVERAGE MONTHLY RAINFALL AND EVAPORATION DATA



The annual rainfall and evaporation characteristics are provided in **TABLE 1**. As shown in **DIAGRAM 2** and **TABLE 1**, the annual evaporation exceeds the annual rainfall at the site, except in the wettest months of the year, between January and March. This indicates that the site needs to manage its stored and recycled water efficiently to prevent the requirement to source water from off site. Additionally, there is a requirement to manage the water resources during the wet season to minimise the risk of spills from site that would cause a loss of water for processing and the potential for a contaminant release to the external environment.

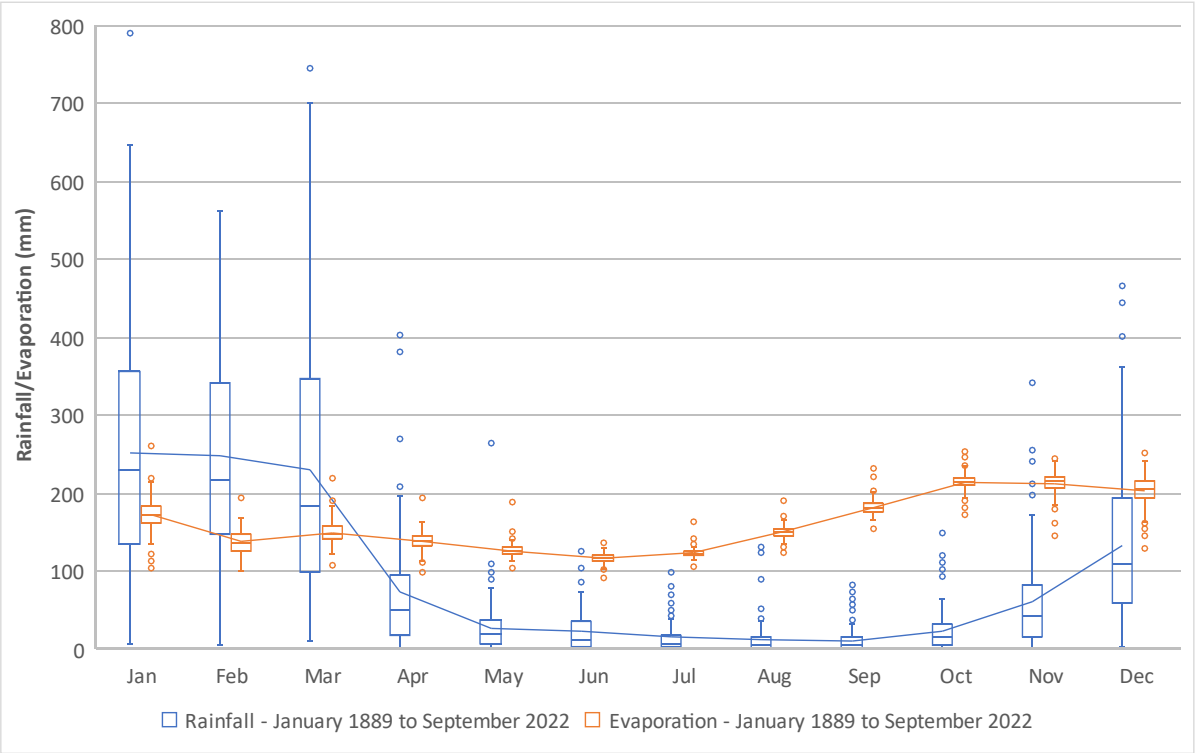
TABLE 1: ANNUAL RAINFALL AND EVAPORATION DATA FROM THE PATCHED DATA DRILL

Characteristic	Depth (mm)
Mean Annual Rainfall	1,107.3
Median Annual Rainfall	892.6
Mean Annual Evaporation	1,837.8
Median Annual Evaporation	1,789

DIAGRAM 3 presents the patched data drill in statistical format, with the whiskers representing the 10th and 90th percentile data, the boxes the 25th to 75th percentile data and the line in the box the 50th percentile (median) values. The box and whisker plot clearly shows that there is a greater range of variation in the rainfall each month than in the evaporation. The plot also indicates that when rainfall events occur, they may have total rainfall depths more than twice the upper quartile values.

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DIAGRAM 3: ANNUAL MONTHLY RAINFALL AND EVAPORATION STATISTICS



2.3 Topography and Hydrology

2.3.1 Topography

The following information has been reproduced from the 2013 Erosion and Sediment Control Plan, which is an appendix of the updated 2022 report **[9]**.

The Mount Carbine Mine Site is relatively rugged with the topography described as varying between level alluvial plains rising to short gently sloping pediments and foot-slopes to high hilly to mountainous lands with very steep slopes (Northcote et al. 1960-1968).

The existing low-grade material stockpile is the northernmost feature of the existing mine infrastructure and is located between two ridgelines, with the northern toe of the stockpile in the headwaters of several streams flowing into Holmes Creek. The tailings area is located on the southern side of the Mulligan Highway, on flatter land than the low-grade rock stockpile. The reject crushed ore stockpile is located between the northern low-grade stockpile and the southern tailings area, with drainage flowing into the tailings dam.

The TSF4 area drains to Manganese Creek, which flows to the east of the mining lease, then south to the Mitchell River.

2.3.2 Hydrology

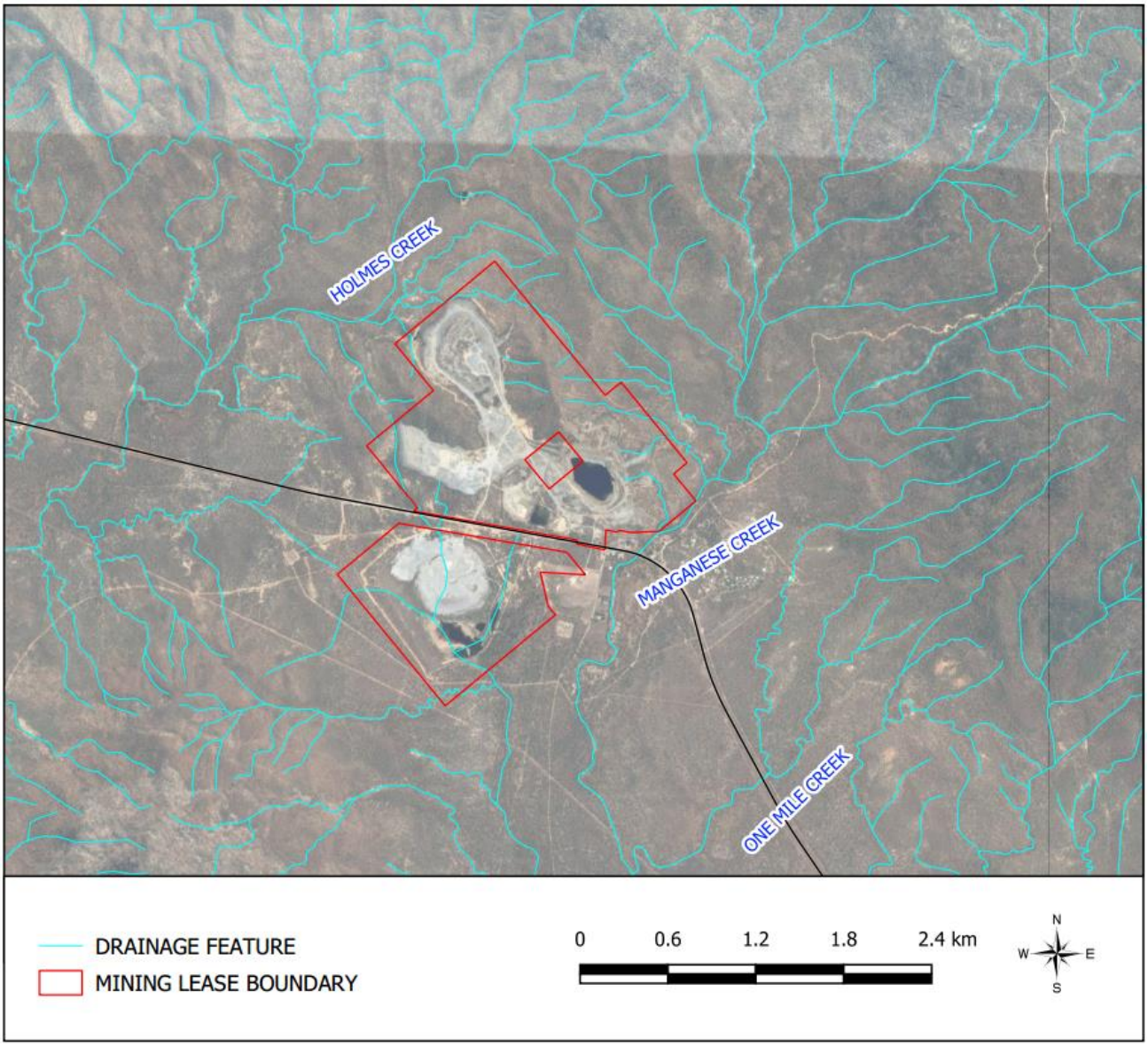
Regionally, the Project is located within the Mitchell River Basin, discharging to the Gulf of Carpentaria. The Mitchell River catchment covers an area of approximately 71,800 km^2 **[10]**. The headwaters of the Mitchell River are located on the Atherton Tableland, approximately 50 km northwest of Cairns, at an approximate elevation of RL 376 m AHD. At its closest point, the Mitchell River flows in a north-westerly direction about 5 km south of the Mount Carbine project site (refer to **DIAGRAM 1**).

Drainage within the Project area reports to the Mitchell River, via the catchments of Manganese Creek and Holmes Creek. Both Manganese Creek and Holmes Creek are ephemeral watercourses. The drainage systems relative to the Project location are depicted in **DIAGRAM 4**.

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Holmes Creek is located to the west of the site, with its closest point approximately 300 m to the northwest of the low-grade material stockpile area. Water from the low grade material stockpile sump that reported to the pit void now reports to the process circuit. Clean surface water runoff from undisturbed surfaces to the east and west of the stockpile drain to Holmes Creek in clean water diversion drains, as indicated on drawing 119190-05-100-002 in **Appendix A**. Manganese Creek is located to the east of the site, with its closest point being about 300 m southeast of the Pit.

DIAGRAM 4: LOCAL DRAINAGE FEATURES



2.4 Geology

The Project site is in the Siluro-Devonian Hodgkinson sedimentary province of north-eastern Queensland. The sediments were complexly folded and regionally metamorphosed prior to and during extensive granitic intrusion in the Carboniferous and Permian periods. Based on the 1:100,000 scale Rumula geological map, the regional geology of the site is mapped as Hodgkinson Basin meta-greywackes and meta-argillites with local meta-basalts **[11]**. The tungsten deposits at Mount Carbine are typically associated with sheeted quartz vein systems related to hydrothermal activity from underlying intrusive granite formations **[7]**.

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2.5 Hydrogeology

2.5.1 Data Source

The following hydrogeology information has been provided by NRA Environmental Consultants.

2.5.2 Groundwater

The hydrogeology information for the Project has been taken from the Mount Carbine Operations – Revised Conceptual Groundwater Model by Rob Lait & Associates (RLA) and Hydrogeologist.com.au**[13]**. Components of the updated groundwater conceptual model relevant to the water management plan are set out below.

1. The primary hydro-stratigraphic unit at Mount Carbine occurs within the Hodgkinson Formation. The fractured rocks of the Hodgkinson Formation comprise a secondary porosity aquifer.
2. Groundwater within the Hodgkinson Formation is typically semi-confined to confined and drilling indicates discrete zones of moderate to high hydraulic conductivity within a generally low hydraulic conductivity bulk rock mass.
3. The potentiometric surface on the south-west of the site (i.e., southwest of the standing wall fault is relatively flat with a low hydraulic gradient. The potentiometric surface on the north-east of site (i.e., north-east of the standing wall fault) is relatively steep with a high hydraulic gradient. This suggests separate hydro-stratigraphic domains either side of the standing wall fault/site, the groundwater chemistry data supports this concept.
4. The potentiometric surface contours south-west of the standing wall fault show that TSF4 (and associated water storage) is leaking, and a localised groundwater mound has formed around this site infrastructure.
5. The salinity and groundwater chemistry across the site is variable and does not readily present any spatial trends or obvious water types. There is a potential clustering of lower chloride / lower bicarbonate groundwater to the north-east of the standing wall fault and higher chloride / higher bicarbonate groundwater to the south-west of the standing wall fault, which supports the separate hydro-stratigraphic domain concept.

Early indications of the open pit groundwater relationship were provided by EQ Resources in October 2022 **[16].** The data presented a relationship between daily groundwater inflow rate and elevation of the water surface within the pit, as shown in **TABLE 2**. As expected, the graph indicates that the groundwater inflow to the pit increases when the water surface is lower, to a maximum of approximately 232 m^3/day at 225 m AHD.

TABLE 2: GROUNDWATER INFLOW RATE VERSUS PIT ELEVATION [16]

Daily Inflow (m^3/d)	Water Surface Elevation in the Pit (m AHD)
0	365
89.58	300
232.17	225

If the water surface elevation in the Open Pit is greater than 365 m AHD, there is potential for recharge to the groundwater system.

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2.5.3 Groundwater - Surface Water Interaction

RLA and Hydrogeologist.com.au (2022) **[13]** identified the following:

- Mining development is assessed as impacting groundwater levels beneath the TSF4 and associated water storages (localised mounding). The downgradient TSF4 monitoring bores MB4A and MB4B have observed groundwater levels approximately 4 mbGL to 7 mbGL. The downgradient TSF4 monitoring bores are located within a drainage feature, and the observed data suggests minimal interaction between groundwaters and surface waters downgradient of the TSF4.
- Groundwater is likely discharging to the sub-surface between the low-grade stockpile and Holmes Creek, with vegetation suggesting wet soil conditions. Based on the available data there is potential for groundwater surface water interaction to be occurring in the upper catchment of Holmes Creek. The groundwater level data, presence of established vegetation (Pandanus at SW20) and the monitoring carried out under the REMP suggests this potential shallow groundwater interaction is a natural, established occurrence rather than an impact of mining.
- Elsewhere, there is minimal interaction between watercourses and groundwater at the Mount Carbine project site RLA (2012). The 2022 REMP (NRA, 2022) report concluded that there is no discernible impact on the aquatic ecosystem and human use environmental values (EVs) associated with the contemporary mining activities.

2.6 Site Features

As discussed in **Section 1.1**, the existing key elements associated with mining activities undertaken on the site include the following:

- Open Cut Pit;
- Crushing Plant (quarry operational area)
- Processing Plant and Workshop;
- TSF4;
- Proposed Waste Rock Dump (WRD); and,
- Clean Water Dam.

The plans to increase production of tungsten include recommencement of mining from the Open Cut Pit. To operate the proposed mining activities, the water stored in the Pit will need to be emptied and surface runoff from the northern part of the site will have to be diverted away from the Pit. It is proposed that the capacity of TSF4 is increased by construction of a downstream embankment raise and incorporation of the existing Clean Water Dam. The existing, disused, TSF3 will also be brought back into service with a raised embankment. Where ground surface elevations allow, surface water runoff from the Low Grade Material stockpile, the Optical Sorter Reject Area and the Quarry Operational Area will be diverted from the Open Cut Pit to TSF3 (refer to the NRA Figure 1 'Project EA Mapped Domains and Quarry and Mining Disturbance Areas' in Appendix A for the layout of the existing features). When full, TSF3 will overflow to TSF4. The existing permissible release location will be retained at the southern point of TSF4 (refer to **Section 7.1.1**). The final upgrade to the water management system were corrective actions to the existing Quarry Sump at the north-eastern end of the Low Grade Material Stockpile. The drawings showing the proposed layout of the site and the upgraded features are provided in **Appendix B**.

A 2016 consequence category assessment **[17]** classified the existing TSF4, the Clean Water Dam and the Open Cut Pit with 'Low' consequence categories. As such, none of the existing water storages on site have regulated structure status. CCA analyses have been undertaken for the proposed designs for TSF3 and TSF 4 and re-evaluated them as 'Low' consequence structures, as reported in the 'Stage 3 Waste and Water Management Design Report' **[18]**. A summary of the DES CCA analyses for TSF3 and TSF4 raises from the design report has been provided in **TABLE 3**.

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TABLE 3: DES CONSEQUENCE CATEGORY ASSESSMENT SUMMARY

Failure Scenario	TSF Raise
Failure to Contain – Seepage	N/A
Failure to Contain – Overtopping	Low
Failure to Contain – Dam Break	Low
Overall	**Low**

The Open Pit will no longer be a water storage and will store less than 2.5 ML of water, so no CCA is required. The Clean Water Dam will be demolished and the area incorporated into the raised TSF4 configuration. Remediation works have been completed on the Quarry Sump to minimise the site-specific risk of seepage, and this is also exempt from the requirements of the 'Manual for assessing consequence categories and hydraulic performance of structures' **[19]**.

The existing and proposed water storage features are described in more detail below. The water management strategy for the construction work to be undertaken for the Stage 3 upgrades is discussed in more detail in **Section 5.2**.

2.6.1 Open Cut Pit

The Open Cut Pit is situated north of the Mulligan Highway; it has been used as a water storage and as discussed in the previous section, is not a regulated structure. The Open Cut Pit is approximately 70 m deep and has a spill elevation of RL 380.0 m AHD. The pit has a stored water surface area of about 9.7 ha at the full supply level (FSL), with an estimated capacity of approximately 3,429 ML **[20]**. The current (5 September 2022) water level within the pit is at RL 347.78 m **[21]**.

The Open Cut Pit currently has upstream catchment areas reporting from quarry disturbance areas on the site. These upstream catchment areas include the Quarry Operational Area and approximately 5 ha of undisturbed land between the Quarry Operational Area and the Old Mine Workings.

In preparation for the recommencement of mining operations in the Open Cut Pit, the Pit is currently being dewatered through use of a series of spray evaporators located on the quarry site, including the haul roads for dust suppression, and by pumping to TSF4, where available capacity exists. For the purposes of water balance modelling (refer Section 6), it has been assumed that once construction of TSF3 and TSF4 raises has been completed (thereby increasing available capacity in these storages) and the Pit dewatering is complete, half of the evaporative sprayers would be transferred to TSF3 to maintain reduced water levels in that storage. When TSF3 is online, any pumping from the Open Cut Pit to TSF4 will cease and the Pit will continue to be dewatered by pumping directly to TSF3 and through use of the remaining evaporative sprayers. The details of the evaporative sprayers in use on site is provided in **TABLE 4** (based on information provided by EQR).

TABLE 4: EVAPORATIVE SPRAYERS

Date	No. of Nozzles	Pumping Rate per sprayer (m^3/h)	Hours of Operation per day	Potential Total Evaporation Loss	
				m^3/d	ML/d
01/09/2022	18	28	10	5,040	5.04
01/12/2022	42	28	10	11,760	11.76

Following completion of the Stage 3 upgrades, surface runoff from the re-formed Low-Grade Ore Stockpile, part of the re-formed Optical Sorter Reject Area and other areas around the Open Cut Pit will be directed to TSF3, along with pumped seepage from the Quarry Sump. The remaining surface runoff catchment draining to the Pit will comprise an area of 34.1 ha, including the Pit and the Waste Rock Dump. Surface runoff draining into the Pit will be collected in a sump where treatment for potential contaminants may occur before being pumped to TSF3 for storage. It is recommended that the water balance and water management plans are reviewed on an annual basis to assess the

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routing of the surface runoff as the material stockpile areas are re-formed. This will require LiDAR data to be re-flown prior to the reviews.

The proposed mining operations in the Open Cut Pit have been planned over three stages. The proposed staging is presented in **TABLE 5** and the pit extents are shown on **DIAGRAM 5**, **DIAGRAM 6** and **DIAGRAM 7**. It should be clarified that the stages of mining in the Open Cut Pit are not the same as the stages for the site development and care should be taken when discussing either one.

The surface runoff draining to the Open Cut Pit will collect in a pit sump and will be pumped to TSF3 for storage (refer to **DIAGRAM 17**).

TABLE 5: PROPOSED STAGING OF MINING IN THE OPEN CUT PIT

Stage	Open Cut Area (ha)	Base Elevation (m AHD)	Ground Surface Elevation (m AHD)	Excavated Depth (m)	Estimated Start Date	Estimated End Date
1	10.3	310	380	70	01/02/2023	01/12/2023
2	18.6	225	435	210	01/12/2023	01/12/2025
3	20.6	225	470	245	01/12/2025	01/09/2027

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DIAGRAM 5: LAYOUT OF MINING STAGE 1 (EXISTING) OPEN CUT PIT



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DIAGRAM 6: PROPOSED LAYOUT OF MINING STAGE 2 OPEN CUT PIT



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DIAGRAM 7: PROPOSED LAYOUT OF MINING STAGE 3 OPEN CUT PIT



2.6.2 Crushing Plant

The crushing plant is in the Quarry Operational Area to the north-west of the Open Cut Pit. As discussed in **Section 2.6.1**, the Quarry Operational Area currently drains to the Open Cut Pit. Following completion of TSF3 upgrade, the surface water runoff from the Quarry Operational Area will be directed to TSF3.

The Crushing Plant area comprises a Raw Water Tank and a dewatering system that recirculates water to the Raw Water Tank. Currently, the Raw Water Tank receives water from the Open Cut Pit at an average rate of 32.3 m^3/h (9 L/s). After the Stage 3 upgrades have been completed, all the water supplied to the Raw Water Tank will be from the Process Water Tank, at a rate of 129.5 m^3/h when the Crushing Plant is in operation. The Process Water Tank is supplied with water from the Process Plant Dewatering system and TSF4, which will act as the raw water dam.

The Crushing Plant will operate during the day shift.

For the purposes of the water balance modelling, the Crushing Plant has been combined with the Processing Plant into a single Retreatment Area.

A process flow diagram for the Stage 3 water usage at the Crushing Plant and Processing Plant has been provided by Jukes Todd in their May 2022 memorandum[22]. The memo contains the key assumptions for the water balance on the site after completion of the Stage 3 upgrades. In addition, the memo provides details of the day shift (12 hours) and night shift water (12 hours) use on the site. A copy of the memo has been provided in **Appendix D** for information. The key assumptions from the

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memo are replicated in **TABLE 6** and have been used to develop the water balance model (refer also to **Section 5.2.4**).

TABLE 6: KEY ASSUMPTIONS FOR THE CRUSHING AND PROCESSING PLANT WATER BALANCE FOR STAGE 3[22]

Water Consumption	Assumed Value
Crushing Plant water requirement	129.5 m^3/h
Crushing Plant water loss	8 m^3/h
Process Plant water requirements	200 m^3/h
Process Plant moisture loss	30 m^3/h
Moisture lost from dewatering and stockpiling of process plant ROM material	6.5 m^3/h
Fine tailings water loss (assumes 70% solids)	2.4 m^3/h
Coarse tailings water loss (assumes 85% solids)	9.5 m^3/h

2.6.3 Processing Plant and Workshop

The Processing Plant and Workshop area is located on the southern portion of the project site to the north of TSF4. Surface runoff from this area reports to TSF4. The Processing Plant has approval to process over 100,000 t/year **[2]**, in a seven day working week. Process water is currently sourced from the Clean Water Dam for reprocessing operations at an average rate of 134.5 m^3/h (37.4 L/s). After the Stage 3 works have been completed, the process water tank supply will be sourced from TSF4 and the Process Plant Dewatering system. Water will be supplied to the Process Plant at a rate of 85 m^3/h during the day shift and 200 m^3/h during the night shift, when the Crushing Plant is not operating (refer also to **Section 5.2.4**).

2.6.4 Tailings Storage Facility 4

It is understood that TSF4 was first constructed during the early stages of mining at the site, approximately 30 to 40 years ago. The TSF exists to contain tailings that have historically been generated from the mine process plant and comprises an above-ground storage facility formed by earthen embankments. In the northern portion of TSF4, tailings have been stockpiled above the crest level of the perimeter embankment, while the southern portion of the TSF consists of a tailings lagoon, bounded by perimeter embankments to the west, south and south east. At the southern corner of TSF4, a concrete lined open channel spillway exists. In October 2013 works were undertaken to reduce the catchment reporting directly to the TSF, via the construction of diversion drains. In October / November 2016, further works were undertaken to enhance the capacity of the diversion channel on the western side of TSF4. Diversion drains are currently in place to divert water around TSF4, along the western, northern and north-eastern sides of the facility.

The proposed Stage 3 upgrade works will raise and extend the TSF4 embankments to increase the storage capacity of the structure. Whilst construction of TSF3 is ongoing, stored water from the Open Cut Pit will be pumped to TSF4 where available capacity exists. The existing Clean Water Dam will be demolished and the area will be incorporated into the expanded TSF4 structure. When all construction on the site has been completed, TSF4 will function solely as a water storage facility, supplying the Process Water Tank. TSF4 will receive excess water from the Process Plant Dewatering system (11.9 m^3/h) and pumped overflows and any spills from TSF3. In addition, TSF4 will receive the contaminated surface water runoff from the area of the Process Plant and Workshops south of Mulligan Highway (refer to **Figures 002 to 004**).

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Spills from TSF4 occur at the permissible release point at the southern corner of the site. The spills flow overland to Manganese Creek and on to Mitchell Creek.

2.6.5 Tailings Storage Facility 3

Although TSF3 is an existing structure, it was decommissioned and currently has no function at the site. The Stage 3 upgrade will raise embankments around TSF3 for use as a water storage facility.

When TSF3 has been constructed, it will receive water pumped from the Pit as part of its dewatering process. As mentioned in **Section 2.6.1**, when TSF3 has been constructed and the Pit dewatering is complete, it is assumed that half of the spray evaporators used to dewater the Pit would be used at TSF3 to reduce the stored water volumes going forward.

Surface water runoff from part of the re-formed Optical Sorter Reject Area, part of the re-formed Low Grade Material Stockpile, the undisturbed area between the Quarry Operational Area and the Old Mine Workings, the Quarry Operational Area and the material stockpile on the west side of TSF3 will be redirected to TSF3. Surface runoff collected in the Pit sump will be pumped to TSF3. Seepage from the Low Grade Material Stockpile Quarry Sump will be pumped to TSF3. When full, excess water in TSF3 will be pumped to TSF4. Any spills from TSF3 will be routed to TSF4.

2.6.6 Low Grade Stockpile Sump (Quarry Sump)

The existing Low Grade Ore Stockpile Sump collected seepage from the Low Grade Material Stockpile for pumping to the Open Cut Pit. The Sump has been upgraded as part of the Stage 3 works and the collected seepage is pumped to TSF4 (TSF3 when available) at a maximum rate of 200 L/s when full. Layout drawing number 119190-05-000-003-A of the upgraded Sump is provided in **Appendix B**.

2.7 Surface Water Catchment Delineation

As discussed in **Section 2.6**, the catchment layouts for the surface water runoff will be altered by the Stage 3 upgrades. The delineation of the catchment land use types reporting to water storage facilities for the existing case and the three stages of mining in the pit after the construction of TSF3 and the raising of TSF4 embankments are shown on **Figures 001**, **002**, **003** and **004** at the end of the report. North of the Mulligan Highway, all the sub-catchments shown on the figures, except the WRD and the Pit, will drain to TSF3.

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3 ENVIRONMENTAL VALUES

3.1 General

The local environmental values have been designated by the Commonwealth and Queensland Governments. The data is available from the following sources.

- Matters of National Environmental Significance (MNES) report **[24]**
- Matters of State Environmental Significance (MSES) report **[25]**
- High Ecological Value (HEV) waters set out by the Queensland Environmental Protection (Water) Policy 2009 (EPP Water) **[25]**
- Wetlands of general ecological significance (GES), set out on the Queensland Government referable wetland mapping site
- Riverine areas, springs or lakes and associated flora and fauna.
- Business Queensland Bore Reports (from Queensland Globe) **[26]**

The environmental reports for the environmental factors are provided in **Appendices E and F**.

In addition to the Queensland Government assessments, Schedule 1 of the 'Environmental Protection (Water and Wetland Biodiversity) Policy 2019' **[27]**, which is a subordinate legislation to the 'Environmental Protection Act 1994' (EP Act) **[28]**, documents the waters for which the legislation applies that are either enhanced or protected and specifies relevant environmental values (EV's) and Water Quality Objectives (WQO's). The MNES report in **Appendix F** provides details of the matters of environmental significance that may occur or relate to an area of 10 km around the Mount Carbine site that are protected by the Environmental Protection Biodiversity and Conservation (EPBC) Act.

3.2 Wetlands and Waterways

Review of Schedule 1 of the 'Environmental Protection (Water and Wetland Biodiversity) Policy 2019' **[27]** indicates that the Mitchell River Basin does not currently have gazetted and mapped EV's or WQO's. Notwithstanding, generalised assessment under the Environmental Policy can be based on the nature of the receiving environment, as described in more detail below.

The MNES report in **Appendix E** states that there were no wetlands of international importance within 10 km of the site **[24]**.

The MNES report Indicates that the site is located within a water resource planning area. A water resource plan is a scheme over a part of the State that advances the sustainable management of Queensland's water **[29]**. This planning area indicates that there is a system in place to allocate the use of water in the area and to provide riverine protection to the watercourses and groundwater that may be used for water supply.

The receiving environment surrounding the project site is considered 'moderately disturbed' as a result of the impacts of low intensity cattle grazing, and exploration activities in the area.

Based upon the hydrological domains downstream of the project site and potential downstream users, classification of Environmental Values (EV's) for the downstream environment may include:

- Aquatic ecosystems;
- Primary industries, including irrigation, stock drinking water, aquaculture and human consumption of aquatic foods;
- Recreation and aesthetics;
- Drinking water;
- Industrial water; and
- Cultural and spiritual values.

The MSES report **[25]** in **Appendix E** states that there are no wetlands or waterways in high ecological value (HEV) waters within Lot SP254833, which contains the Mount Carbine Mine site.

3.3 Groundwater

The Environmental Management Plan **[7]** reported environmental values for the area in the absence of definition in legislation, and these values remain applicable. The Environmental Management Plan presented information that showed that:

- Groundwater in the area is moderately alkaline.
- Shallower groundwater is generally of lower electrical conductivity than the deeper groundwater. As electrical conductivity is one measure of water salinity, the deeper groundwater is more saline than the shallower groundwater. Higher salinity groundwater is generally an indication of longer residence time within the aquifer zone. Therefore it is likely that the hydraulic conductivity of the deeper aquifer zone is less than the hydraulic conductivity of the shallower aquifer zone, with consequent lower groundwater flow velocity in the deeper aquifer zone.
- Electrical conductivity of the groundwater indicates that the water is naturally brackish and not suitable for human consumption.

Therefore, the following values have been nominated for the project:

- stock watering
- firefighting (industrial).

3.4 Protected Fauna

The MSES report (**Appendix E**) has not identified any protected special wildlife reserves, state marine parks or fish habitat areas within Lot SP254833.

The MSES did identify a number of threatened (endangered or vulnerable) wildlife within Lot SP254833. The Mount Carbine site is surrounded by an area identified as both Wildlife habitat – special least concern and endangered or vulnerable. The list of animals within each category is provided in the MSES report in **Appendix E**.

3.5 Protected Vegetation

The vegetation surrounding the Mount Carbine site is classified as Category B **[25]**, which is remnant vegetation shown on a regional ecosystem or remnant map as an endangered regional ecosystem, an of concern regional ecosystem or a least concern regional ecosystem. The MSES report in **Appendix E** has identified this vegetation as 'Protected Areas – nature refuges'. This protected area is named the Brooklyn Nature Refuge. Map 4 in the MSES report has subdivided this protected area into different types of regulated vegetation. An extract of the map is provided in **DIAGRAM 8**. The area surrounding the mine site is identified as essential habitat. Further areas of essential habitat and endangered or of concern vegetation exist between the Mount Carbine site and the Mitchell River.

DIAGRAM 8: AREAS OF REGULATED VEGETATION



Extract from MSES report in **Appendix E**.

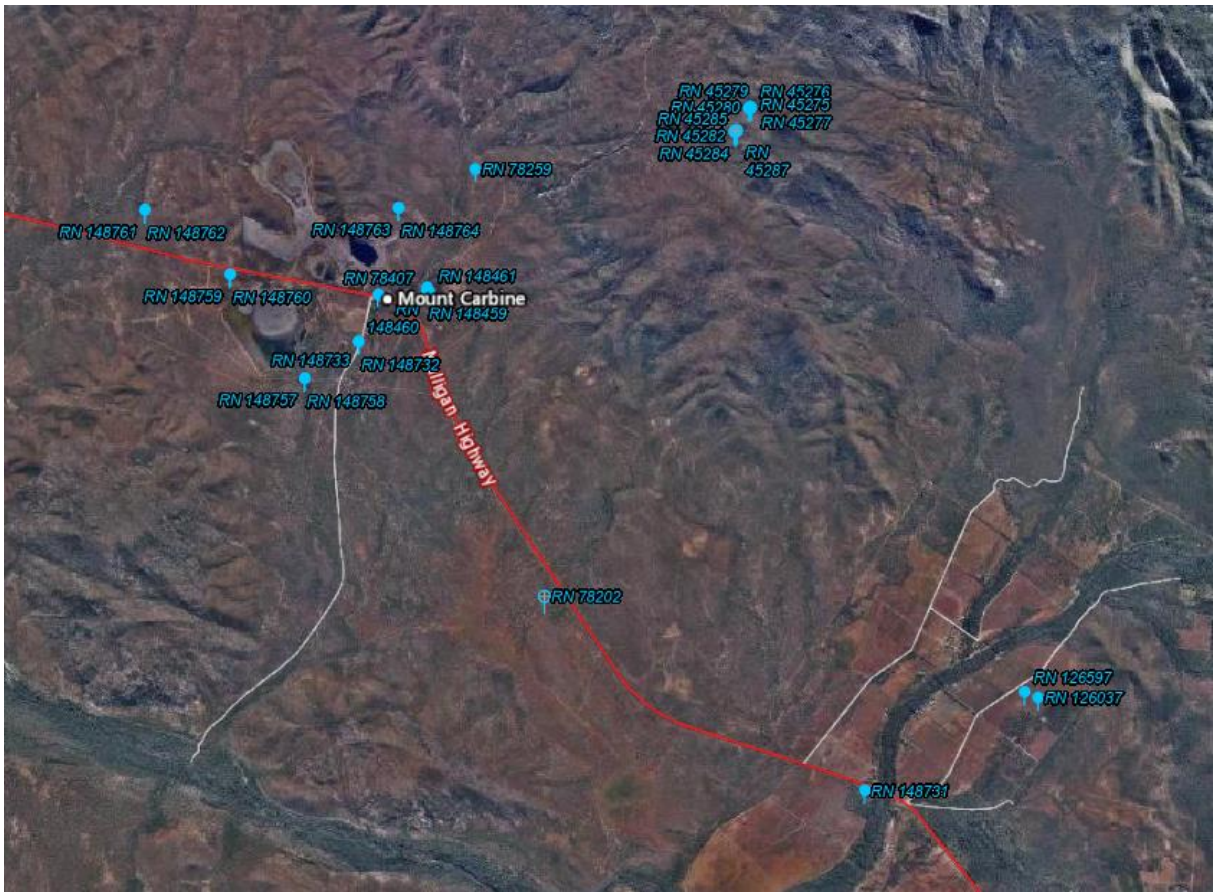
3.6 Groundwater Aquifers

The DES Wetland Info database **[29]** does not hold any aquifer data in the Mareeba Shire region. There are 36 sub-artesian groundwater bores within 20 km of the Mount Carbine site. A summary of the bore locations is provided in **TABLE 7** and in **DIAGRAM 9**. The water quality data contained within the borehole records are either decades old or do not exist. As an alternative to reviewing all

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the borehole water quality data, the groundwater records from the mine site have been reviewed. A figure showing the locations of the groundwater boreholes on the site is in **Appendix C**. More information on the groundwater water quality is provided in **Section 4**.

DIAGRAM 9: BOREHOLE LOCATIONS WITHIN 20 KM OF THE PROJECT



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TABLE 7: GROUNDWATER BORES WITHIN 20 KM OF MOUNT CARBINE

Registered Number	Original Name	Latitude	Longitude	Drilled date
45276	FARM 1 BORE 5	-16.50982854	145.1719553	
45277	FARM 1 BORE 2	-16.50995882	145.1719553	
45279	FARM 1 BORE 3	-16.50982854	145.171825	
45275	FARM 1 BORE 1	-16.50982854	145.171825	
45280	FARM 1 BORE 6	-16.50995882	145.1717599	
45278	FARM 1 BORE 4	-16.50995882	145.1716947	
45287	FARM 2 BORE 7	-16.51217359	145.1704571	
45285	FARM 2 BORE 3	-16.51217359	145.1704571	
45283	FARM 2 BORE 5	-16.51217359	145.1704571	
45284	FARM 2 BORE 2	-16.51230387	145.1704571	
45286	FARM 2 BORE 4	-16.51217359	145.1703268	
45281	FARM 2 BORE 6	-16.51230387	145.1701965	
78259	VILLAGE BORE	-16.51595173	145.1435547	7-May-92
148764	MB 3	-16.51979169	145.1356174	27-Nov-11
148758		-16.53665636	145.1259379	17-Nov-11
148757	MB 4	-16.5366474	145.1259474	16-Nov-11
148732		-16.53299266	145.1315189	15-Nov-11
148733	MB 6	-16.53298371	145.1315283	15-Nov-11
148458		-16.5283333	145.0061111	8-Jul-10
78407		-16.52832723	145.1335146	12-Feb-92
148760		-16.52637676	145.1182623	20-Nov-11
148759	MB 1	-16.52636781	145.1182718	18-Nov-11
148762	MB 5	-16.52001744	145.1094722	24-Nov-11
148761	MB 5	-16.52000849	145.1094817	24-Nov-11
148763	MB 3	-16.51980064	145.135608	27-Nov-11
148457		-16.5180556	145.0066667	1-Jul-10
183803		-16.49194444	145.0008333	25-Oct-19
126037		-16.56814132	145.2015144	28-May-02
126597		-16.5676269	145.2001356	27-Feb-03
148731		-16.57732341	145.1836657	21-Nov-11
148461		-16.5280201	145.1387784	3-Jul-10
148459		-16.5279513	145.1384787	5-Jul-10
148460		-16.5276753	145.1385185	6-Jul-10
45641		-16.50087602	144.9890476	
45164		-16.49961587	144.9891621	1-Jan-70
45163		-16.49824116	144.9890476	1-Jan-66

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4 CONTAMINANT SOURCE STUDY

4.1 Preamble

A contaminant source study identifies the origin and chemical composition of different types of water on the mining project. The objective of this is maintain the biological integrity of the surface waters and groundwater at the project site and to ensure the quality of the water does not adversely affect any environmental values or the health, welfare and amenity of people, fauna and land users by meeting statutory requirements and acceptable standards.

4.2 Receiving Environment

4.2.1 Catchment Conditions

The Mount Carbine mine site is in the upper reaches of the Mitchell River catchment in Far North Queensland. The site is located approximately 5 km from the Mitchell River and any surface runoff or spills have the potential to contaminate the surface water network or the local groundwater system. The Mitchell River originates on the Atherton Tableland, in the Great Dividing Range, 48 km northwest of Cairns and flows approximately 750 km northwest across the Cape York Peninsula from Mareeba Shire to the Gulf of Carpentaria. The watershed of the Mitchell River is 41,315 km^2 **[29]**. As shown on **DIAGRAM 4** and discussed in **Section 2.3.2**, the mine site is bounded by Holmes Creek to the west and Manganese Creek to the east. In this location, Homes Creek and Manganese Creek are ephemeral.

4.3 Origin and Chemical Composition of Contaminants

4.3.1 Origin of Contaminants

With reference to the NRA figure showing the EA mapped domains and quarry and mining disturbance areas **[3]** in **Appendix A**, the contaminant sources can be classified into mining disturbance and quarry disturbance areas. The areas of site in the different classifications are provided in **TABLE 8**.

TABLE 8: CONTAMINANT SOURCES

Contaminant Source	
Mining Disturbance	**Quarry Disturbance**
Open Pit	Low Grade Material Stockpile
Processing Plant and Workshop	Quarry Operational Area
Clean Water Dam	Reject Stockpile
Old mine Workings	TSF3 (not operational)
Overburden Stockpile	Process Water Pond (not operational)
Old Stockpile Area	Tailings Stockpile in TSF4
Roads around the Open Pit	Water Storage in TSF4
Core Yard and Laydown Area	
Offices and Laboratory	
Sulphide Disposal Dump	
Previous Mill and ROM Pad	

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4.3.2 Chemical Composition of Contaminants from Different Sources

4.3.2.1 Tailing Storage Facility 4 ***[7]***

The tailings geochemistry was developed from water quality monitoring from TSF4 and elemental analysis from 2001 to 2013. The monitoring data indicated that the water in TSF4 was circum-neutral to slightly alkaline. This indicates that the no significant acidification occurred in the tailings material, which reflects the composition of the non-acid forming low grade stockpile material. The chemical composition of the water in TSF4 is presented in **TABLE 9**.

TABLE 9: WATER MONITORING DATA FOR TSF4 (2001-2013) [7]

Element	Units	Median Quantity	EA Release Quality Objective
pH	-	7.15	6.0 – 7.5
Electrical Conductivity	µS/cm	230	5000
Sulphate	mg/L	31	20 x 80th percentile of reference site concentration
Fluoride	mg/L	2.4	Default value or 20 x 80th percentile of reference site concentration
Aluminium (total)	mg/L	0.12	1.1 or 20 x 80th percentile of reference site concentration, whichever is higher
Antimony (total)	mg/L	<0.003	20 or 20 x 80th percentile of reference site concentration, whichever is higher
Arsenic (total)	mg/L	0.038	0.26 or 20 x 80th percentile of reference site concentration, whichever is higher
Cadmium (total)	mg/L	0.0001	0.004 or 20 x 80th percentile of reference site concentration, whichever is higher
Chromium (total)	mg/L	<0.001	0.02 or 20 x 80th percentile of reference site concentration, whichever is higher
Cobalt (total)l	mg/L	0.001	0.028 or 20 x 80th percentile of reference site concentration, whichever is higher
Copper (total)	mg/L	0.002	0.028 or 20 x 80th percentile of reference site concentration, whichever is higher
Lead (total)	mg/L	0.0005	0.068 or 20 x 80th percentile of reference site concentration, whichever is higher
Manganese (total)	mg/L	0.11	38 or 20 x 80th percentile of reference site concentration, whichever is higher
Mercury (total)	mg/L	<0.0001	-
Molybdenum (total)	mg/L	0.097	0.68 or 20 x 80th percentile of reference site concentration, whichever is higher
Nickel (total)	mg/L	<0.001	0.22 or 20 x 80th percentile of reference site concentration, whichever is higher
Selenium (total)	mg/L	<0.003	0.02 or 20 x 80th percentile of reference site concentration, whichever is higher
Tin (total)	mg/L	0.008	-
Tungsten (total)	mg/L	0.034	20 x 80th percentile of reference site concentration
Zinc (total)	mg/L	0.009	0.16 or 20 x 80th percentile of reference site concentration, whichever is higher

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4.3.2.2 *Low Grade Material Stockpile*

Testing of samples from the low grade stockpile all indicated that the material was non-acid forming and hence generation of strongly acidic drainage was not expected to occur **[7]**.

Testing of the sampled material from the low grade stockpile indicated that arsenic, selenium, cadmium and antimony were significantly enriched.

The 2013 Environmental Management Plan **[7]** also indicated that the quality of the seepage from the toes of the low grade stockpile was circum-neutral. The test results of the seepage indicated a range of elements were present in its chemical composition, as listed in **TABLE 10**.

TABLE 10: ELEMENTS IN SEEPAGE FROM THE LOW GRADE STOCKPILE (2011-2013) [7]

Element	Units	Median Value (mg/L)
pH (Lowest value reported was 6.4)	-	6.7
Electrical Conductivity	µS/cm	925
Sulphate	mg/L	435
Fluoride	mg/L	9.3
Aluminium	mg/L	1.75
Zinc	mg/L	0.18
Nickel	mg/L	0.031
Manganese	mg/L	0.018
Arsenic	mg/L	0.009
Tungsten	mg/L	0.006
Selenium	mg/L	0.004
Copper	mg/L	0.004
Cadmium	mg/L	0.0016
Cobalt	mg/L	0.0005
Chromium	mg/L	0.0005

4.3.2.3 *Clean Water Dam*

The Clean Water Dam receives recycled water from the processing plant and surface runoff from the upstream quarry catchment. As a result, it is expected to have similar chemical constituents to the Low Grade Material Stockpile and TSF4. The Clean Water Dam spills to TSF4 so does not directly contribute to spills to the natural environment. The Clean Water Dam will be incorporated into TSF4 as part of the raise construction.

4.3.2.4 *Open Cut Pit*

Results from water quality sampling in the Open Pit on 26 August 2021 were provided by MCQ site staff. The results of the testing are presented in **TABLE 11**.

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TABLE 11: WATER MONITORING DATA FOR THE OPEN PIT (26 AUGUST 2021)

Element	Units	Median Quantity
pH	-	7.5
Electrical Conductivity	µS/cm	670
Fluoride	mg/L	6.8
Aluminium (total)	mg/L	0.020
Antimony (total)	mg/L	<0.003
Arsenic (total)	mg/L	0.1
Boron (total)	mg/L	0.023
Cadmium (total)	mg/L	<0.0001
Chromium (total)	mg/L	<0.001
Cobalt (total)l	mg/L	<0.001
Copper (total)	mg/L	0.001
Lead (total)	mg/L	<0.001
Manganese (total)	mg/L	0.029
Mercury (total)	mg/L	<0.00005
Molybdenum (total)	mg/L	0.1
Nickel (total)	mg/L	0.001
Selenium (total)	mg/L	<0.003
Tungsten (total)	mg/L	0.024
Uranium	Mg/L	0.0006
Zinc (total)	mg/L	<0.005

The results indicated that at the time of sampling, the water stored in the Open Pit was circum-neutral. Fluoride levels are elevated, but no metals were detected at enriched levels in the water samples.

The water quality within the Open Pit is suitable for use within the retreatment processes on site.

4.4 Reuse of Contaminated Water

The site does not have any external water supply, so all water used in the retreatment processes is from surface runoff collected from the quarry catchments, TSF4 and the Open Pit. The water balance in **Section 6.** provides details of spill frequencies from the different storages under the proposed water management regime.

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5 WATER MANAGEMENT SYSTEM

5.1 Stormwater Management Objectives

The key water management objective is to control and minimise the release of potentially mine-impacted water from the site to the extent that the current users and environmental values of the receiving environment are not detrimentally impacted. The stormwater systems that are likely to be encountered in relation to the Project can be characterised as follows:

Clean Water	-	Stormwater occurring around the project area, but not in contact with active mining/operating areas.
Site Water	-	All water generated from mine affected areas and associated operating surfaces within the project area.

Typical sources and characteristics, and the management of these waters are as follows:

- Clean water will remain unimpacted by site activities and is to be diverted around mining/operating areas and discharged via effective hydraulic controls back to the watercourse network. A key objective of stormwater management is to prevent capture or containment of any clean water.
- Site water is to be captured and managed in relation to its water quality and the source of the water. Site water is to be managed through onsite water management structures to prevent uncontrolled release from the site. The key objective for site water management is to minimise catchment areas from which site water is generated, as well as maximising the containment of site water at its source to enable direct reuse.

5.2 Water Management Strategy

5.2.1 Preamble

This section refers to the Stage 3 water management strategy, not the existing case, although some elements are unchanged.

The layout of the Stage 3 drainage channels in the Project's water management system is shown on **Figure 005** at the end of the report. The pumping regime is discussed in **Section 5.2.4**.

There is no external supply of water to the site. All water used in the Crushing Plant and Processing Plant will be sourced from site affected surface water runoff that is collected and stored on site in TSF4 for reuse.

The discussion of the water management strategy has been separated into the clean water management, the site affected site water management and the pumping regime.

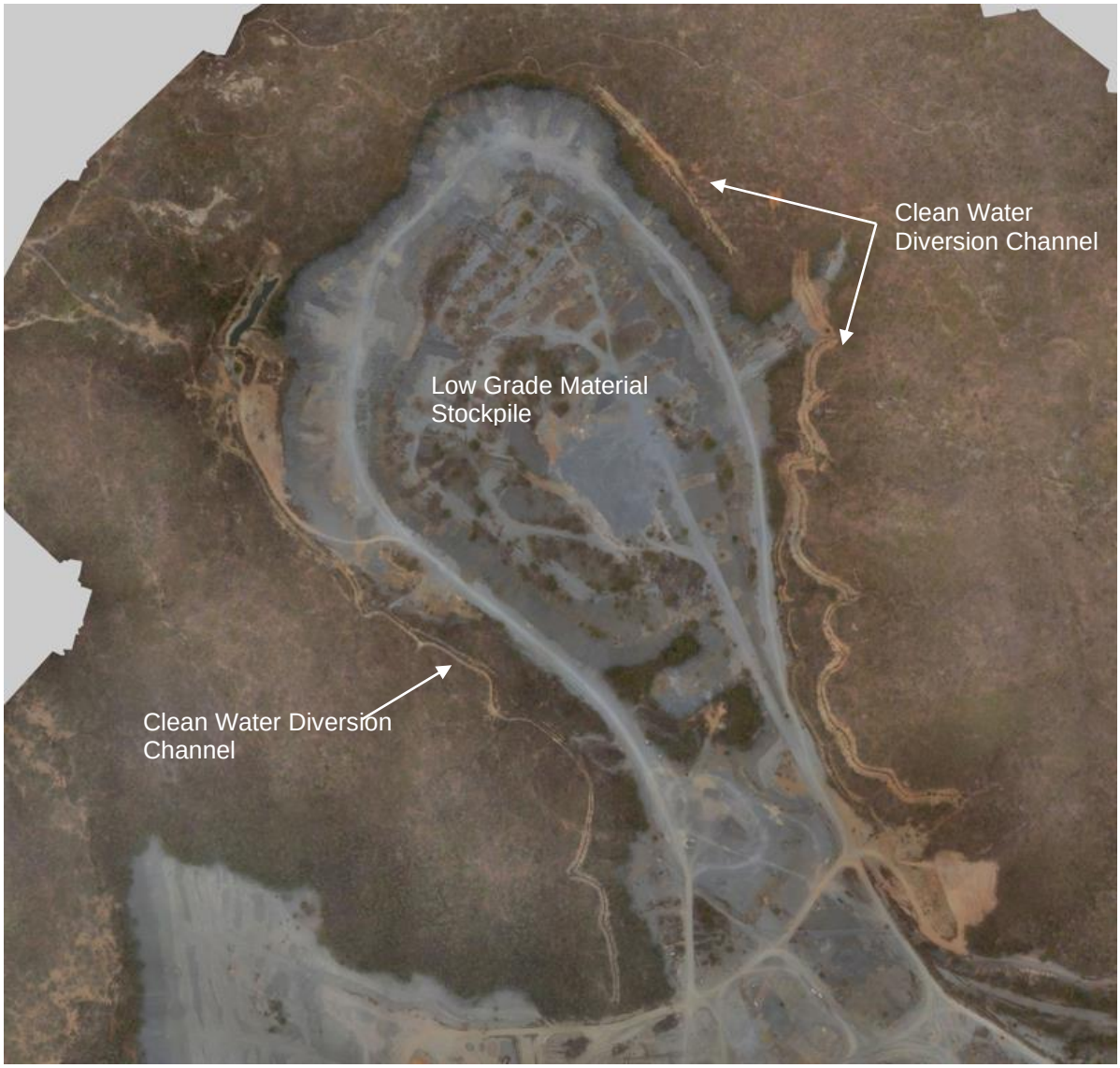
5.2.2 Clean Water Management

All clean water surface runoff is diverted around the mine impacted areas. The diversion drainage channel around TSF4 will divert clean surface water runoff both clockwise and anticlockwise from the surrounding sub-catchments to enter the tributary of Manganese Creek to the southeast of the site **[31]**.

Existing clean water diversion channels are located on both the west and east sides of the low-grade stockpile and convey surface water runoff from the adjacent catchments to tributaries of Holmes Creek. These diversion channels can be seen on drawing number 119190-05-100-003A in **Appendix B** and **PHOTO 1**.

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PHOTO 1: CLEAN WATER DIVERSION CHANNELS AT THE LOW GRADE STOCKPILE



5.2.3 Site Water Management

Seepage from the Low Grade Material Stockpile will be collected in the upgraded Quarry Sump and pumped to TSF3.

Surface runoff from all areas north of Mulligan Highway report to TSF3, with the exception of the Open Cut Pit sub-catchment which will be collected in the Pit sump and be pumped to TSF3.

Surface runoff from the processing plant and workshop area will report to TSF4.

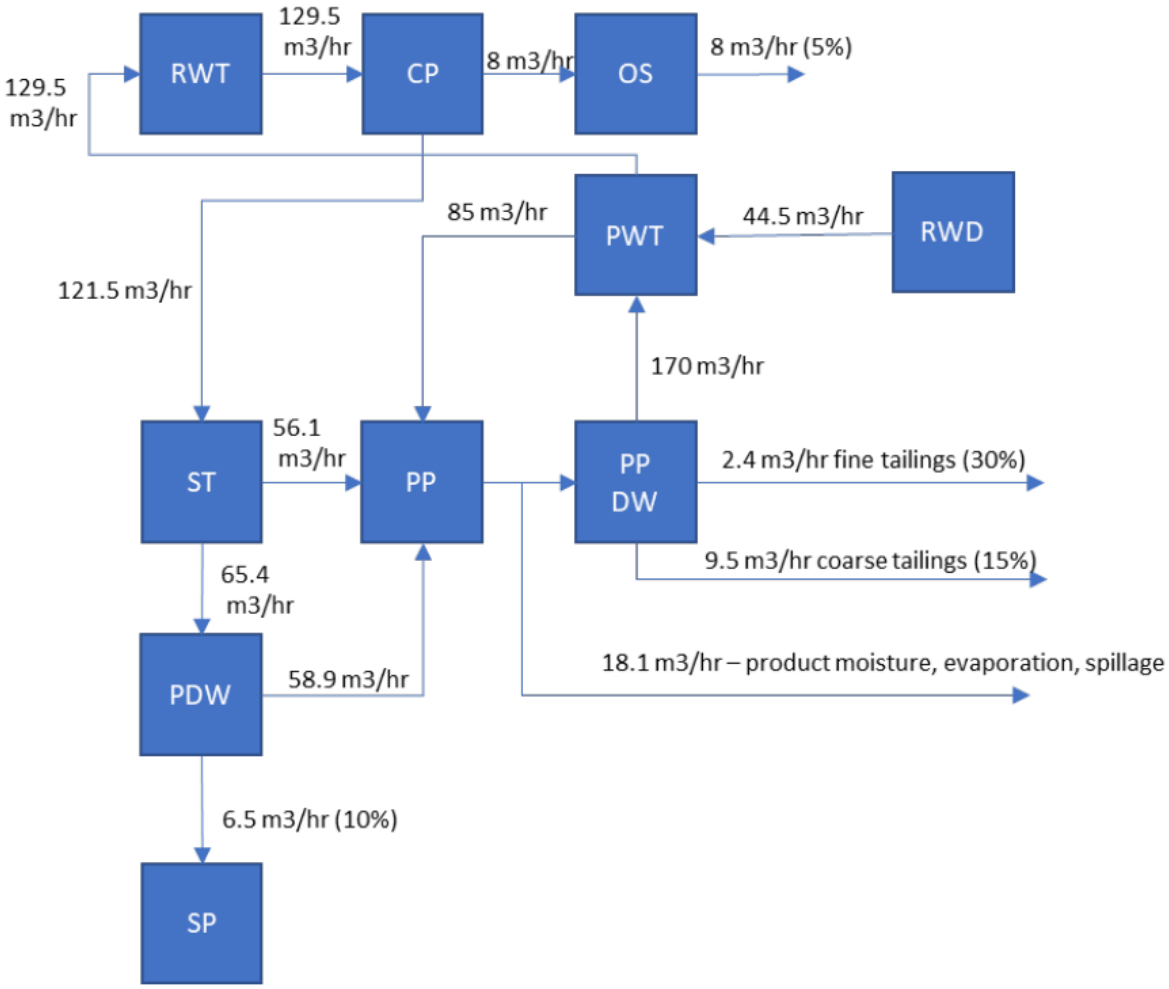
5.2.4 Pumping Regime

As discussed earlier in this section, all clean surface water runoff will be diverted around the site in diversion channels. No clean water is supplied to the site by water main or borehole extraction. All pumping on the site is of mine impacted water for retreatment processes or site movement between storages, as discussed in **Sections 2.6** and **5.2.3**.

Pump routing and expected maximum transfer rates were provided from discussions with site personnel and the memo from Jukes Todd **[22]**. A copy of the memo is provided in **Appendix D**, the key assumptions are presented in **Section 2.6.2** and the process flow charts are replicated in **DIAGRAM 10** and **DIAGRAM 11**. These site water demands are provided in tabular format in **TABLE 12**.

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DIAGRAM 10: PROCESS FLOW DIAGRAM – DAY SHIFT

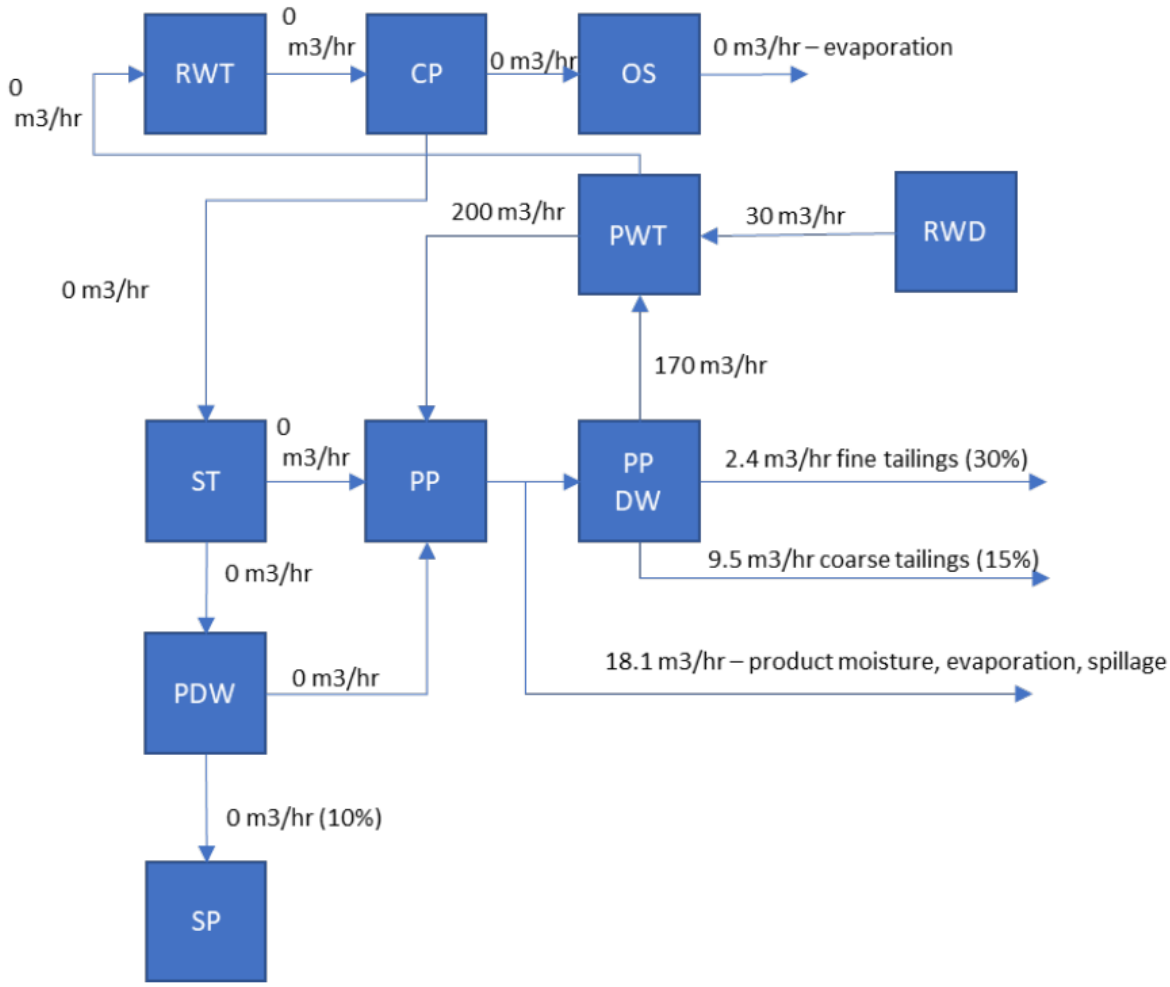


Legend:

RWT – Crushing Plant Raw Water Tank
CP – Crushing Plant
OS – Ore Sorter
PWT – Process Water Tank
RWD – Raw Water Dam
ST – Surge Tank
PP – Process Plant
PP DW – Process Plant Dewatering
PDW – Product Dewatering
SP – Product Stockpile

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DIAGRAM 11: PROCESS FLOW DIAGRAM – NIGHT SHIFT



Legend:

RWT – Crushing Plant Raw Water Tank
CP – Crushing Plant
OS – Ore Sorter
PWT – Process Water Tank
RWD – Raw Water Dam
ST – Surge Tank
PP – Process Plant
PP DW – Process Plant Dewatering
PDW – Product Dewatering
SP – Product Stockpile

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TABLE 12: SITE WATER BALANCE

Process	Peak hourly water demand			
	Day Shift		Night Shift	
	(m^3/h)	(L/s)	(m^3/h)	(L/s)
Supply from TSF4				
Supply from TSF4 to Process Water Tank (PWT)	44.5	12.4	30	8.3
Crushing Plant				
Supply from PWT to Crushing Plant	129.5	36.0	0	0
Recycling from Surge Tank and Product Dewatering Cell to Process Plant	115.0	31.9	0	0
Evaporation and material moisture loss from Product Stockpile (10%)	6.5	1.8	0	0
Evaporation and material moisture loss from Ore Sorter (5%)	8	2.2	0	0
Processing Plant				
Supply from PWT to Processing Plant	85.0	23.6	200	55.6
Processing Plant requirements (product moisture loss, evaporation and spillage)	18.1	5.0	18.1	5.0
Recycling from the Process Plant Dewatering Cell to the PWT	170	47.2	170	47.2
Fine material moisture loss (30%)	2.4	0.7	2.4	0.7
Coarse material moisture loss (15%)	9.5	2.6	9.5	2.6
Other water demands from TSF3				
Dust Suppression and Operational Requirements	20 m^3/h, 8 hours per day	5.6 L/s, 8 hours per day	0	0
Evaporative Sprayers 21 No. from TSF3, operating 10 hours/day, if rainfall is less than 5 mm/day	588 m3/day	163.3 L/day	0	0

Site water transfers between storages, other than for the process water or operational demands listed in **TABLE 12** are shown in **TABLE 13**.

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TABLE 13: SITE WATER TRANSFERS BETWEEN STORAGES

Source	Destination	Rate	Activation Condition	Deactivation Condition
Open Cut Pit	TSF4	100 L/s	Occurs when water elevation within TSF4 is below RL 356.2 m.	Ceases when water elevation within TSF4 is above RL 356.2 m.
Open Cut Pit	TSF3	100 L/s	Occurs when water elevation within TSF3 is below RL 374.0 m.	Ceases when water elevation within TSF3 is above RL 374.0 m.
TSF3	TSF4	110 L/s	Occurs when water elevation within TSF4 is less than RL 356.2 m And Water elevation in TSF3 is above RL 374.5 m.	Ceases when water elevation within TSF4 is greater than RL 356.2 m Or Water elevation in TSF3 is below RL 374.5 m..
Low Grade Material Stockpile	TSF3	0.7 ML/d	As required (TBC)	When empty (TBC)

Information regarding the pumps currently in use on site was provided by EQR site personnel. This information is replicated in **TABLE 14**.

TABLE 14: PUMPS IN USE AT THE MINE SITE

Pump Location	Pump Model	Estimated Duty Capacity (l/s)
TSF4 to Process Water Tank	Sykes 150-115	150
Low Grade Stockpile Sump to TSF3	Southern Cross 250x200-315	200
Open Pit to TSF3	Multiflo 360G	100
TSF3 to TSF4	Ajax 125-100	150
Total		**600**

5.3 Review of Capacity of Clean Water Diversion Channels

5.3.1 Introduction

The capacities of the diversion channels were reviewed in the 2021 water management plan **[32]** and the review has been retained in this report.

The channel dimensions were extracted from the LiDAR model at the downstream end of the catchments, that is, at the outlet/discharge point of the channels. The clean water diversion channel dimensions were clearly defined by the LiDAR data, so assessments of all four of the channels were made.

A XPStorm model was developed for each of the drainage channel catchments. The rainfall data for the site were obtained from the Bureau of Meteorology website **[33]** and the temporal pattern ensemble was downloaded from the Australian Rainfall and Runoff (ARR) Data Hub **[34]**. The design

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storm events for the 50%, 20%, 10% and 1% AEP events were simulated and the median results for each of the temporal pattern ensembles were used in this assessment.

Details of the model set up is provided in the following sections.

5.3.2 Catchment Delineation

The catchments for each drainage diversion were delineated and sub-catchments created to clearly represent the routing down the drainage diversions. The catchment and sub-catchment layouts are shown on **Figure 006** at the end of the report. The catchment and sub-catchment areas are presented in **TABLE 15**.

TABLE 15: CLEAN WATER DIVERSION CATCHMENT AREAS

Diversion Channel	Sub-Catchment Reference	Area (ha)
TSF4 East	TSF4_A	8.83
	Total Area	**8.83**
TSF4 West	TSF4_B1	9.94
	TSF4_B2	9.24
	TSF4_B3	27.44
	TSF4_B4	15.26
	TSF4_B5	17.30
	Total Area	**79.18**
Low Grade Stockpile West	B1	2.77
	B2	6.60
	B3	3.81
	Total Area	**13.18**
Low Grade Stockpile East	C1	2.35
	C2	5.03
	C3	5.33
	C4	4.44
	Total Area	**17.15**

5.3.3 Catchment Parameters

The Manning's 'n' values applied to the drainage channels and catchments were based on the aerial photography of the site. The applied Manning's roughness parameters and initial and continuing losses are presented in **TABLE 16**. The loss parameters applied to the model were obtained from the ARR Data Hub for the site **[34]**.

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TABLE 16: MANNING'S ROUGHNESS PARAMETERS

Surface	Manning's 'n' Roughness Value	Initial loss / Continuing loss
Overland flow over natural surface, sparse grass, trees and shrubs	0.13	35 mm / 2.8 mm/h
Drainage Channel, clean, straight, no rifts or pools.	0.025	35 mm / 2.8 mm/h

5.3.4 Diversion Channel Dimensions and Capacities

Typical drainage channel dimensions were extracted from the LiDAR data for inclusion in the XPStorm model and for calculation of their capacities. The channel dimensions were extracted at the downstream end of the diversion channels and are presented in **DIAGRAM 12**. The equivalent channel dimensions used in the calculation are provided in **TABLE 17**. The capacities of the channels were calculated using Manning's formula, as set out in **Equation 1**.

EQUATION 1: MANNING'S FORMULA

$$Q = \left(\frac{1}{n}\right) AR^{\frac{2}{3}}\sqrt{S}$$

Where:

Q = Flow Rate (m^3/s)

A = Flow Area (m^2)

n = Manning's Roughness Coefficient

R = Hydraulic Radius (m)

S = Channel slope (m/m)

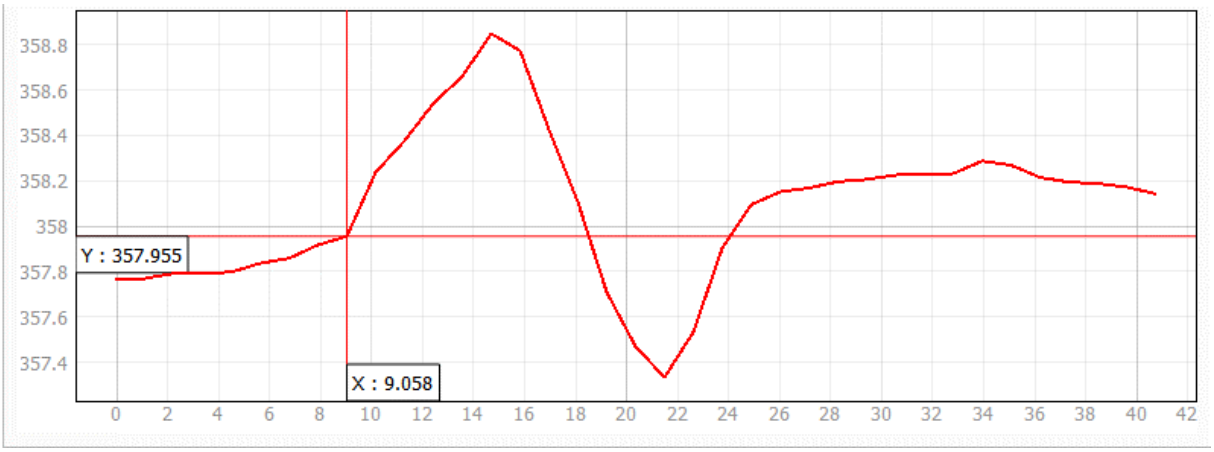
TABLE 17: DRAINAGE CHANNEL DIMENSIONS AND CAPACITIES

Drainage Channel	Base Width (m)	Channel Depth (m)	Side Slopes V:H	Channel Capacity (m^3/s)
TSF4 East	0 (V-drain)	1	1:5	7.4
TSF4 West	1	1	1:3	6.8
Low Grade Stockpile West	0 (V-drain)	1	1:3	16.9
Low Grade Stockpile East	1.0	1.0	1:3	6.8

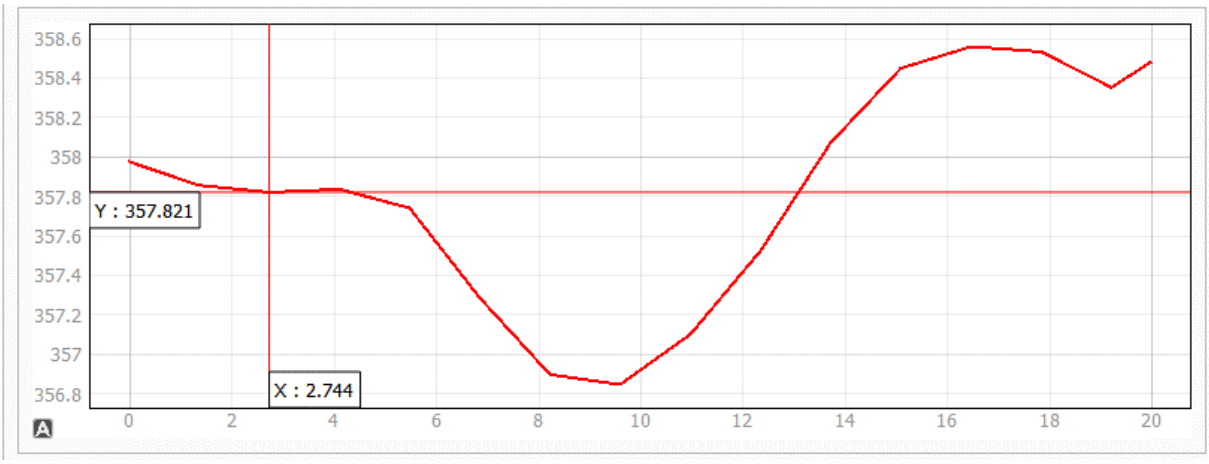
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DIAGRAM 12: CROSS SECTIONS OF CLEAN WATER DIVERSION CHANNELS.

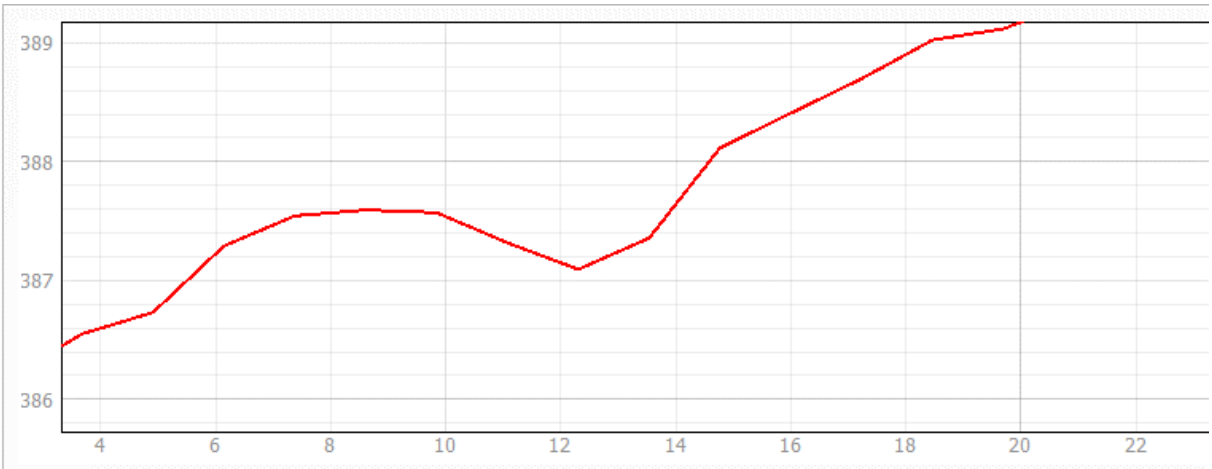
i. TSF4 East



ii. TSF4 West

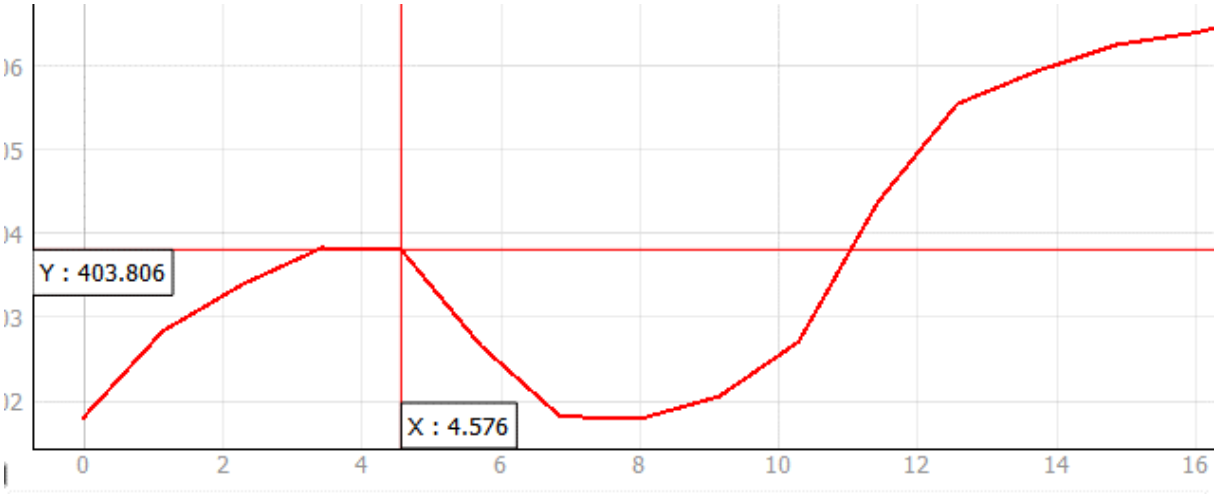


iii. Low Grade Stockpile West



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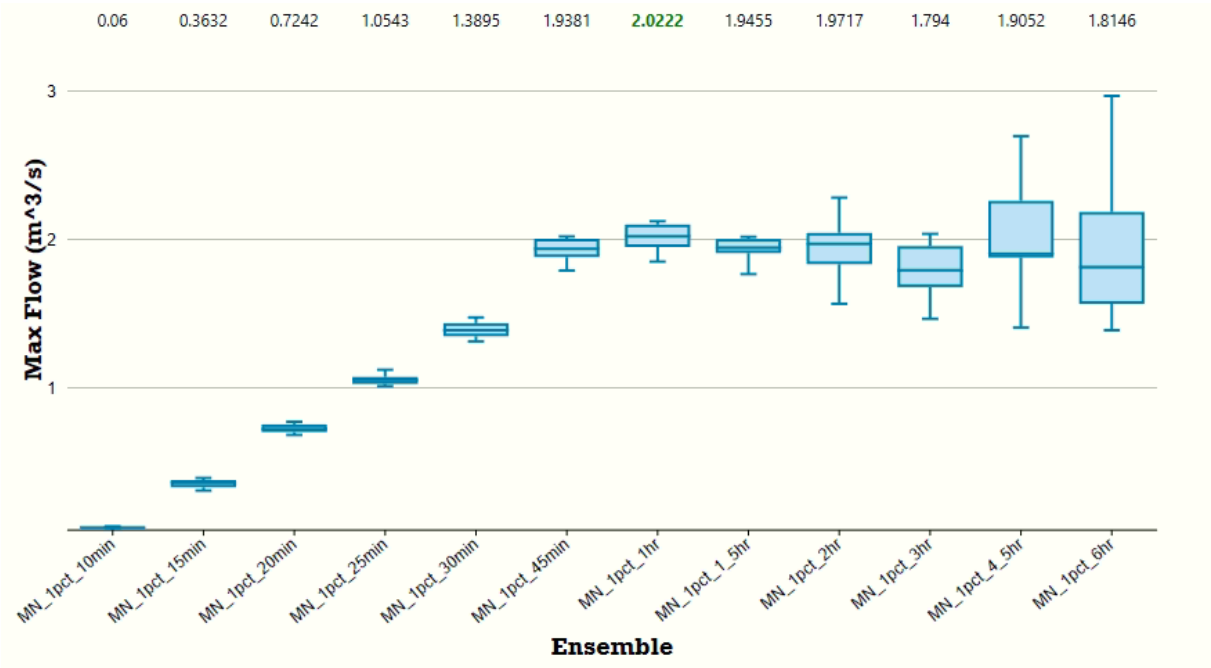
iv. Low Grade Stockpile East



5.3.5 Results and Discussion

The results of the XPStorm modelling produced estimates of the rainfall runoff quantities at the downstream end of the diversion channels. The estimated median discharges for the 50%, 20%, 10% and 1% AEP design storm events and the estimated channel capacity for each diversion channel are presented in **TABLE 18**. Box and whisker plots of the 1% AEP peak discharge results in the four catchments are presented in **DIAGRAM 13**, **DIAGRAM 14**, **DIAGRAM 15** and **DIAGRAM 16**. The plots show the peak discharges of the ten ensemble temporal patterns for each storm duration. The whiskers represent the 10th and 90th percentile values, the boxes the 25th to 75th percentile values and the line in the box the 50th percentile (median) values. The largest median peak discharge values for each storm event were used in the diversion channel capacity assessment.

DIAGRAM 13: 1% AEP PEAK DISCHARGES FOR TSF4 EAST CLEAN WATER DIVERSION CATCHMENT



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DIAGRAM 14: 1% AEP PEAK DISCHARGES FOR TSF4 WEST CLEAN WATER DIVERSION CATCHMENT

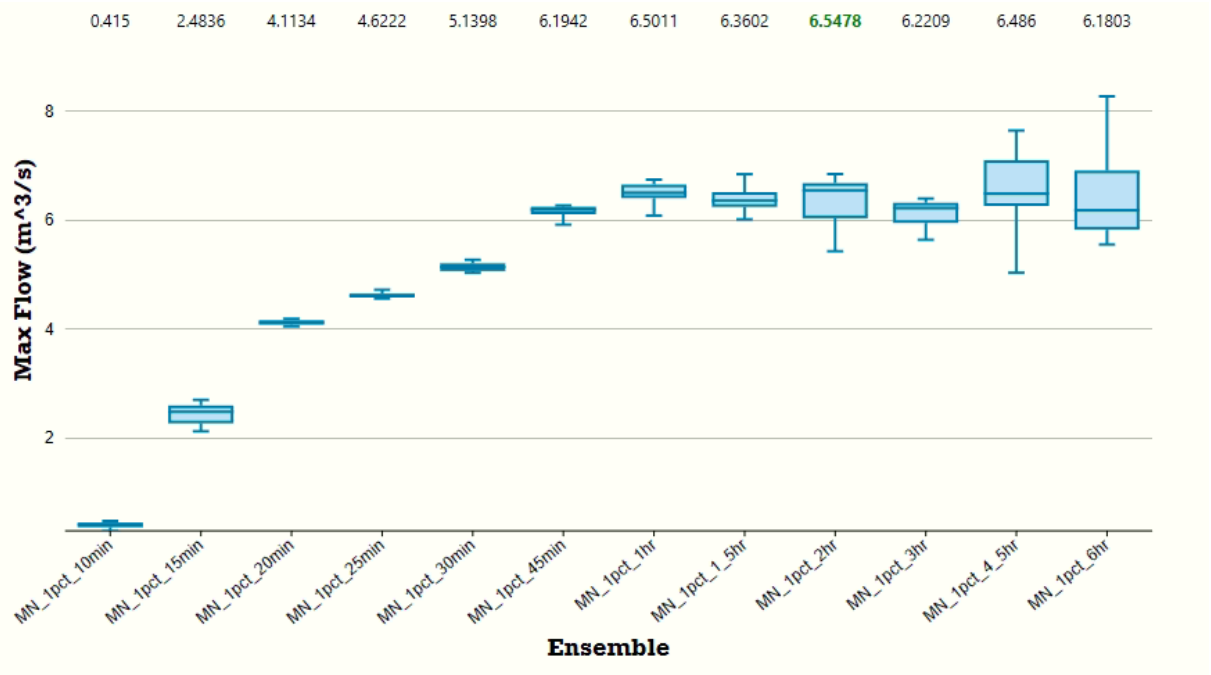
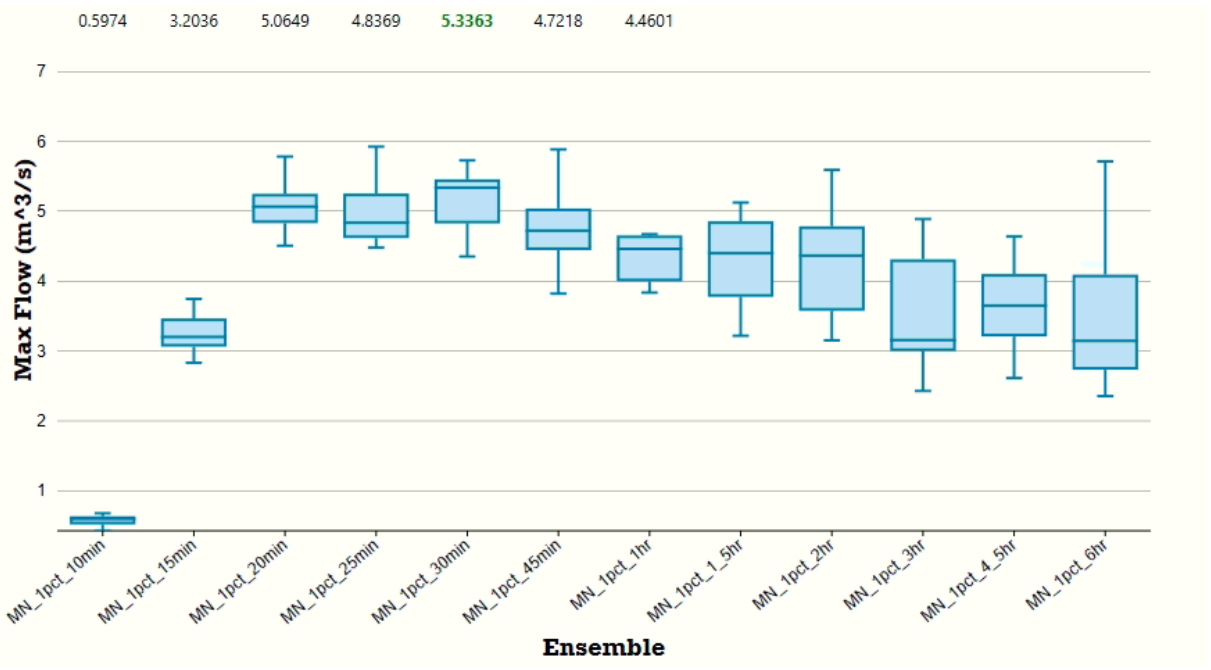
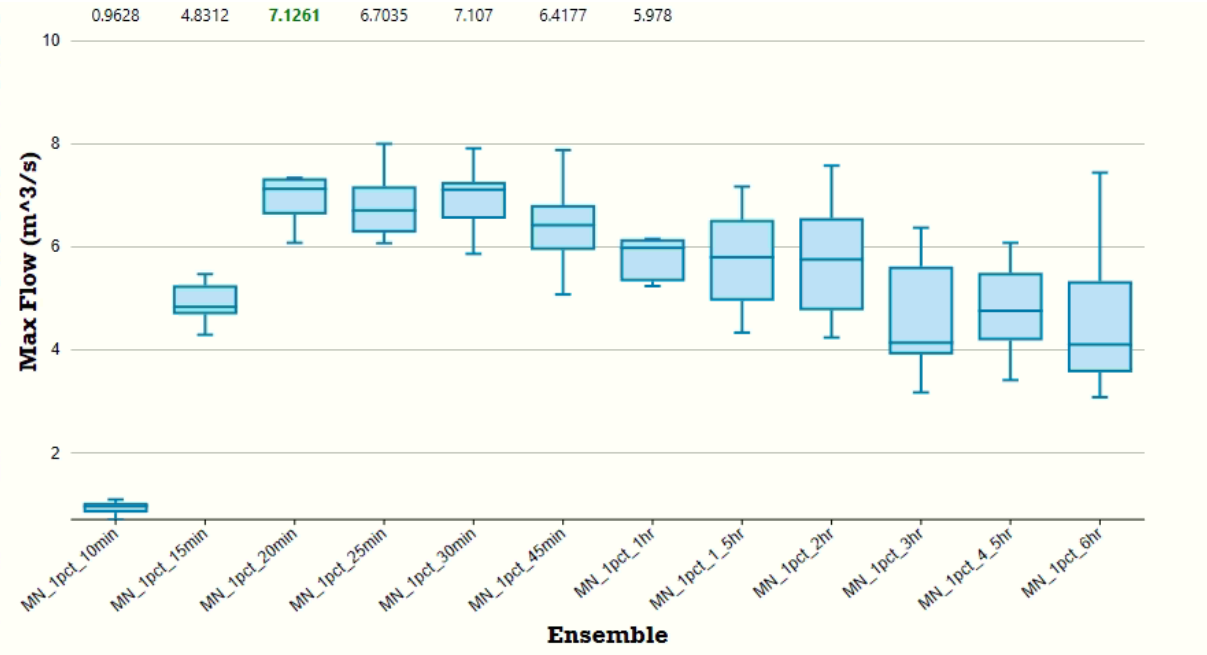


DIAGRAM 15: 1% AEP PEAK DISCHARGES FOR THE LOW GRADE STOCKPILE WEST CLEAN WATER DIVERSION CATCHMENT



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DIAGRAM 16: 1% AEP PEAK DISCHARGES FOR THE LOW GRADE STOCKPILE EAST CLEAN WATER DIVERSION CATCHMENT



From the results, it can be seen that with the exception of the clean water diversion channel on the eastern side of the low grade stockpile, all the diversion channels have sufficient capacity to contain the estimated discharge in the 1% AEP design storm event. For events less than the 1% AEP design storm, all drainage channels had sufficient capacity to convey the estimated surface runoff quantities.

TABLE 18: DIVERSION CHANNEL ESTIMATED DISCHARGE FOR 1% AEP DESIGN STORM EVENT

Drainage Channel	Channel Capacity (m^3/s)	Estimated Discharge (m^3/s)			
		50% AEP	20% AEP	10% AEP	1% AEP
TSF4 East	7.35	0.67	1.05	1.17	2.02
TSF4 West	6.80	4.20	4.92	5.12	6.58
Low Grade Stockpile West	16.92	1.43	2.54	2.95	5.34
Low Grade Stockpile East	6.81	1.90	3.43	3.98	7.13

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6 SITE WATER BALANCE ASSESSMENT

6.1 Preamble

Water balance modelling was conducted to assess the performance of the site water management system under the increased retreatment regime for the Stage 3 operations. The objectives of the water balance model were:

- to assess the performance of the proposed operational site water management system; and
- to identify the quantity of runoff and site water generated from the mining activities and surrounding catchments based on a range of realistic climatic events.

6.2 Water Balance Model Development

A new water balance model was developed for the proposed Stage 3 operations. A dynamic probabilistic simulation modelling approach, using GoldSim Pro Version 14.1, was adopted for this purpose, based on a daily climatic record for the site. An integrated catchment yield analysis for site catchments was also coupled with the water balance model. Using the available Silo Data Drill climatic record, 132 No. Monte Carlo sampling realisations were used to generate probabilistic distribution results.

The model was based on the conditions outlined in this report, with the duration from September 2022 to September 2027, when the mining operations in the Open Cut Pit are planned to cease. The water balance model included the staged emptying of the Open Cut Pit from September 2022 to the projected closure of the open cut mining operation in 2027. The agreed dates for the different water balance operations until completion of the Stage 3 upgrades are presented in **TABLE 19**.

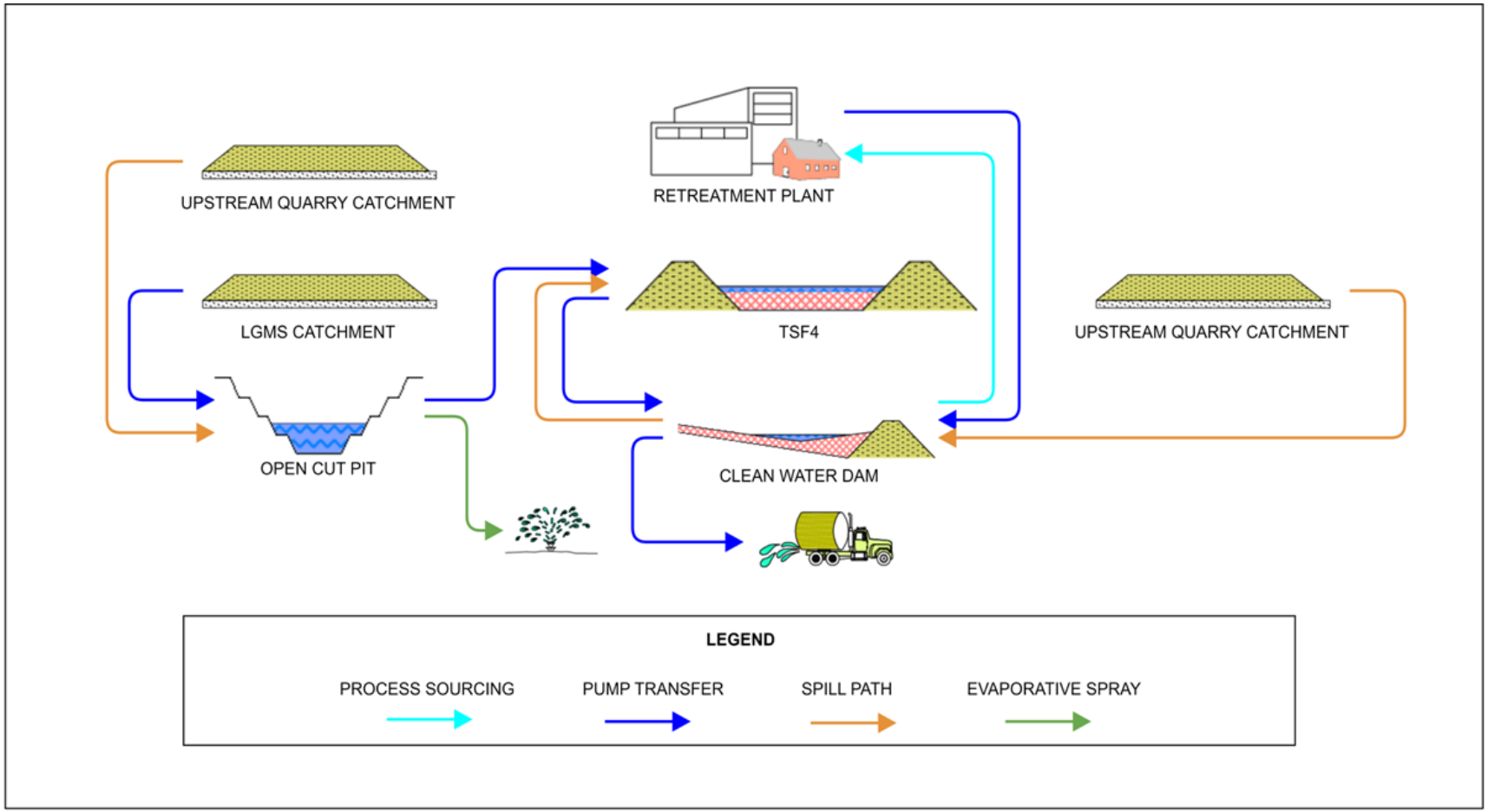
TABLE 19: TIMING OF STAGE 3 CONSTRUCTION

Phase	Date
Commence dewatering Open Cut Pit with evaporative sprayers and pumping to TSF4	01/09/2022
Completion of TSF3 and TSF4 construction	15/12/2022
Pumping from Open Cut Pit to TSF3	15/12/2022
Transfer of half the evaporative sprayers from the Open Cut Pit to TSF3	01/02/2023
Commencement of mining from the Open Cut Pit (Dependent on dewatering of Open Cut Pit)	01/02/2023

The key elements in this site water balance model are described below, with a process flow diagram representing the initial dewatering of the Open Cut Pit prior to construction of TSF3 shown in **DIAGRAM 17** and the post TSF3 and TSF4 upgrade conditions shown in **DIAGRAM 18**.

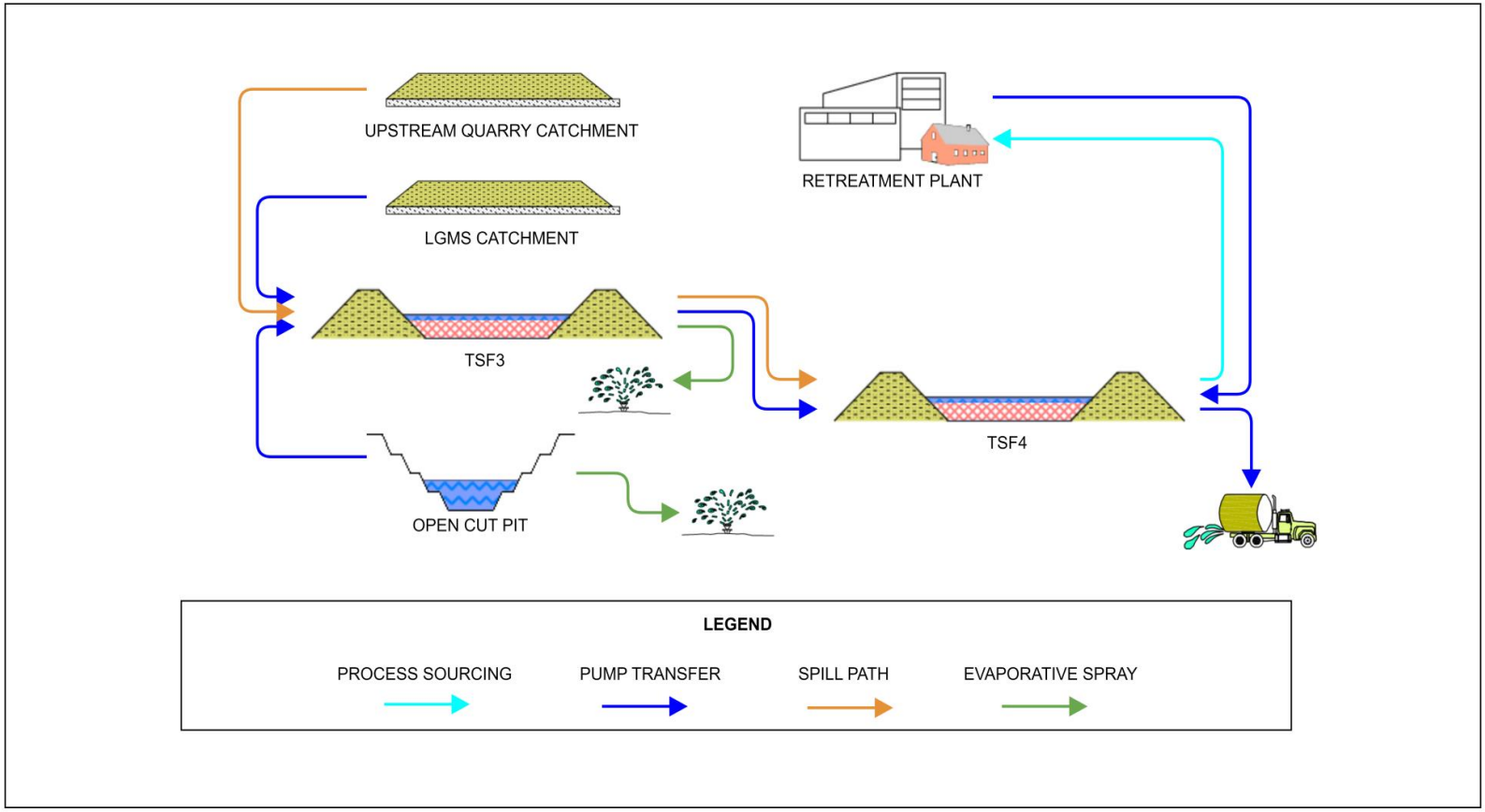
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DIAGRAM 17: PROCESS FLOW DIAGRAM (PRIOR TO CONSTRUCTION OF TSF3)



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DIAGRAM 18: PROCESS FLOW DIAGRAM POST CONSTRUCTION OF TSF3 AND TSF4 UPGRADE



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6.3 Modelling Assumptions and Relevant Data

6.3.1 Assumptions

The following assumptions were made in the development of the water balance model.

- The delineated catchment areas were re-estimated based on the LiDAR survey data provided by MCQ for the Mount Carbine site **[35]**. Plans of the sub-catchment layouts for the phased mining of the Open Cut Pit are provided in **Figures 001** to **004** at the end of this report.
- All dewatering in the retreatment processes is accounted for in the mass balance of the water, as agreed with MCQ and set out in **TABLE 12**.
- The timing of the changes in the process flows is based on the projected timeframes provided by MCQ.
- The stage storage characteristics of the Open Cut Pit are based on the profiles provided by EQR **[20]**.
- The stage storage characteristics of the upgraded TSF4, TSF3 and the Low Grade Material Stockpile Sump are based on the designs prepared by ATCW.
- The WRD that will be nominally formed to the north of TSF3 between May 2023 and December 2024 has been progressively included in the pit catchment over this period, to reflect capture of runoff from this area for transfer and treatment within the pit, if required.

6.3.2 Base Model Inputs

The water balance model was developed to reflect site conditions within the modelling horizon. Data inputs for the model are summarized below.

6.3.2.1 Storage Conditions

Primary water balance inputs for the site storages are outlined in **TABLE 20**. The initial water levels for available storages were estimated based on the TSF3 and TSF4 designs. The capacities of the staged storages for the Open Cut Pit voids were provided by EQR **[20]**.

TABLE 20: WATER BALANCE MODEL – SITE STORAGE PROPERTIES

Storage	Full Supply Level (FSL)	Storage Capacity (ML)	Initial Storage Level
Open Cut Pit – Pre-dewatering*	RL 380.0 m	3,429	RL 347.78 m
Open Cut Pit – Stage 1	RL 380.0 m	3,429	N/A
Open Cut Pit – Stage 2	RL 380.0 m	8,444	N/A
Open Cut Pit – Stage 3	RL 380.0 m	11,040	N/A
TSF3	RL 375.5 m	326.8	RL 366.2 m
TSF4*	RL 357.5 m	418.0	RL 356.35 m

* Initial water levels for TSF4 and the Open Cut Pit were supplied by EQ Resources as at 5 September 2022.

6.3.2.2 Pumping Schedule

Pump routing and typical transfer rates were based on discussions with site personnel. Site transfers from storages and process water sourcing are as presented in **TABLE 13** and **TABLE 14** respectively.

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The efficiency of the evaporative sprayers is dependent on seasonal weather conditions. The assumed seasonal efficiency applied to the evaporative sprayers in the model was as shown in **TABLE 21**.

TABLE 21: SEASONAL EFFICIENCY OF THE EVAPORATIVE SPRAYERS

Season	Efficiency
Summer (December to February)	100%
Spring and Autumn (September to November, March to May)	75%
Winter (June to August)	50%

To allow for the seasonal variation in the seepage from the Low Grade Material Stockpile, the estimated seepage into the sump was applied according to the assumed factors in **TABLE 22**.

TABLE 22: SEASONAL FACTORS APPLIED TO SEEPAGE PRODUCTION

Season	Seepage Production Rate as Percentage of 0.7ML/d
Summer (December to February)	100%
Spring and Autumn (September to November, March to May)	75%
Winter (June to August)	50%

6.3.2.3 Retreatment Water Sourcing

Process water is sourced from TSF4 in a loop circuit within the processing area. Based on discussions with site personnel, it is understood that the plant water demand will be approximately 200 m^3/h (55.6 L/s), with a day shift intake of approximately 44.5 m^3/h (12.4 L/s) from TSF4 to the Process Water Tank that serves both the Crushing Plant and the Process Plant. The night shift intake will be approximately 30 m^3/h. The balance of the water required by the processing area is from recycling and dewatering within the plant. The supply requirements for the Process Plant and Crushing Plant were combined into a single Retreatment Plant demand within the water balance model (WBM).

6.3.2.4 Catchment Runoff Estimation

Rainfall runoff in the WBM is simulated using the Australian Water Balance Model (AWBM) **[36]**. The AWBM is a nationally recognised catchment scale water balance model that estimates catchment yield as a flow rate from rainfall and evaporation.

AWBM simulation of flow from six different sub-catchment types was undertaken: natural, undisturbed areas, hardstand (roads and infrastructure areas), open cut pit, active waste rock emplacement, rehabilitated waste rock emplacement and tailings. Within the model, areas of open water, such as in storages, have the same characteristics as hardstand. Areas of future sub-catchment types were taken from the plans provided by EQR and the design layouts by ATCW.

AWBM simulation of flow from each sub-catchment type was undertaken. The model AWBM parameters were updated from the previous WBM **[32]**, based on previous model experience at similar project locations. The AWBM parameters in the model are summarised in **TABLE 23**.

The catchment and sub-catchment areas corresponding to the sub-catchment types in **TABLE 23**. were calculated using aerial imagery and survey data, as described in **Section 2.7**.

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The sub-catchment areas varied slightly over the duration of the water balance model simulation due to the expansion of the Open Cut Pit from mining, construction of TSF3 and the TSF4 embankment raise. The changes in sub-catchment type over the duration of the model are provided in **TABLE 24**.

TABLE 23: MODEL AWBM PARAMETERS BY SUB-CATCHMENT TYPE

Parameter	Sub-Catchment Type					
	Natural	Open Cut	Spoil/Waste	Rehabilitated	Hardstand/ Open Water	Tailings
C1	12	5	35	20	5	5
C2	120	20	200	55	5	5
C3	240	20	240	100	5	25
A1	0.134	0.1	0.2	0.1	0.5	0.2
A2	0.433	0.9	0.8	0.3	0.5	0.2
A3	0.433	0	0	0.6	0	0
k_s	0.8	0.2	0.2	0.2	0.1	0.1
k_b	0.861	0.96	0.9	0.9	0.94	0
BFI	0.2	0	0.9	0.9	0	0

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TABLE 24: SURFACE TYPES AND SUB-CATCHMENT AREAS

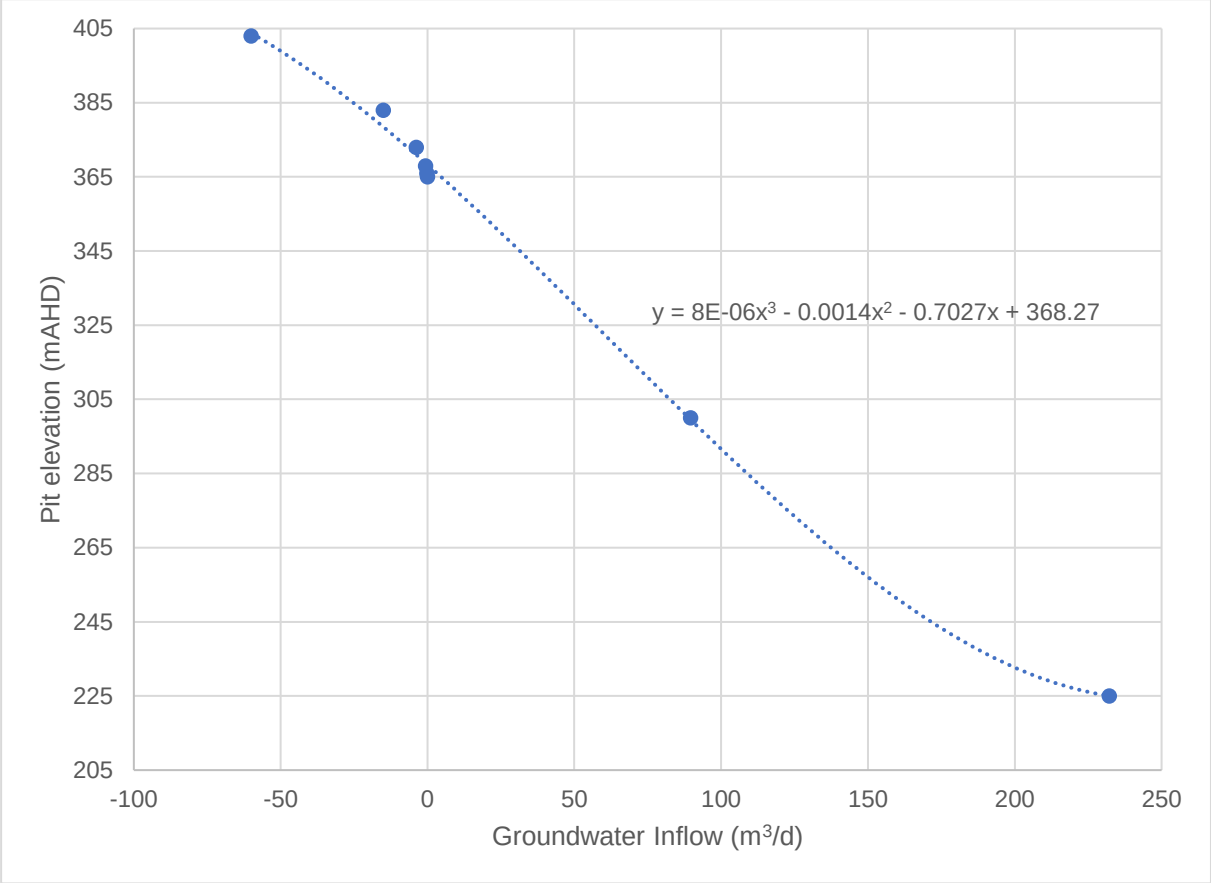
Storage	Date	Catchment Area by Land Use Type (ha)						
		Natural	Pit	Waste	Rehab	Hardstand	Tailings	Sum
Pit	1/09/2022	0.00	12.59	0.00	0.00	10.48	0.00	23.07
	15/12/2022	0.00	12.59	0.00	0.00	10.48	0.00	23.07
	1/05/2023	0.00	12.59	0.00	0.00	10.48	0.00	23.07
	1/12/2023	0.00	18.71	1.47	0.00	6.96	0.00	27.14
	1/05/2024	0.00	18.71	2.93	0.00	6.96	0.00	28.61
	1/12/2024	0.00	18.71	4.40	0.00	6.96	0.00	30.07
	1/12/2025	0.00	24.71	4.40	0.00	5.03	0.00	34.14
	1/09/2027	0.00	24.71	4.40	0.00	5.03	0.00	34.14
TSF3	1/09/2022	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	15/12/2022	5.08	0.00	15.37	0.00	10.41	0.00	30.85
	1/05/2023	5.08	0.00	15.37	0.00	10.41	0.00	30.85
	1/12/2023	5.08	0.00	13.20	0.00	10.41	0.00	28.68
	1/05/2024	5.08	0.00	11.73	0.00	10.41	0.00	27.22
	1/12/2024	5.08	0.00	10.26	0.00	10.41	0.00	25.75
	1/12/2025	2.64	0.00	8.63	0.00	18.81	0.00	30.08
	1/09/2027	2.64	0.00	8.63	0.00	18.81	0.00	30.08
TSF4	1/09/2022	0.00	0.00	0.00	0.00	39.41	24.75	64.16
	15/12/2022	0.00	0.00	0.00	0.00	42.36	24.75	67.12
	1/09/2027	0.00	0.00	0.00	0.00	42.36	24.75	67.12
Clean Water Dam	1/09/2022	16.09	0.00	15.37	0.00	8.62	0.00	40.08
	15/12/2022	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1/09/2027	0.00	0.00	0.00	0.00	0.00	0.00	0.00

6.3.2.5 Groundwater Inflows and Outflows to the Open Cut Pit

A relationship between the groundwater inflow/outflow to the Open Cut Pit void and the elevation of the water stored in the Pit was provided by EQR **[37]**. The relationship is presented graphically in **DIAGRAM 19**. The raw data provided indicated that there is outflow from the Pit when the water surface elevation is above RL 365 m AHD and increasing inflow as the water surface elevation in the Pit is lowered. It should be noted that the pit will spill when the water surface elevation reaches RL 380 m AHD.

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DIAGRAM 19: RELATIONSHIP BETWEEN THE GROUNDWATER INFLOW AND WATER SURFACE ELEVATION IN THE OPEN CUT PIT



In the later stages of mining in the Open Cut Pit, the mine extends into the hill to the northwest, but the spill level will remain at RL 380 m AHD at the southern edge of the open cut.

6.4 Modelled Case

To address the key requirement of the WMP to control and minimise the spill risk of potentially mine affected water from the site, the following scenario was modelled within the WBM.

- Operational model based on the staged development of mining within the Open Cut Pit, from dewatering to full operation.

6.5 Water Balance Results

The water balance model results for the site storages have been presented as probability plots depicting percentile outcomes for water storage volumes in each storage.

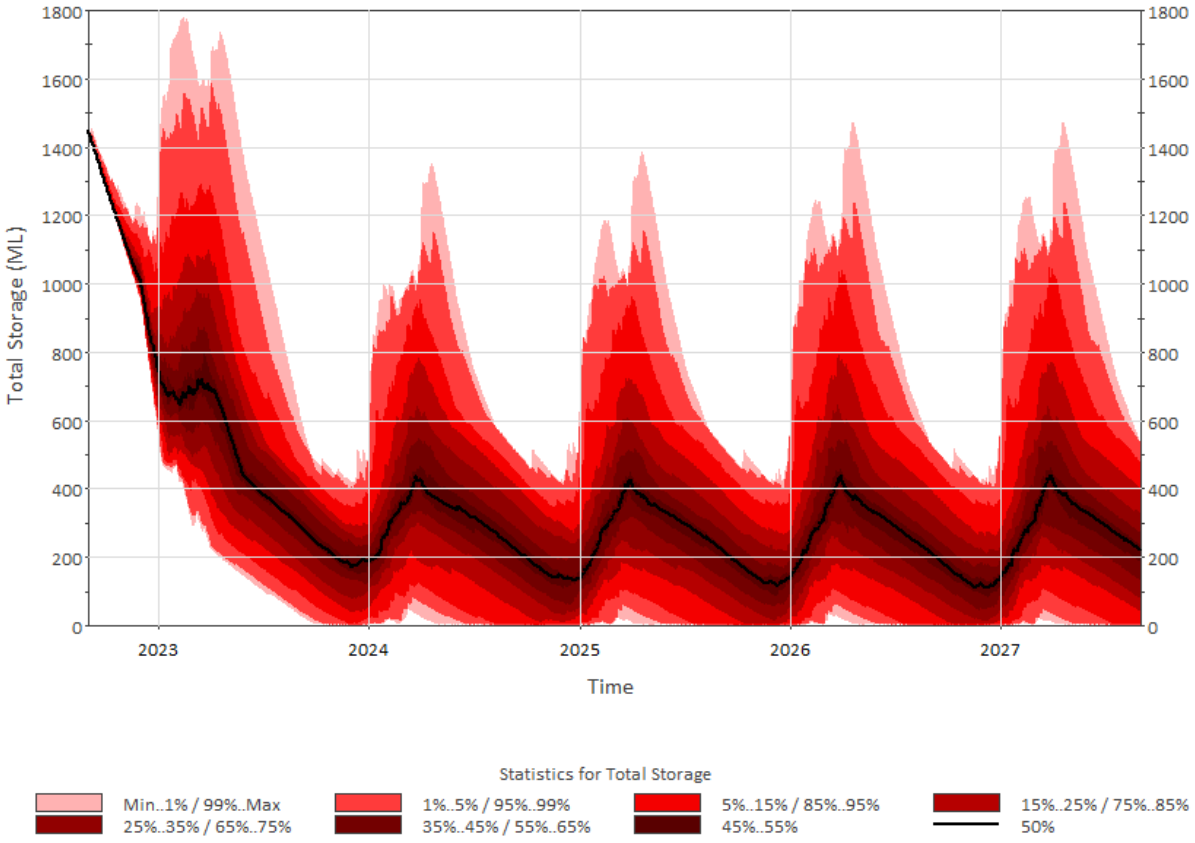
The total volume of water on the site, shown in **DIAGRAM 20**, indicates that from September 2022, the total volume of water stored on site is reducing, driven primarily by dewatering of the Open Cut Pit through the use of the evaporative sprayers. As the 2022/23 wet season commences, there is an increase in stored water on the site, although dewatering of the Pit continues. It should be noted that the Pit is also dewatered by pumping to TSF4 where capacity exists and from December 2022 to TSF3, but it is the evaporative sprayers that have the greatest impact on removing water from the total volume on site.

The WBM indicates that the Pit dewatering will be completed in the first half of 2023 and subsequently the total water volume on the site is affected by the seasonal rainfall patterns and the increase in Open Cut Pit mine extents. The mean peak volume stored on site is estimated to be approximately 450 ML from 2026 when the Stage 3 Pit extents are at their greatest. The 50% line on **DIAGRAM 20**

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represents the 50th percentile probability value of total water stored on the site from the simulations using the historical data.

DIAGRAM 20: TOTAL WATER VOLUME FOR THE SITE – OPERATIONAL CASE



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DIAGRAM 21: STORED VOLUME IN OPEN CUT PIT – OPERATIONAL CASE

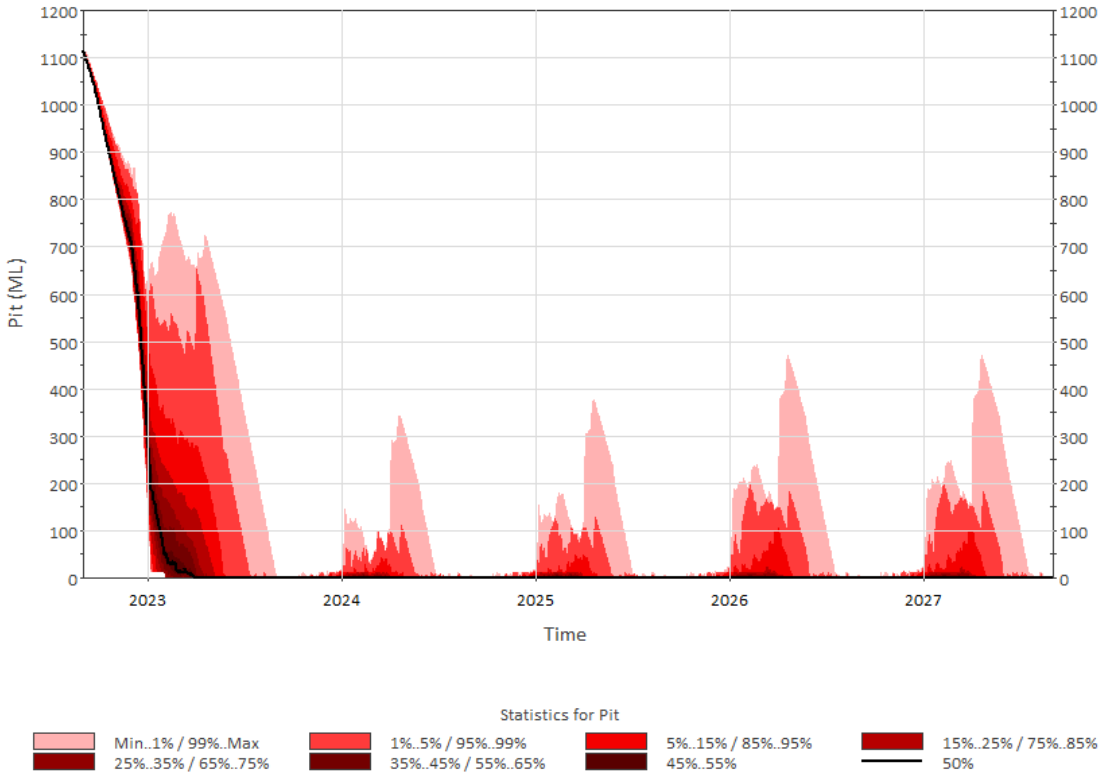
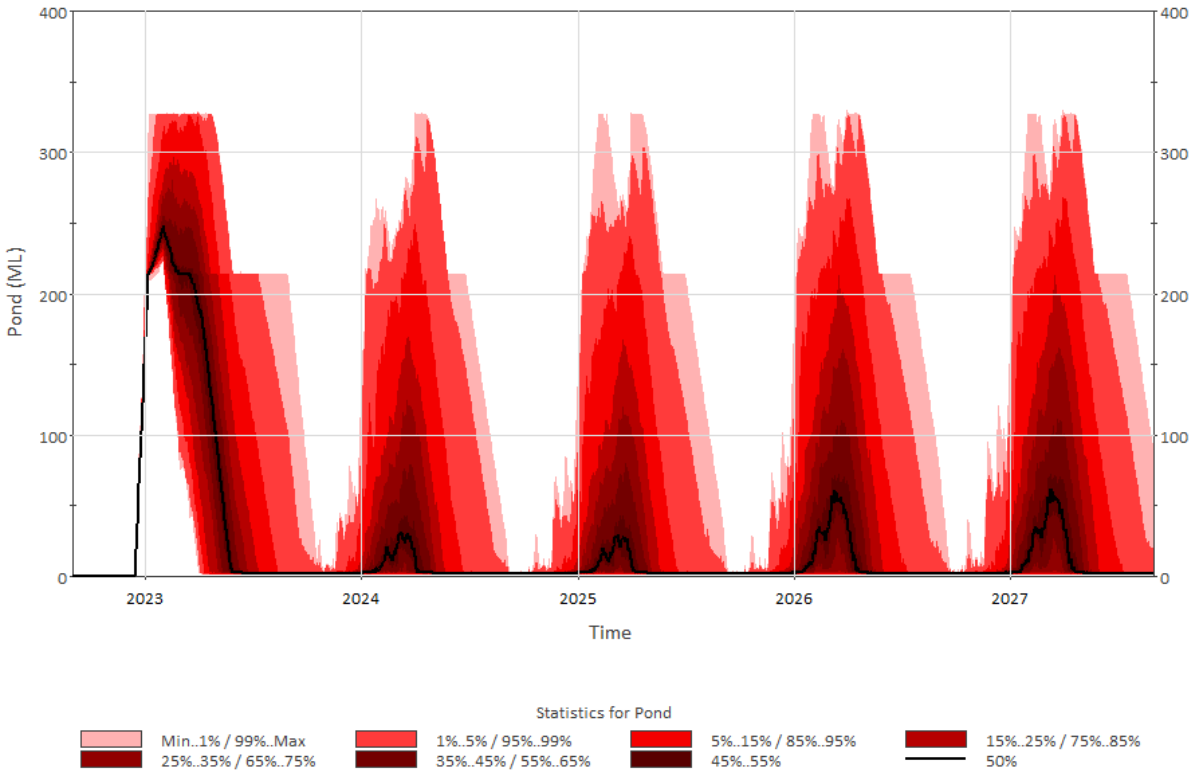


DIAGRAM 21 represents the stored volume within the Open Cut Pit. As expected, the diagram indicates that the Pit is being dewatered from September 2022 but has a potential increase in stored volumes due to the 2022/23 wet season. After the Pit is dewatered, no further runoff from external catchments is received by the Pit (with runoff generally directed to the upgraded TSF3) and only runoff from the Pit sub-catchment is stored. As mentioned previously, the Pit Stage 3 operations increase the area of the void and hence the volume of rainfall and surface runoff collected. This is reflected in the increase in potential stored volume until 2026, although the mean probability (50%) stored volume is close to zero. It should be noted that stored surface runoff in the Pit will be pumped out to TSF3 when constructed (estimated date 15/12/2022).

The results of the modelling indicate that the Pit will not have uncontrolled spills during its operation as an open cut mine.

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DIAGRAM 22: STORED VOLUME IN TSF3 – OPERATIONAL CASE

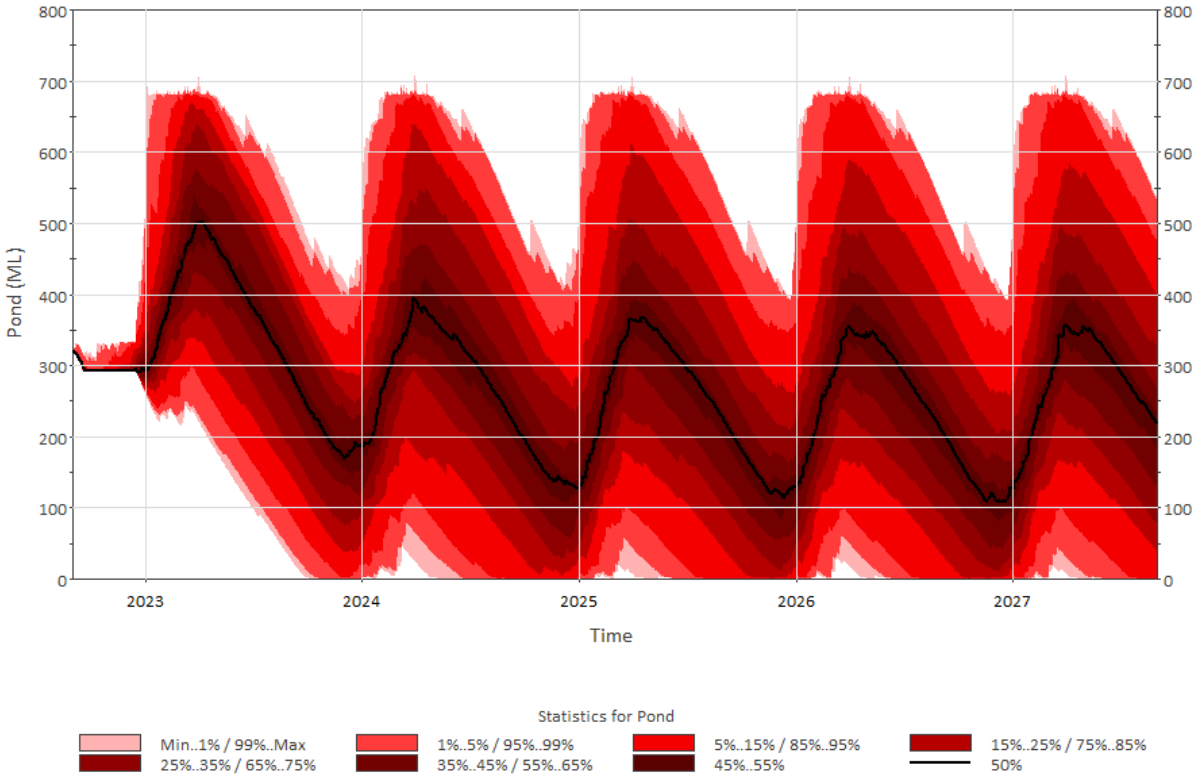


The modelled stored water volume in TSF3 is shown in **DIAGRAM 22**. The diagram indicates that TSF3 has a greater probability of spilling over the 2022/23 wet season than in subsequent years. This increased spill risk is because TSF3 will be receiving greater volumes of water from the dewatering of the Open Cut Pit in 2022 to early 2023.

The plot has a level section at the end of the wet season in every year. This level section represents the threshold of pumping to TSF4 to reduce the likelihood of spills from TSF3 (refer to **TABLE 13** in **Section 5.2.4**).

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DIAGRAM 23: STORED VOLUME IN TSF4 – OPERATIONAL CASE



The plot of stored water in TSF4 in **DIAGRAM 23** shows that there will be an elevated volume of water stored over the 2022/23 wet season than in subsequent years. This large volume of water will be stored in TSF4 due to the dewatering of the Open Cut Pit to the storage prior to the construction of TSF3. The dewatering of the Pit has also occurred when the existing TSF4 storage is already nearly full.

A summary of the modelling results in the form of spill risks is provided in **TABLE 25**. These values represent the modelled statistical likelihood of a storage experiencing a spill over the modelling horizon of five years.

TABLE 25: WET SEASON SPILL PROBABILITIES – OPERATIONAL CASE

Storage	Modelled Spill Probability – Operational Case		
	2022 (annualised risk for September to December)	2023 (annualised risk from January to December)	2024 to 2027
Open Cut Pit	0	0	0
TSF3	N/A	20%	2%
TSF4	52%	23%	12%

The estimated modelled spill probabilities presented in **TABLE 25** demonstrate that, when completed, the spill risk from the site will be reduced once the Open Cut Pit is dewatered and both TSF3 and TSF4 upgrades have been completed. There will be no spill risk from the Open Cut Pit; spills from TSF3 will report to TSF4; and the spills from TSF4 will be via the permissible release point at the southern point of the site. It is noted that the WBM indicated that all the spills from TSF3 and TSF4 will be contained within their design spillways and are not over-embankment spills.

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The existing site layout had a spill risk of 3.9% from TSF4, with a spill risk of 3.1% from the Open Cut Pit. The raising of TSF4 embankment and the construction of TSF3 have mitigated a large amount of the potential impact of the Pit no longer being available for storage of water on the site.

6.6 Summary

The results outlined in **TABLE 25** indicate that there will be no spill risk from the Open Cut Pit whilst it is being dewatered and operated as a mine. Over the 2022/2023 wet season, there is a high spill risk for TSF4 (52%), but this spill risk will reduce after the Pit is dewatered and the water storages have equalised. The WBM estimated that the spill risks in TSF3 and TSF4 will be approximately 2% and 12% respectively, from 2024. It should be noted that the spills from TSF3 will report to TSF4.

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7 SITE WATER MONITORING

7.1 Regulatory Context

Under the current Environmental Authorities (EA's), the activities on site are:

- Extraction and screening of not more than 1,000,000 t of material per year **[1]**; and
- Mineral processing of mineral products greater than 100,000 t per year **[2]**.

The Stage 3 application is to re-commence mining from the Open Cut Pit.

The processing plant will operate 24 hours a day, seven days per week, with an estimated processing time of 511 hours per month, the remaining hours being downtime for maintenance.

7.1.1 Receiving Water

There is one permissible release point of contaminated water from the site, as described in EA EPML00956913 **[2]**. The release point is from TSF4 spillway to Manganese Creek. The details of the release point are provided in **TABLE 26**. Table D2 of the EA provides release quality objectives for releases from TSF4.

The EA provides details of the receiving water monitoring points. The locations of these monitoring points have been replicated in **TABLE 27**.

A receiving environment monitoring program (REMP) has been developed by NRA Environmental Consultants **[38]** to monitor, identify and describe any adverse impact to surface water environmental values, quality and flows due to the mining activities. From the EA, the REMP monitoring frequency must be, at a minimum, as set out below.

- *for receiving waters and sediment quality, biannually (once at the end of the wet season and once at the end of the dry season); and*
- *For water quality of receiving waters during a release or flow event, one sample must be taken within 12 hours of the event commencing. Where release or flow events have durations of greater than 24 hours, samples must be taken daily for 1 week and once a week thereafter until the release or flow event ceases.* **[2]**

TABLE 26: RELEASE POINT LOCATION

Release Point	Description of Release	Receiving Water	Coordinates (GDA94 MGA Zone 55)		Monitoring Frequency
			Easting	Northing	
OW4	TSF4 Spillway	Manganese Creek	299526	8170822	For all parameters, 1 sample must be taken within 12 hours of a release event commencing and for release events with a duration of greater than 24 hours, samples must be taken daily for 1 week and once a week thereafter until the release event ceases.

Table reproduced from Table D1 in EA EPML00956913 **[2]**.

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TABLE 27: RECEIVING WATERS COMPLIANCE MONITORING LOCATIONS

Monitoring Point	Description	Coordinates (GDA94 MGA Zone 55)	
		Easting	Northing
Compliance Point			
SW15	TSF4 gully – site release monitoring point at the boundary of the licensed place (approximately 250 m from OW4 release point). Reports to Manganese Creek.	299920	8170844
Manganese Creek			
SW7	Manganese Creek (approximately 40 m upstream of confluence with gully).	300507	8168109
Holmes Creek			
SW17	Unnamed tributary of Holmes Creek (at ML4867 northeast boundary).	299381	8173168
SW4	Holmes Creek (immediately upstream of crossing with Mulligan Highway.	297426	8172386
Reference Points			
Manganese Creek			
SW1	Manganese Creek, upstream of site inputs.	301816	8172340
Holmes Creek			
SW16	Reference site – Holmes Creek upstream of site and historic disturbance.	299715	8174372

Table reproduced from Table D4 in EA EPML00956913 **[2]**.

Surface water monitoring locations are shown on the figure in **Appendix C [7]**. The water and sediment monitoring locations are both upstream and downstream of any potential spills from the mine site.

7.1.1.1 Groundwater

EA EPML00956913 **[2]** sets out the requirements for groundwater monitoring. In particular, the EA states that MCQ must not release any contaminants to groundwater. The location of groundwater monitoring bores and their monitoring frequency are replicated from the EA in **TABLE 28**.

The groundwater quality objectives for both shallow and deep groundwater are listed in table D6 of the EA.

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TABLE 28: COMPLIANCE GROUNDWATER MONITORING LOCATIONS AND FREQUENCY

Monitoring Point	Description	Coordinates (GDA94 MGA Zone 55)		Surface RL (m AHD)	Monitoring Frequency
		Easting	Northing		
Compliance Bores					
Shallow					
MB4A	Downslope of TSF4 water pond	299994	8170776	353.49	1 sample every 3 months
MB5A	Downstream of Holmes Creek	298226	8172597	357.30	
MB6A	Manganese Creek	300597	8171181	357.19	
Deep					
MB4B	Downslope of TSF4 water pond	299994	8170776	353.30	1 sample every 3 months
MB5B	Downstream of Holmes Creek	298226	8172597	357.41	
MB6B	Manganese Creek	300597	8171181	357.28	
RFB	Rural Fire Brigade	301144	8171764	360.87	
Reference Bores					
Shallow					
MB1A	Upslope of TSF4	299177	8171929	36.54	1 sample every 3 months
MB3A	Upslope of pit	301004	8172643	376.50	
Deep					
MB1B	Upslope of TSF4	299177	8171929	364.91	1 sample every 3 months
MB3B	Upslope of pit	301004	8172643	376.89	

Table reproduced from Table D5 in EA EPML00956913 **[2]**.

The locations of the compliance groundwater monitoring points are shown on the figure in **Appendix C [7]**.

A request to revise the groundwater monitoring requirements in the EA is being requested as part of the Stage 3 application for amendment.

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8 EMERGENCY AND CONTINGENCY PROCEDURES

To manage the water levels within the site water storages, an emergency contingency plan has been developed by EQ Resources to minimise unplanned spills to the natural environment and to ensure an adequate supply of water for operational purposes.

The planned response to an unplanned rainfall event(s) is as follows.

1. Processing operations are intended to continue as processing is a net consumer of water.
2. Where TSF3 appears likely to overtop, water will be transferred to TSF4.
    a. The logic is that TSF4 is planned to be operated not at capacity; rather TSF3 is the storage area intended to service makeup water requirements and TSF3 will therefore be run closer to capacity than TSF4.
    b. TSF4 is the licenced release point.
3. Where TSF3 and TSF4 are likely to overtop,
    a. Overtopping will be via the designed spillway
        i. Landholders and DES will be notified if a discharge event appears likely; and
        ii. if discharge occurs, Landholders and DES will be notified.
    b. Release monitoring (quantity of water and quality of release and receiving environment) will occur as has occurred for past release events.

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9 EROSION AND SEDIMENT CONTROL PLAN

An erosion and sediment control plan (ESCP) **[9]** for the Mt Carbine Project has been prepared by NRA Environmental Consultants in compliance with the requirements of the EA **[2]**. The ESCP was updated in April 2022 for the existing (Stage 2) site conditions, but the principles in the document should be applied to the future Stage 3 site arrangements.

A copy of the ESCP has been provided in **Appendix G** of this document.

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10 CONCLUSIONS AND RECOMMENDATIONS

10.1 Conclusions

This report presents a water management plan for the Stage 3 development of the Mount Carbine Project. The plan is based on information and data provided by EQ Resources and NRA Environmental Consultants. The key outcomes from the plan are summarised below.

- The proposed water mass balance for the retreatment and mined ore processes may be managed using site water collected in the two storages on site during wet weather. No additional water supply is required.
- After the Open Cut Pit has been dewatered, there is an estimated spill risk of 12% from TSF4 to the Release Point and 2% from TSF3 to TSF4.
- The estimated spill risk from the Open Pit is 0%, due to the pumped dewatering that is scheduled to occur until the pit is empty and available for mining and the continuing use of evaporative sprayers and pumping to TSF3.
- The clean water diversion drains have been estimated to have sufficient capacity to convey all but the 1% AEP surface runoff to the east of the Low Grade Stockpile around the Project.
- An Emergency and Contingency Plan is in place in the event of uncontrolled spills from any water storage.
- The Erosion and Sediment Control Plan was updated in April 2022 for the site conditions at that time. The principles described in the Plan may be applied to the Stage 3 site configuration until the Plan is updated.

10.2 Recommendations

The following recommendations for future water management plans are undertaken.

1. Increased monitoring of the groundwater inflows and outflows to the Open Cut Pit be undertaken in the future. This monitoring will provide additional information for any future updates to the water balance model, which will refine the estimates of probability of spills from TSF3 and TSF4.
2. To account for the changes in the surface runoff across the site due to reforming of the Low Grade Material Stockpile, Quarry Operational Area, Optical Sorter Reject Stockpile Area, Open Cut Pit, and the planned construction of TSF embankment raises and waste rock dump, it is recommended the water balance model be reviewed on an annual basis using newly flown LiDAR data. It is recommended that the capacities of the diversion drains are reviewed at the same time. This will inform any changes required to the Water Management Plan.

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[30] Australia and New Zealand Environment Conservation Council (2020), 'Australia and New Zealand Guidelines for Fresh and Marine Water Quality'.
[31] NRA Environmental Consultants (2013), 'Concept Water Management Plan for the Mount Carbine Tungsten Project – Stage 1', Technical Note, dated 12 June 2013.
[32] ATC Williams (2021), 'Mt Carbine Mining Water Management Plan', 119190-03R01_1, November 2021.
[33] Bureau of Meteorology (2021), 'Design Rainfall Data System', http://www.bom.gov.au/water/designRainfalls/revised-ifd/, accessed November 2021.
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[36] Broughton, W.C. (2004), 'The Australian Water Balance Model', Environmental Modelling and Software, Vol 19, pp 943-956.
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[38] NRA Environmental Consultants (2020), 'Mt Carbine Mine Receiving Environment Monitoring Programme', version 2.0. R01, prepared for Mt Carbine Quarries Pty Ltd, 30 October 2020

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TAILINGS.WATER.WASTE.

FIGURES

298350E 298800E 299250E 299700E 300150E 300600E 301050E 301500E 301950E

8173200N 8172900N 8172600N 8172300N 8172000N 8171700N 8171400N 8171100N 8170800N

153666
50799
104800
125909
84345
49257
7391
25762
247520
29588
394055

N

NOTES:
1. CATCHMENT LAND USE TYPE AREAS SHOWN USED AS INPUTS TO THE AWBM TO DETERMINE CATCHMENT RUNOFF VOLUMES.
2. CATCHMENT LAND USE TYPE AREAS SHOWN IN SQUARE METRES.

0 250 500 m

CRS: GDA94 / MGA Zone 55

NOTE: IMAGERY SOURCED FROM xx xx.date

LEGEND

CATCHMENT LAND USE TYPES

- NATURAL
- HARDSTANDING/OPEN WATER
- TAILINGS
- PIT SURFACE
- WASTE ROCK

EQ RESOURCES

MOUNT CARBINE TUNGSTEN PROJECT
CATCHMENT LAND USE TYPES REPORTING TO STORAGE FACILITIES
EXISTING

ATC WILLIAMS

FIGURE 001

119190.04

DATE: 2022-11-24

N:\Synergy\Projects\119\119190 SMI Mt Carbine\04 Stage 3 Water Mgt Plan\Data and Calcs\QGIS\119190.04_Mt_Carbine.qgz

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8173200N 8172900N 8172600N 8172300N 8172000N 8171700N 8171400N 8171100N 8170800N

153666
50799
104800
125909
54827
49257
247520
29588
394055

N

NOTES:
1. CATCHMENT LAND USE TYPE AREAS SHOWN USED AS INPUTS TO THE AWBM TO DETERMINE CATCHMENT RUNOFF VOLUMES.
2. CATCHMENT LAND USE TYPE AREAS SHOWN IN SQUARE METRES.

0 250 500 m

CRS: GDA94 / MGA Zone 55

NOTE: IMAGERY SOURCED FROM xx xx date

LEGEND

CATCHMENT LAND USE TYPES

- NATURAL
- HARDSTANDING/OPEN WATER
- TAILINGS
- PIT SURFACE
- WASTE ROCK

EQ RESOURCES

MOUNT CARBINE TUNGSTEN PROJECT
CATCHMENT LAND USE TYPES REPORTING TO STORAGE FACILITIES
PIT STAGE 1

ATC WILLIAMS

FIGURE 002

119190.04

DATE: 2022-11-24

N:\Synergy\Projects\119\119190 SMI Mt Carbine\04 Stage 3 Water Mgt Plan\Data and Calcs\QGIS\119190.04_Mt_Carbine.qgz

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8173200N 8172900N 8172600N 8172300N 8172000N 8171700N 8171400N 8171100N 8170800N

146621
50799
69622
84020
54827
187126
49257
247520
29588
394055

NOTES:
1. CATCHMENT LAND USE TYPE AREAS SHOWN USED AS INPUTS TO THE AWBM TO DETERMINE CATCHMENT RUNOFF VOLUMES.
2. CATCHMENT LAND USE TYPE AREAS SHOWN IN SQUARE METRES.

0 250 500 m

CRS: GDA94 / MGA Zone 55

NOTE: IMAGERY SOURCED FROM xx xx date

LEGEND

CATCHMENT LAND USE TYPES

- NATURAL
- HARDSTANDING/OPEN WATER
- TAILINGS
- PIT SURFACE
- WASTE ROCK

EQ RESOURCES

MOUNT CARBINE TUNGSTEN PROJECT
CATCHMENT LAND USE TYPES REPORTING TO STORAGE FACILITIES
PIT STAGE 2

ATC WILLIAMS

FIGURE 003

119190.04

DATE: 2022-11-24

N:\Synergy\Projects\119\119190 SMI Mt Carbine\04 Stage 3 Water Mgt Plan\Data and Calcs\QGIS\119190.04_Mt_Carbine.qgz

298350E 298800E 299250E 299700E 300150E 300600E 301050E 301500E 301950E

8173200N 8172900N 8172600N 8172300N 8172000N 8171700N 8171400N 8171100N 8170800N

N

26446
130273
50306
84020
54827
247131
49257
247520
29588
394055

NOTES:
1. CATCHMENT LAND USE TYPE AREAS SHOWN USED AS INPUTS TO THE AWBM TO DETERMINE CATCHMENT RUNOFF VOLUMES.
2. CATCHMENT LAND USE TYPE AREAS SHOWN IN SQUARE METRES.

0 250 500 m

CRS: GDA94 / MGA Zone 55

NOTE: IMAGERY SOURCED FROM xx xx date

LEGEND

CATCHMENT LAND USE TYPES

- NATURAL
- HARDSTANDING/OPEN WATER
- TAILINGS
- PIT SURFACE
- WASTE ROCK

EQ RESOURCES

MOUNT CARBINE TUNGSTEN PROJECT
CATCHMENT LAND USE TYPES REPORTING TO STORAGE FACILITIES
PIT STAGE 3

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FIGURE 004

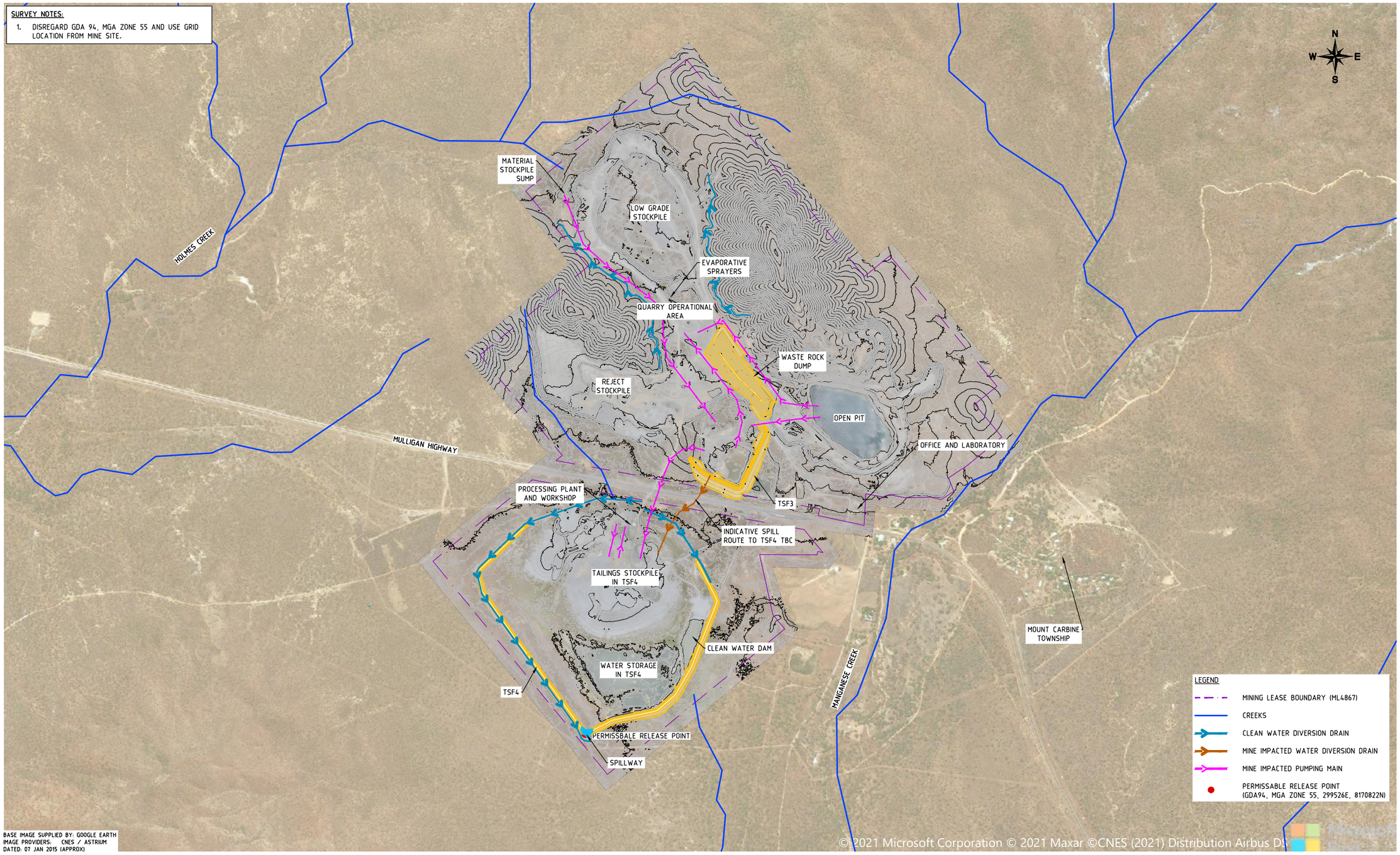
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DATE: 2022-11-24

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SURVEY NOTES:

1. DISREGARD GDA 94, MGA ZONE 55 AND USE GRID LOCATION FROM MINE SITE.



BASE IMAGE SUPPLIED BY: GOOGLE EARTH
IMAGE PROVIDERS: CNES / ASTRIUM
DATED: 07 JAN 2015 (APPROX)

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150 0 150 300 450 600 750
SCALE OF METRES 1:15,000 @ A3

CLIENT: SMI MT CARBINE
PROJECT TITLE: STAGE 3 WATER MANGEMENT PLAN
PROJECT NUMBER: 119190-04

DRAWING TITLE: EMBANKMENT
DESIGN STAGE: GENERAL ARRANGEMENT
PLOT TITLE:

FOR INFORMATION ONLY

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DATUM: NOV. 2022
SCALE: 1:1,000
Sheet size A3

12D WORKING FOLDER: N:\SYNERGY\PROJECTS\119\119190 SMI MT CARBINE\04 STAGE 3 WATER MGT PLAN\CADD\CAD 12D PROJECT: 119190-04-FIG-005.DWG

PLOT FILE: PLOTED: 11 29 2022 11:42 AM



LEGEND

Clean Water Drainage Diversions

Sub-catchment Boundaries

MT. CARBINE PROJECT

DRAINAGE DIVERSION CATCHMENT PLAN

ATC WILLIAMS

FIGURE 006

119190-03

DATE: 2021-11-19

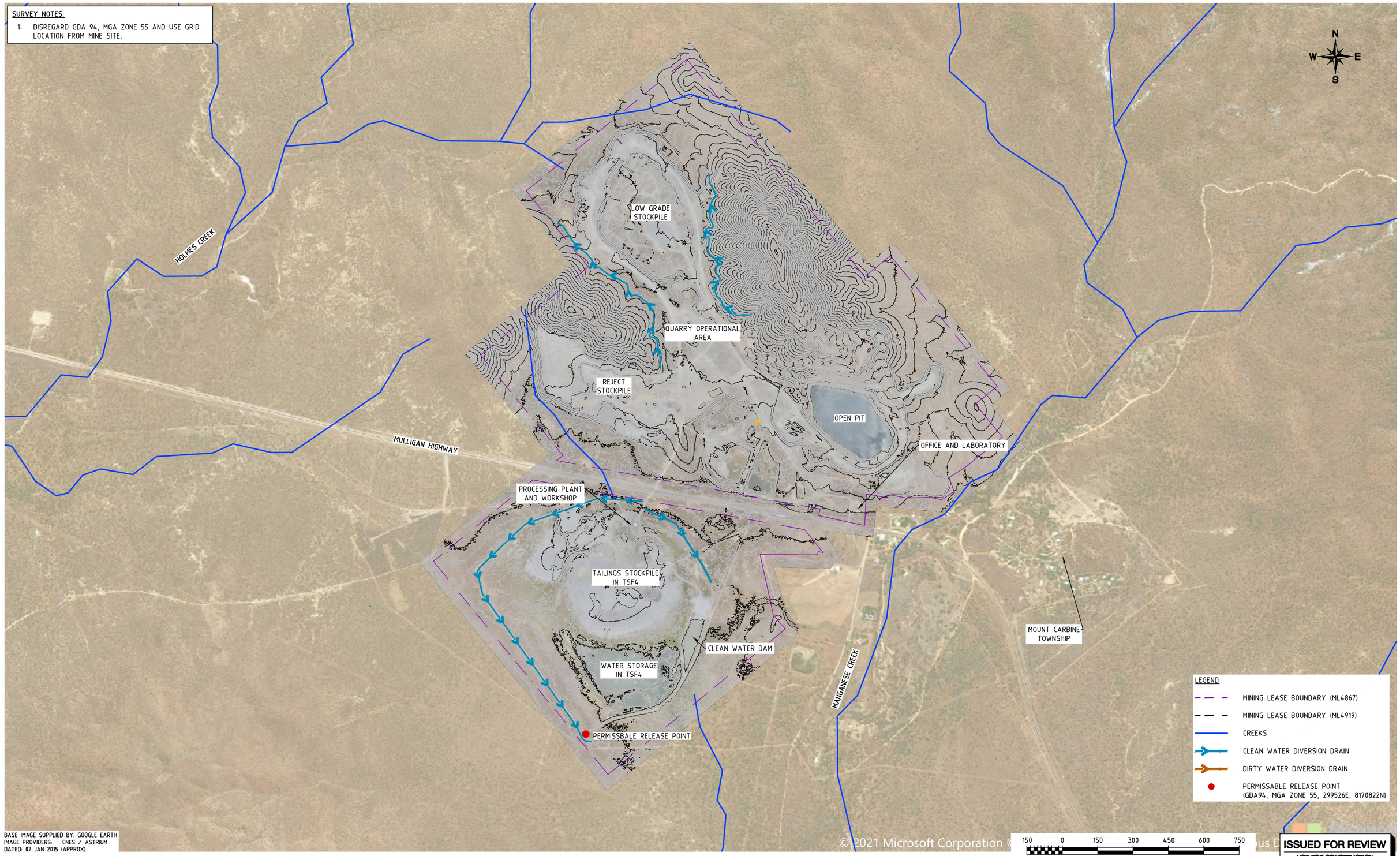
\\atcbnemvpfs01\Synergy\Synergy\Projects\119\119190 SMI Mt Carbine\03 2021 Water

APPENDICES

APPENDIX A – MOUNT CARBINE EXISTING SITE LAYOUT PLANS

SURVEY NOTES:

1. DISREGARD GDA 94, MGA ZONE 55 AND USE GRID LOCATION FROM MINE SITE.



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MT CARBINE QUARRIES PTY LTD
TSF3 AND TSF4 SCOPE REPORT

EXISTING CONDITIONS

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Mt Carbine Tungsten Project ERC general arrangements

Project: 2022 Estimated Rehabilitation Cost for EA EPML00956913

Mining lease

Mt Carbine Quarry EA boundary

Quarry area

2022 ERC disturbance (mining)

Existing disturbance areas

Existing disturbance (roads)

Proposed disturbance (pipeline)

N

0 250

Metres

Source: EQ Resources 2021, JUKESTODD 2021, Airmap 3D 2021.

NRA Ref: 380011.04
Date: March 2022

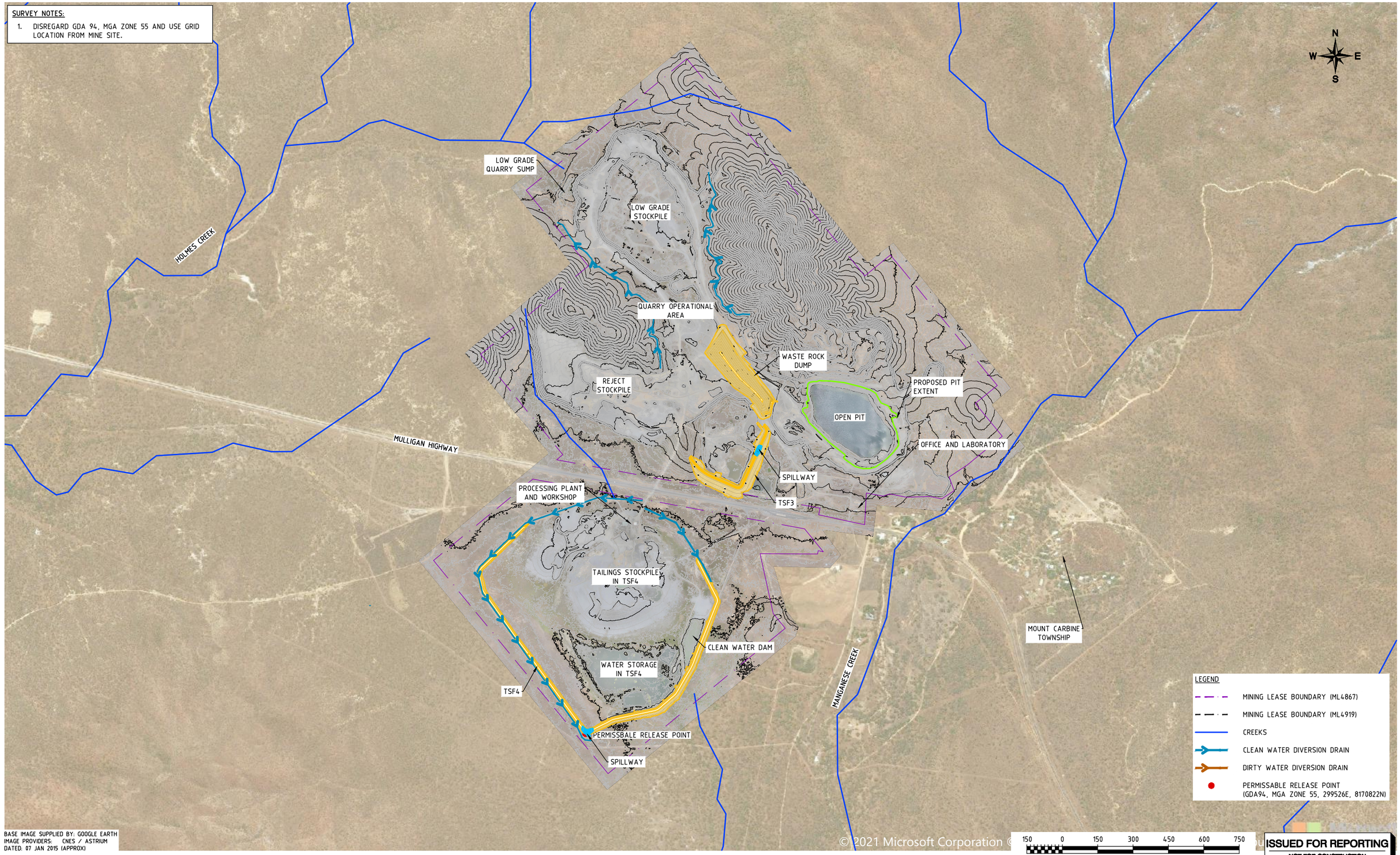
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Recommended print size: A3

APPENDIX B – MOUNT CARBINE PROPOSED SITE LAYOUT PLANS

SURVEY NOTES:

1. DISREGARD GDA 94, MGA ZONE 55 AND USE GRID LOCATION FROM MINE SITE.



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DATED: 07 JAN 2015 (APPROX)

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150 0 150 300 450 600 750

SCALE OF METRES 1:15,000 @ A3

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SITE LAYOUT

DWG. No. 119190-05-100-003

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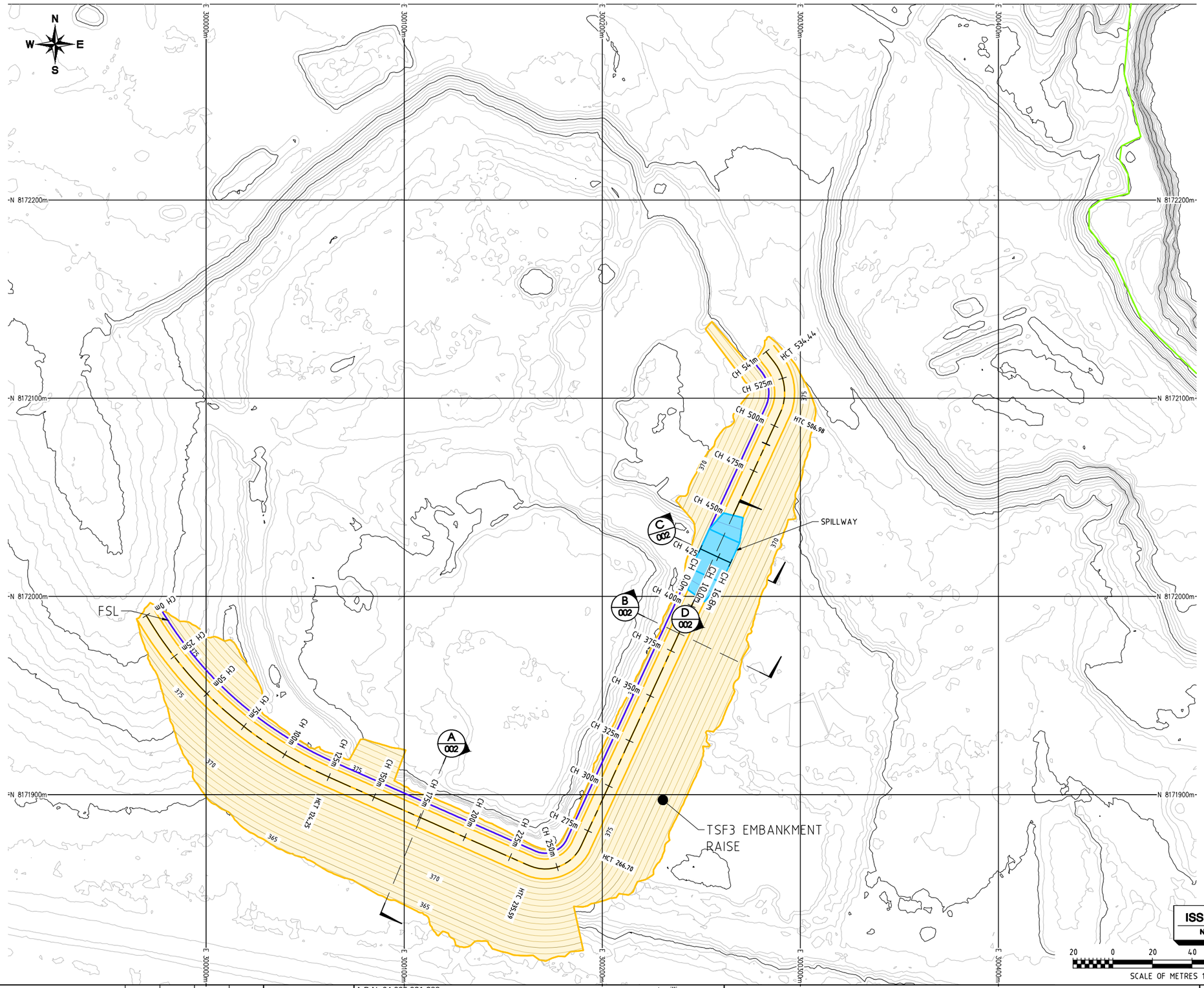
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SURVEY NOTES:

1. DISREGARD GDA 94, MGA ZONE 55 AND USE GRID LOCATION FROM MINE SITE.



No.	DESCRIPTION	DATE	DRAWN	CHECK'D	APPR'D
A	ISSUED FOR REVIEW	27/10/22	JC	KT	RH

SCALE: 1:2000	
JOB No.	119190-05
DATE	JUL 2022
DESIGN	RH
DRAWN	HPN
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TAILINGS STORAGE FACILITY 3
GENERAL ARRANGEMENT

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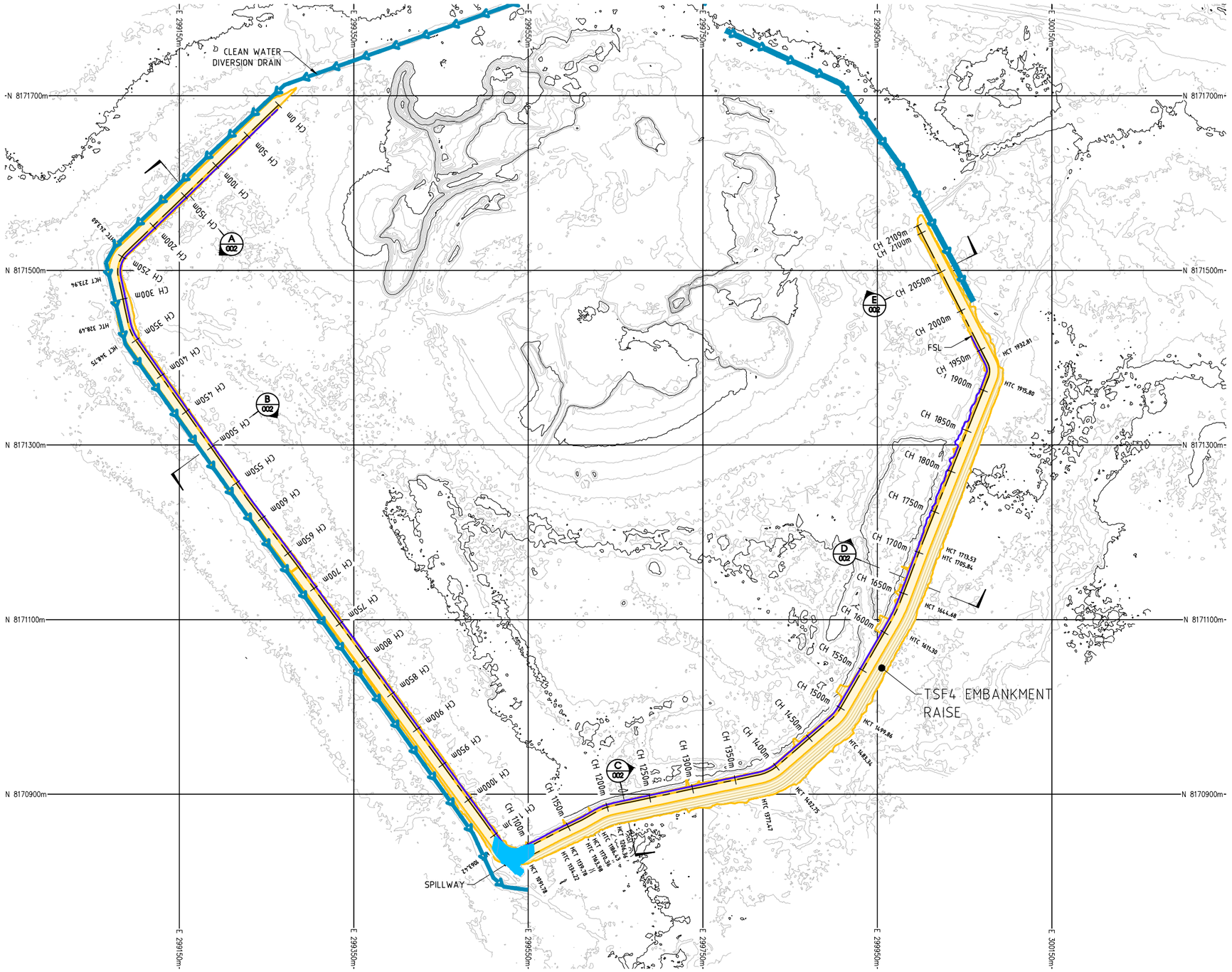
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Printed on: Thursday, 27 October 2022 12:16:26 PM By: James Camille

NOTES:

1.- CLEAN WATER TO BE DIVERTED OUTSIDE OF TSF4 AS DIRECTED.



50 0 50 100 150 200 250

SCALE OF METRES 1:5000 @ A3

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APPROVED	RH

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TAILINGS STORAGE FACILITY 4
GENERAL ARRANGEMENT

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NOTES:

1.- CONNECT ROCK FILL TO LOW GRADE STOCKPILE AS DIRECTED MINIMUM THICKNESS OF ROCK FILL TO BE 600mm.

N 8173250m
N 8173200m
N 8173150m
N 8173100m
N 8173050m
E 299350m
E 299400m
E 299450m
E 299500m
E 299550m
E 299600m

CH 134.361
CH 130.0
CH 120.0
CH 110.0
CH 100.0
CH 90.0
CH 80.0
CH 70.0
CH 60.0
CH 50.0
CH 40.0
CH 30.0
CH 20.0
CH 10.0
CH 0.000

GROUND WATER COLLECTION PIPE

LOW GRADE STOCKPILE AREA

A 004
B 005
C 005
D 005

COLLECTION SUMP
(REFER DETAIL 1 ON DRAWING 004)

SCALE OF METRES 1:1000 @ A3

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A	ISSUED FOR REVIEW	30/08/22	HPN	KT	RH

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JOB No.	119190-05
DATE	JUL 2022
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CHECKED	KT
APPROVED	RH

CHECK PRINT
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	INITIALS	STATUS	DATE
1. DRAFTER			
2. CHECKER			
3. PROJECT MANAGER			

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INFORMATION FOR ENGINEER / DRAFTER IN BLUE PEN

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MT CARBINE QUARRIES PTY LTD
STAGE 3 WATER MANAGEMENT PLAN

QUARRY SUMP REMEDIAL WORKS
LAYOUT PLAN

DWG. No. 119190-05-000-003

SHEET SIZE A3 | Rev. A

SHEET 1 OF 1

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WORKS
OGRESS

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October 2022 04:53:11 PM By: James Camille

APPENDIX C – RECEIVING WATER, SEDIMENT AND GROUNDWATER MONITORING LOCATIONS PLAN

TAILINGS.WATER.WASTE.

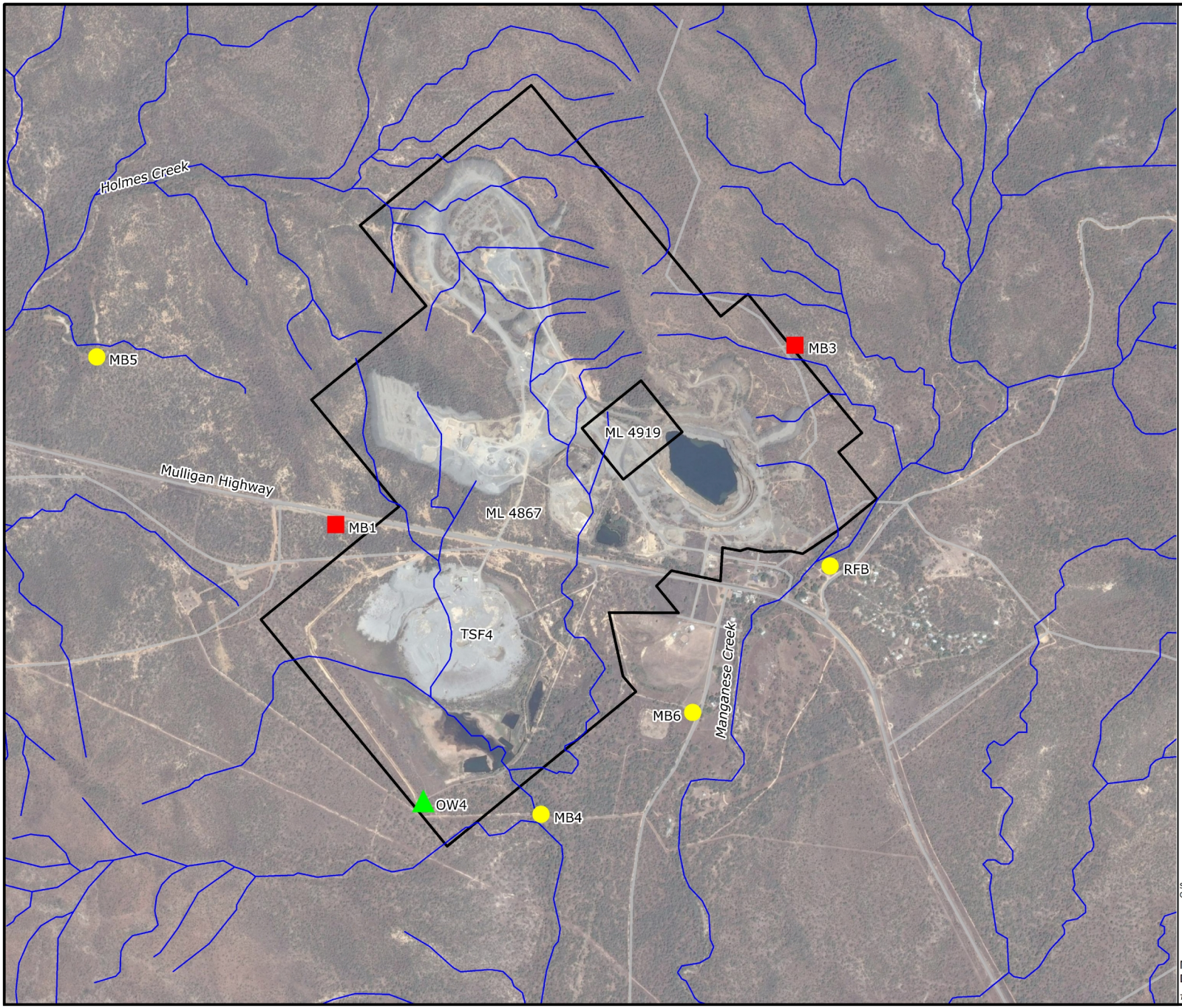


Figure 1: Compliance and reference monitoring bores in the environmental authority

Project: Groundwater Quality Assessment – August 2022 Monitoring

Mining lease boundary

Road

Drainage

Groundwater monitoring bore

Compliance

Reference

Note: each bore location (excluding RFB) includes a shallow bore ('A') and deep bore ('B') for EA assessment purposes

Surface water monitoring site

N

0 750

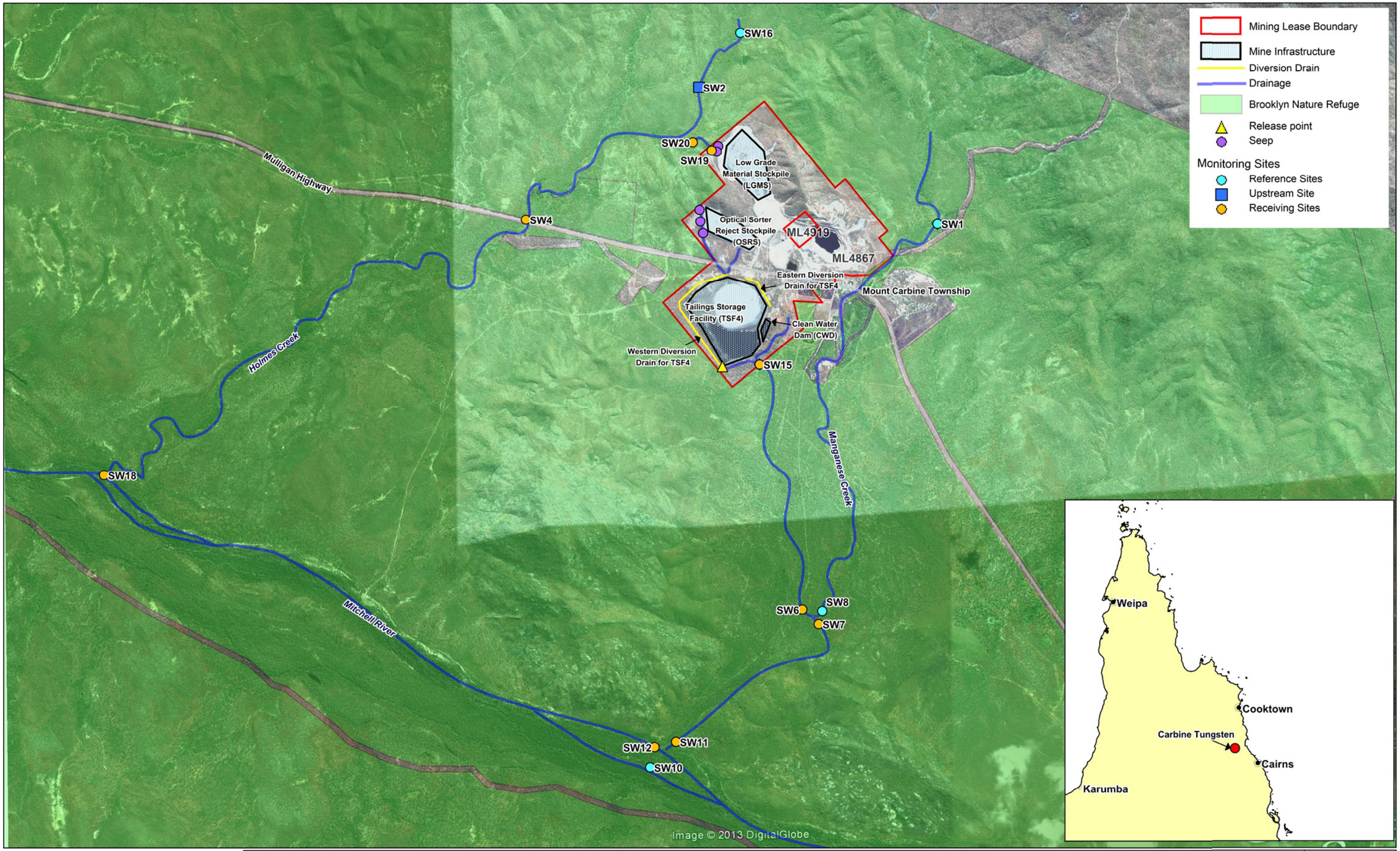
Metres

Source:
Queensland Department of Resources 2022, Google Earth 2019

NRA Ref: 380010.03
Date: October 2022

T:_AAA\380\WOR\380010_03\380010.03_GW BoresAug22_221013.wor

Recommended print size: A4



Environmental Approval & Compliance Solutions
www.natres.com.au

PROJECT: Carbine Tungsten Receiving Environment Monitoring Program
TITLE: Monitoring site locations

JOB NO: 380005.04
DATE: August 2014

N

SOURCE:
© State of Queensland (Department of Natural Resources and Mines) 2012.
Carbine Tungsten Pty Ltd
Google Earth
File Path: T:_AAA\380\WOR\380005_04\380005.04_REMP sites_140801.wor

0 2.5
Kilometres

Figure 1

Recommended print size: A3

APPENDIX D – ‘MT CARBINE WATER BALANCE FOR PHASE 2’, MEMORANDUM

TAILINGS.WATER.WASTE.

JUKESTODD
ADVISORS & PROJECT MANAGERS

MEMORANDUM

	Total number of pages: 3	Date: 19/05/2022
To:	Tim Anderson	
Cc:	Kevin MacNeill	
From:	Peter Jukes	
Subject:	Mt Carbine Water Balance for Phase 2	

Below summarises the crushing and processing plant water balance for the Phase 2 development of the Mt Carbine Complex, operating under the assumption that the open pit is no longer included in the water circuit for supply or storage.

Key assumptions:

- Crushing plant water requirements – 129.5m3/hr
- Crushing plant moisture loss – 8m3/hr – 5% by weight through +6m, -30mm material reporting to ore sorter (remainder sent to process plant as slurry)
- Process plant water requirements – 200m3/hr
- Moisture loss through process plant – 30m3/hr (0.5m3/t feed assuming 60tph throughput aligned to current plant performance)
- Additional 6.5m3/hr lost from dewatering and stockpiling of process plant ROM material (product dewatering, 10% moisture)
- 2.4m3/hr loss at fine tailings (assumes 70% solids)
- 9.5m3 loss at coarse takings (assumes 85% solids)
- Balance of loss through product moisture, evaporation and spillage

The crushing plant and process plant particle size distributions were based on information supplied by Mincore for the BFS. The water requirements for the crushing plant were supplied by Mincore for the BFS. The process plant water requirements were based on operational averages from the existing plant.

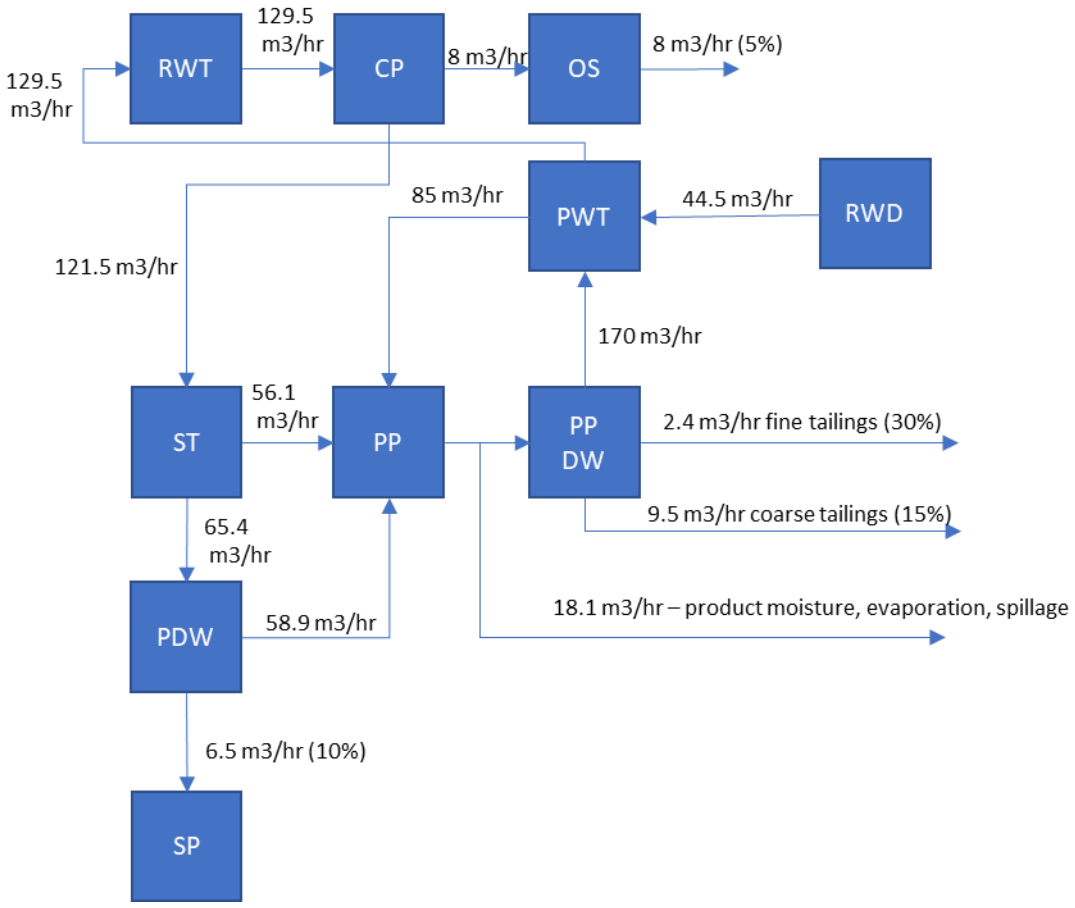
Two block flow scenarios were developed, based on day shift and night shift. During day shift, the crushing and screening plant operates at 350tph and slurry feeds -6mm material directly to the processing plant. Approximately half of the slurry material is dewatered and stockpiled while the other half is fed directly into the processing plant.

During night shift, the crushing and screening plant is not operating and the dewatered material from the crushing plant is dry fed into the processing plant.

In addition to the water usage below, Mt Carbine is currently using approximately 160m3 per day for dust suppression and other operational requirements.

JUKESTODD
ADVISORS & PROJECT MANAGERS

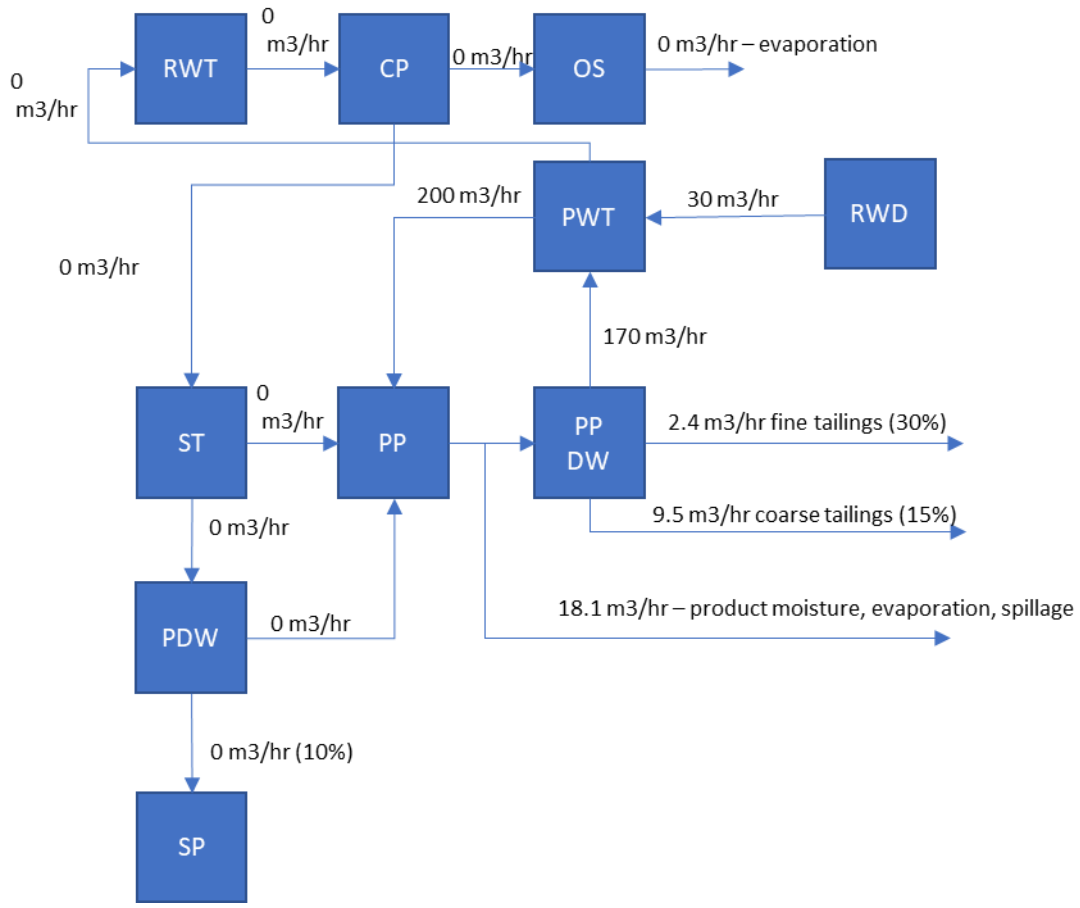
Day Shift:



Legend:
RWT – Crushing Plant Raw Water Tank
CP – Crushing Plant
OS – Ore Sorter
PWT – Process Water Tank
RWD – Raw Water Dam
ST – Surge Tank
PP – Process Plant
PP DW – Process Plant Dewatering
PDW – Product Dewatering
SP – Product Stockpile

JUKESTODD
ADVISORS & PROJECT MANAGERS

Night Shift:



APPENDIX E – QUEENSLAND GOVERNMENT ENVIRONMENTAL REPORTS

State Assessment and Referral Agency

Date: 05/11/2021

Queensland Government

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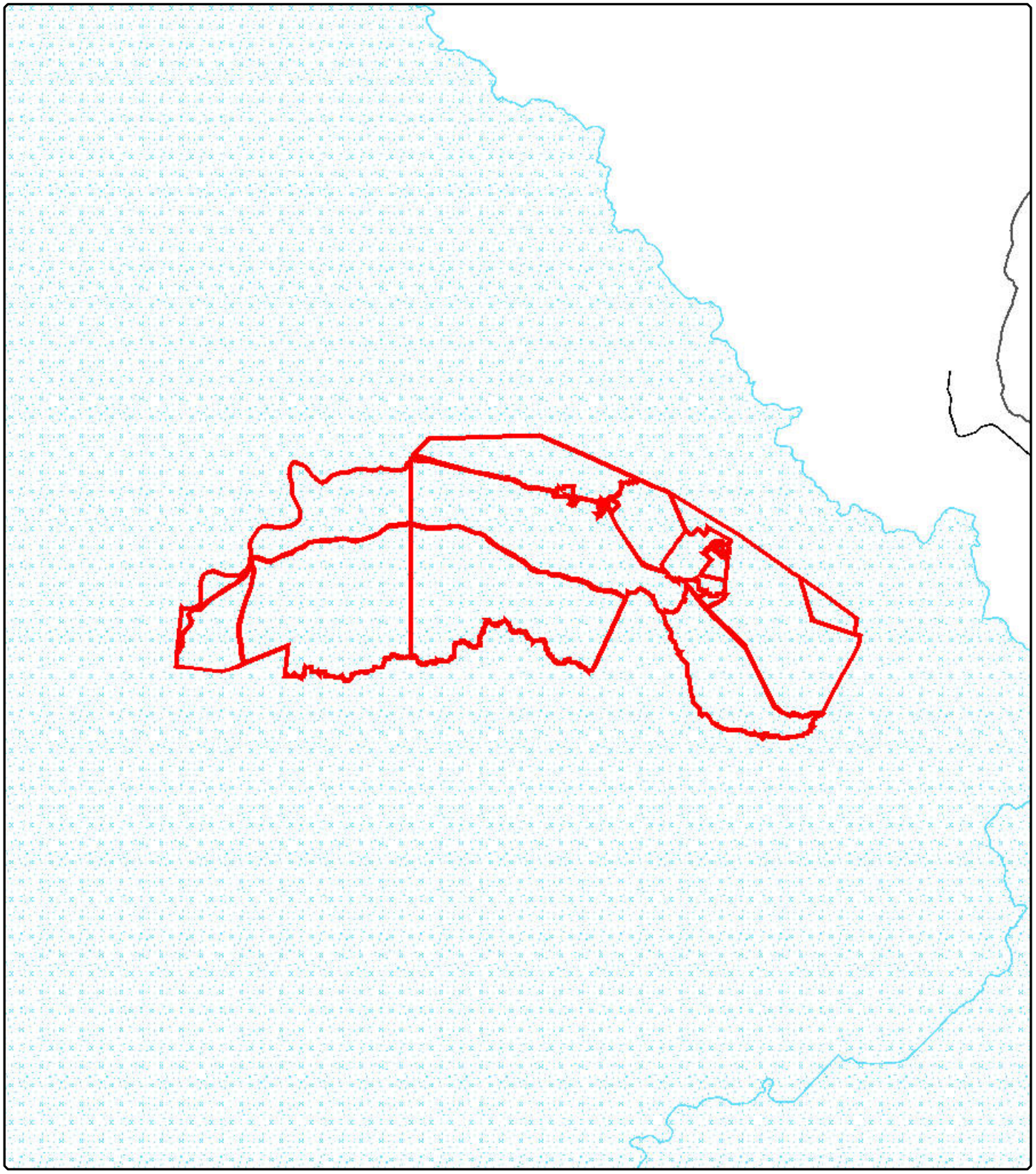


Matters of Interest for all selected Lot Plans

Queensland waterways for waterway barrier works
Water resource planning area boundaries
Regulated vegetation management map (Category A and B extract)
State-controlled road
Area within 25m of a State-controlled road

Matters of Interest by Lot Plan

Lot Plan: 13SP254833 (Area: 590000000 m^2)
Queensland waterways for waterway barrier works
Water resource planning area boundaries
Regulated vegetation management map (Category A and B extract)
State-controlled road
Area within 25m of a State-controlled road



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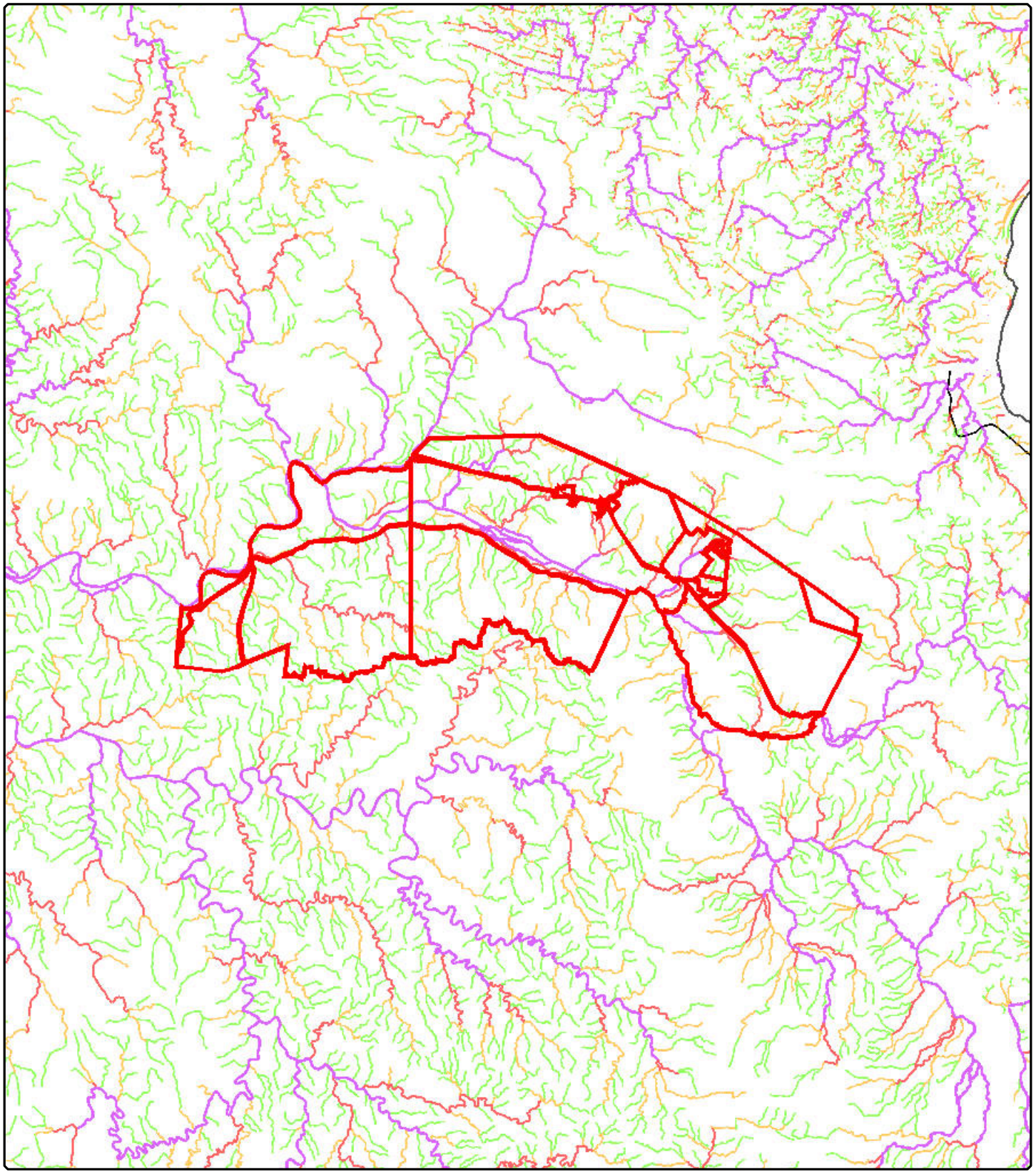
Water resource planning area boundaries

Water resource planning area boundaries

0 7,200 14,400 21,600 28,800

Metres

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0 7,200 14,400 21,600 28,800

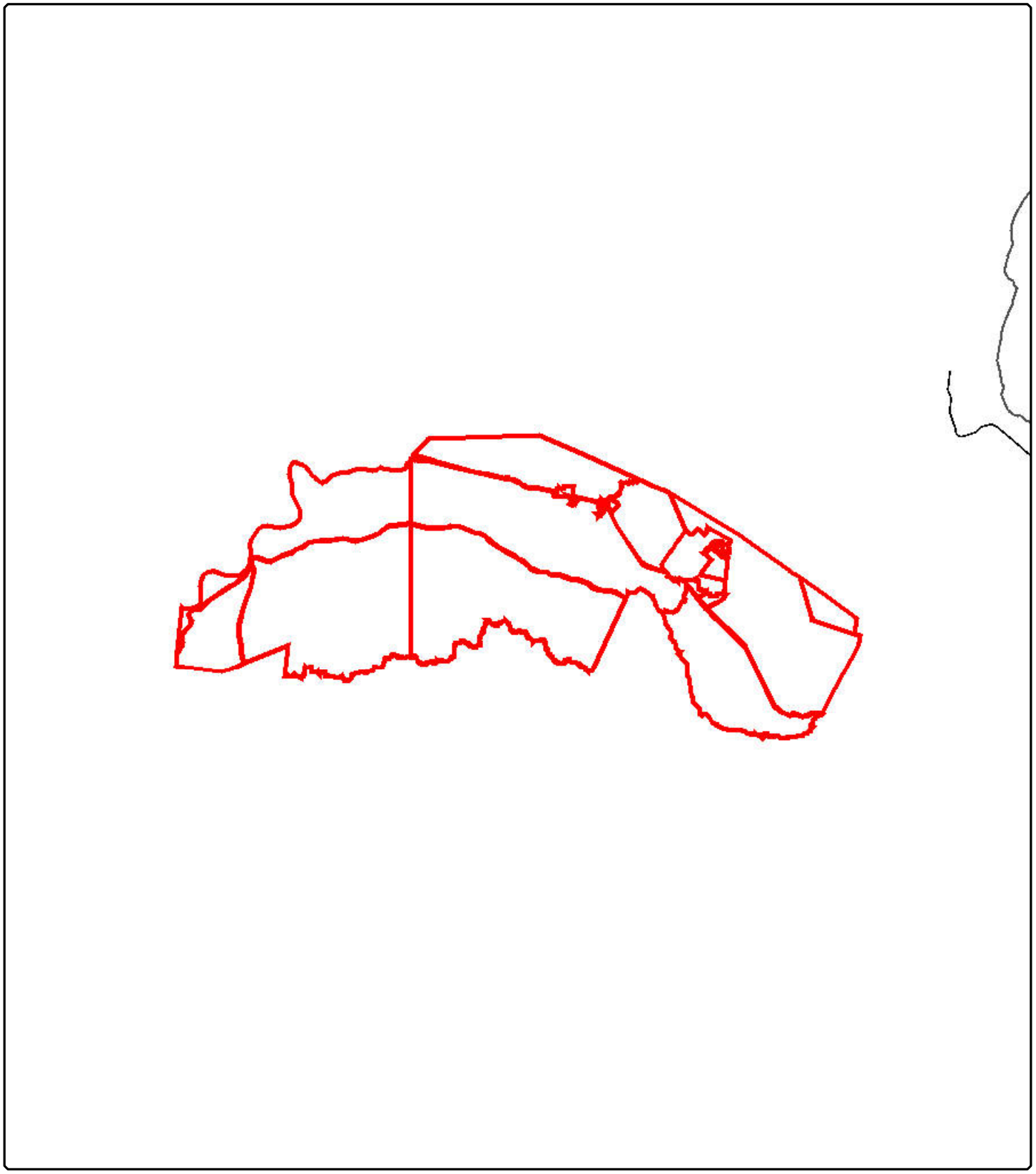
Metres

Legend

Queensland waterways for waterway barrier works

- 1 - Low
- 2 - Moderate
- 3 - High
- 4 - Major

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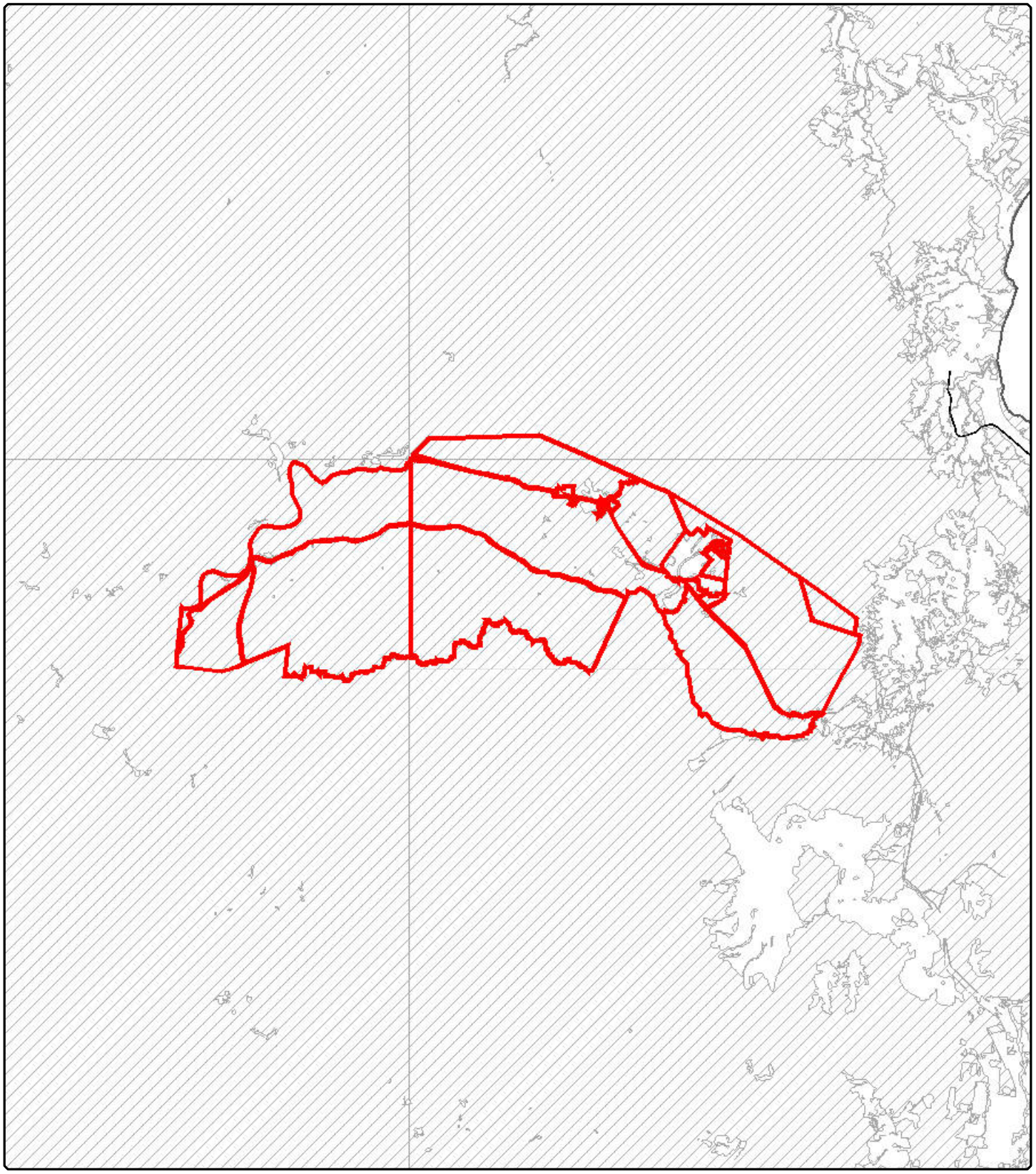
Area within 25m of a State-controlled road

This layer is not displayed at the current map scale

0 7,200 14,400 21,600 28,800

Metres

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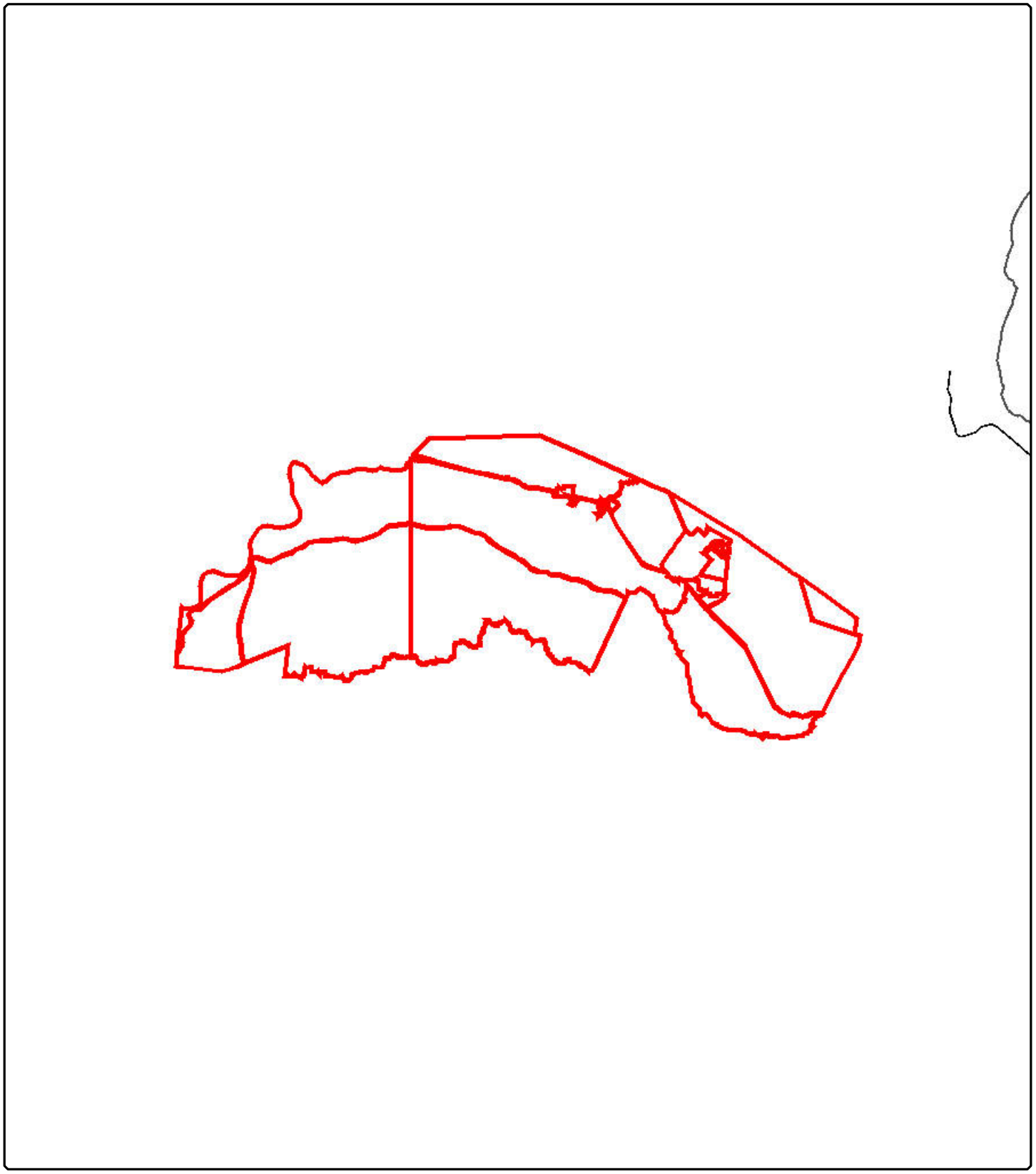
Regulated vegetation management map (Category A and B extract)

- Category A on the regulated vegetation management map
- Category B on the regulated vegetation management map

0 7,200 14,400 21,600 28,800

Metres

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N

Legend

State-controlled road

This layer is not displayed at the current map scale

0 7,200 14,400 21,600 28,800

Metres

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Queensland Government

Department of Environment and Science

Environmental Reports

Biodiversity and Conservation Values

Biodiversity Planning Assessments and Aquatic Conservation Assessments

For the selected area of interest
Lot: 13 Plan: SP254833

Environmental Reports - General Information

The Environmental Reports portal provides for the assessment of selected matters of interest relevant to a user specified location, or Area of Interest (AOI). All area and derivative figures are relevant to the extent of matters of interest contained within the AOI unless otherwise stated. Please note, if a user selects an AOI via the "Central co-ordinates" option, the resulting assessment area encompasses an area extending from 2km radius from the point of interest.

All area and area derived figures included in this report have been calculated via reprojecting relevant spatial features to Albers equal-area conic projection (central meridian = 146, datum Geocentric Datum of Australia 1994). As a result, area figures may differ slightly if calculated for the same features using a different co-ordinate system.

Figures in tables may be affected by rounding.

The matters of interest reported on in this document are based upon available state mapped datasets. Where the report indicates that a matter of interest is not present within the AOI (e.g. where area related calculations are equal to zero, or no values are listed), this may be due either to the fact that state mapping has not been undertaken for the AOI, that state mapping is incomplete for the AOI, or that no values have been identified within the site.

The information presented in this report should be considered as a guide only and field survey may be required to validate values on the ground.

Please direct queries about these reports to: biodiversity.planning@des.qld.gov.au

Disclaimer

Whilst every care is taken to ensure the accuracy of the information provided in this report, the Queensland Government makes no representations or warranties about its accuracy, reliability, completeness, or suitability, for any particular purpose and disclaims all responsibility and all liability (including without limitation, liability in negligence) for all expenses, losses, damages (including indirect or consequential damage) and costs which the user may incur as a consequence of the information being inaccurate or incomplete in any way and for any reason.



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Summary Information

Tables 1 to 8 provide an overview of the AOI with respect to selected topographic and environmental values.

Table 1: Area of interest details: Lot: 13 Plan: SP254833

Size (ha)	58,779.14
Local Government(s)	Mareeba Shire
Bioregion(s)	Einasleigh Uplands, Wet Tropics
Subregion(s)	Hodgkinson Basin, Macalister, Daintree - Bloomfield
Catchment(s)	Mitchell

The following table identifies available Biodiversity Planning Assessments (BPAs) and Aquatic Conservation Assessments (ACAs) with respect to the AOI.

Table 2: Available Biodiversity Planning and Aquatic Conservation Assessments

Assessment Type	Assessment Area and Version
Biodiversity Planning Assessment(s)	Einasleigh Uplands v1.1, Wet Tropics v1.1
Aquatic Conservation Assessment(s) (riverine)	Eastern Gulf of Carpentaria v1.1
Aquatic Conservation Assessment(s) (non-riverine)	Eastern Gulf of Carpentaria v1.1

Table 3: Remnant regional ecosystems within the AOI as per the Qld Herbarium's 'biodiversity status'

Biodiversity Status	Area (Ha)	% of AOI
Endangered	619.09	1.05
Of concern	4,516.50	7.68
No concern at present	52,370.06	89.1

The following table identifies the extent and proportion of the user specified area of interest (AOI) which is mapped as being of "State", "Regional" or "Local" significance via application of the Queensland Department of Environment and Science's *Biodiversity Assessment and Mapping Methodology* (BAMM).

Table 4: Summary table, biodiversity significance

Biodiversity significance	Area (Ha)	% of AOI
State Habitat for EVNT taxa	6,072.94	10.33
State	34,190.47	58.17
Regional	8,928.42	15.19
Local or Other Values	7,829.73	13.32

Table 5: Non-riverine wetlands intersecting the AOI

Non-riverine wetland types intersecting the area of interest	#
Number of Palustrine wetlands	15
Number of Lacustrine wetlands	18
Total number of non-riverine wetlands	33

NB. The figures presented in the table above are derived from the relevant non-riverine Aquatic Conservation Assessment(s). Later releases of wetland mapping produced via the Queensland Wetland Mapping Program may provide more recent information in regards to wetland extent.

Table 6: Named waterways intersecting the AOI

Name	Permanency
MARY CREEK	Non-perennial
MCLEOD RIVER	Non-perennial
MITCHELL RIVER	Non-perennial
PENNYWEIGHT CREEK	Non-perennial
RIFLE CREEK	Non-perennial
WOLSTENCROFT CREEK	Non-perennial

Refer to **Map 1** for general locality information.

The following two tables identify the extent and proportion of the user specified AOI which is mapped as being of "Very High", "High", "Medium", "Low", or "Very Low" aquatic conservation value for riverine and non-riverine wetlands via application of the Queensland Department of Environment and Science's *Aquatic Biodiversity Assessment and Mapping Method* (AquaBAMM).

Table 7: Summary table, aquatic conservation significance (riverine)

Aquatic conservation significance (riverine wetlands)	Area (Ha)	% of AOI
Very High	58,719.59	99.9
High	41.66	0.07
Medium	18.04	0.03
Low	0.0	0.0
Very Low	0.0	0.0

Table 8: Summary table, aquatic conservation significance (non-riverine)

Aquatic conservation significance (non-riverine wetlands)	Area (Ha)	% of AOI
Very High	5.07	0.01
High	0.0	0.0
Medium	283.9	0.48
Low	0.0	0.0
Very Low	0.0	0.0

Biodiversity Planning Assessments

Introduction

The Department of Environment and Science (DES) attributes biodiversity significance on a bioregional scale through a Biodiversity Planning Assessment (BPA). A BPA involves the integration of ecological criteria using the *Biodiversity assessment and Mapping Methodology* (BAMM) and is developed in two stages: 1) **diagnostic criteria**, and 2) **expert panel criteria**. The diagnostic criteria are based on existing data which is reliable and uniformly available across a bioregion, while the expert panel criteria allows for the refinement of the mapped information from the diagnostic output by incorporating local knowledge and expert opinion.

The BAMM methodology has application for identifying areas with various levels of significance solely for biodiversity reasons. These include threatened ecosystems or taxa, large tracts of habitat in good condition, ecosystem diversity, landscape context and connection, and buffers to wetlands or other types of habitat important for the maintenance of biodiversity or ecological processes. While natural resource values such as dryland salinity, soil erosion potential or land capability are not dealt with explicitly, they are included to some extent within the biodiversity status of regional ecosystems recognised by the DES.

Biodiversity Planning Assessments (BPAs) assign three levels of overall biodiversity significance.

- **State significance** - areas assessed as being significant for biodiversity at the bioregional or state scales. They also include areas assessed by other studies/processes as being significant at national or international scales. In addition, areas flagged as being of State significance due to the presence of endangered, vulnerable and/or near threatened taxa, are identified as "State Habitat for EVNT taxa".
- **Regional significance** - areas assessed as being significant for biodiversity at the subregional scale. These areas have lower significance for biodiversity than areas assessed as being of State significance.
- **Local significance and/or other values** - areas assessed as not being significant for biodiversity at state or regional scales. Local values are of significance at the local government scale.

For further information on released BPAs and a copy of the underlying methodology, go to:

http://www.qld.gov.au/environment/plants-animals/biodiversity/planning/

The GIS results can be downloaded from the Queensland Spatial Catalogue at:

http://qspatial.information.qld.gov.au/geoportal/

The following table identifies the extent and proportion of the user specified AOI which is mapped as being of "State", "Regional" or "Local" significance via application of the BAMM.

Table 9: Summary table, biodiversity significance

Biodiversity significance	Area (Ha)	% of AOI
State Habitat for EVNT taxa	6,072.94	10.33
State	34,190.47	58.17
Regional	8,928.42	15.19
Local or Other Values	7,829.73	13.32

Refer to **Map 2** for further information.

Diagnostic Criteria

Diagnostic criteria are based on existing data which is reliable and uniformly available across a bioregion. These criteria are diagnostic in that they are used to filter the available data and provide a "first-cut" or initial determination of biodiversity significance. This initial assessment is then combined through a second group of other essential criteria.

A description of the individual diagnostic criteria is provided in the following sections.

Criteria A. Habitat for EVNT taxa: Classifies areas according to their significance based on the presence of endangered, vulnerable and/or rare (EVNT) taxa. EVNT taxa are those scheduled under the *Nature Conservation Act 1992* and/or the

Environment Protection and Biodiversity Conservation Act 1999. It excludes highly mobile fauna taxa which are instead considered in Criterion H and brings together information on EVNT taxa using buffering of recorded sites or habitat suitability models (HSM) where available.

Criteria B. Ecosystem value: Classifies on the basis of biodiversity status of regional ecosystems, their extent in protected areas (presence of poorly conserved regional ecosystems), the presence of significant wetlands; and areas of national importance such as the presence of Threatened Ecological Communities, World Heritage areas and Ramsar sites. Ecosystem value is applied at a bioregional (**B1**) and regional (**B2**) scale.

Criteria C. Tract size: Measures the relative size of tracts of vegetation in the landscape. The size of any tract is a major indicator of ecological significance, and is also strongly correlated with the long-term viability of biodiversity values. Larger tracts are less susceptible to ecological edge effects and are more likely to sustain viable populations of native flora and fauna than smaller tracts.

Criteria D. Relative size of regional ecosystems: Classifies the relative size of each regional ecosystem unit within its bioregion (**D1**) and its subregion (**D2**). Remnant units are compared with all other occurrences with the same regional ecosystem. Large examples of a regional ecosystem are more significant than smaller examples of the same regional ecosystem because they are more representative of the biodiversity values particular to the regional ecosystem, are more resilient to the effects of disturbance, and constitute a significant proportion of the total area of the regional ecosystem.

Criteria F. Ecosystem diversity: Is an indicator of the number of regional ecosystems occurring within an area. An area with high ecosystem diversity will have many regional ecosystems and ecotones relative to other areas within the bioregion.

Criteria G. Context and connection: Represents the extent to which a remnant unit incorporates, borders or buffers areas such as significant wetlands, endangered ecosystems; and the degree to which it is connected to other vegetation.

A summary of the biodiversity status based upon the diagnostic criteria is provided in the following table.

Table 10: Summary of biodiversity significance based upon diagnostic criteria with respect to the AOI

Biodiversity significance	Description	Area (Ha)	% of AOI
State	Remnant contains an RE that is one of the largest of its type in the bioregion (D1) & Remnant has high connectivity or buffers an endangered RE or Sig. Wetland (G)	13,168.16	22.4
State	Remnant contains at least 1 Endangered or 2 Vulnerable or Near Threatened species (A)	6,072.94	10.33
State	Remnant contains at least 1 Endangered RE (B1)	52.3	0.09
State	Remnant contains at least 1 Endangered RE (B1) & World Heritage Area (B1)	113.54	0.19
State	Remnant contains at least one Of Concern RE (B1) & Is part of moderately large Tract (C) & Contains a RE that is a moderately large RE of its type in the bioregion (D1) & Has high connectivity or buffers an endangered RE or Significant Wetland (G)	11.19	0.02
State	Remnant contains at least one Of Concern RE (B1) & Remnant contains an RE that is one of the largest of its type in the bioregion (D1)	4,053.33	6.9
State	Remnant contains at least one Of Concern RE (B1) & Remnant is part of moderately large Tract (C) & Remnant contains a RE that is a moderately large RE of its type in the bioregion (D1) & Remnant has Ecosystem diversity in the top quartile (F)	18.58	0.03
State	World Heritage Area (B1)	1,090.43	1.86
Regional	Remnant contains an RE that is one of the largest of its type in the subregion (D2)	930.01	1.58
Regional	Remnant contains at least 1 RE with <10 pc extent remaining or rare in subregion (B2)	666.46	1.13
Regional	Remnant contains at least 1 RE with 10-30 percent extent remaining in the subregion (B2) & Remnant is part of moderately large Tract (C) & Remnant has high connectivity or buffers an endangered RE or Significant Wetland (G)	6.77	0.01
Regional	Remnant contains at least 1 Vulnerable or Near Threatened species (A)	384.89	0.65
Regional	Remnant contains at least one Of Concern RE (B1)	7,566.49	12.87
Local or Other Values	Refer to diagnostic data for additional information	21,648.10	36.83

Assessment of diagnostic criteria with respect to the AOI

The following table reflects an assessment of the individual diagnostic criteria noted above in regards to the AOI.

Table 11: Assessment of individual diagnostic criteria with respect to the AOI

Diagnostic Criteria	Very High Rating - Area (Ha)	Very High Rating - % of AOI	High Rating - Area (Ha)	High Rating - % of AOI	Medium Rating - Area (Ha)	Medium Rating - % of AOI	Low Rating - Area (Ha)	Low Rating - % of AOI
A: Habitat for EVNT Taxa	6,073.07	10.3	415.1	0.7	34,562.82	58.8	14,732.33	25.1
B1: Ecosystem Value (Bioregion)	5,458.04	9.3	12,143.28	20.7	37,866.05	64.4	315.95	0.5

Diagnostic Criteria	Very High Rating - Area (Ha)	Very High Rating - % of AOI	High Rating - Area (Ha)	High Rating - % of AOI	Medium Rating - Area (Ha)	Medium Rating - % of AOI	Low Rating - Area (Ha)	Low Rating - % of AOI
B2: Ecosystem Value (Subregion)	1,316.39	2.2			48,901.11	83.2	5,565.82	9.5
C: Tract Size			55,713.36	94.8			69.96	0.1
D1: Relative RE Size (Bioregion)	17,648.56	30.0	2,925.07	5.0	7,216.39	12.3	27,993.30	47.6
D2: Relative RE Size (Subregion)	22,436.08	38.2	2,428.78	4.1	5,125.14	8.7	25,793.14	43.9
F: Ecosystem Diversity	19,263.25	32.8	21,099.83	35.9	4,019.88	6.8	11,400.36	19.4
G: Context and Connection	51,048.24	86.8	3,781.68	6.4	936.54	1.6	16.86	

Other Essential Criteria

Other essential criteria (also known as expert panel criteria) are based on non-uniform information sources and which may rely more upon expert opinion than on quantitative data. These criteria are used to provide a "second-cut" determination of biodiversity significance, which is then combined with the diagnostic criteria for an overall assessment of relative biodiversity significance. A summary of the biodiversity status based upon the other essential criteria is provided in the following table.

Table 12: Summary of biodiversity significance based upon other essential criteria with respect to the AOI

Biodiversity significance	Description	Area (Ha)	% of AOI
State	Refer to Expert Panel data for additional information	189.37	0.32
State	Remnant contains Core Habitat for Priority Taxa (H) & Remnant contains Special Biodiversity Values (view Expert Panel data for further information) (I)	1,795.83	3.06
State	Remnant contains Special Biodiversity Values (view Expert Panel data for further information) (I)	10,737.62	18.27
State	Remnant contains Special Biodiversity Values (view Expert Panel data for further information) (I) & Remnant forms part of a bioregional corridor (J)	11,832.06	20.13
State	Remnant forms part of a bioregional corridor (J)	290.03	0.49
Regional	Refer to Expert Panel data for additional information	1,062.92	1.81
Regional	Remnant contains Special Biodiversity Values (view Expert Panel data for further information) (I)	6,573.27	11.18
Regional	Remnant contains Special Biodiversity Values (view Expert Panel data for further information) (I) & Remnant forms part of a bioregional corridor (J)	44.05	0.07
Regional	Remnant forms part of a bioregional corridor (J)	28.98	0.05
Local	Remnant contains Special Biodiversity Values (view Expert Panel data for further information) (I)	0.4	0.0

A description of each of the other essential criteria and associated assessment in regards to the AOI is provided in the following sections.

Criteria H. Essential and general habitat for priority taxa: Priority taxa are those which are at risk or of management concern, taxa of scientific interest as relictual (ancient or primitive), endemic taxa or locally significant populations (such as a flying fox camp or heronry), highly specialised taxa whose habitat requirements are complex and distributions are not well correlated with any particular regional ecosystem, taxa important for maintaining genetic diversity (such as complex spatial patterns of genetic variation, geographic range limits, highly disjunct populations), taxa critical for management or monitoring of biodiversity (functionally important or ecological indicators), or economic and culturally important taxa.

Criteria I. Special biodiversity values: areas with special biodiversity values are important because they contain multiple taxa in a unique ecological and often highly biodiverse environment. Areas with special biodiversity values can include the following:

- Ia - centres of endemism - areas where concentrations of taxa are endemic to a bioregion or subregion are found.
- Ib - wildlife refugia (Morton *et al*. 1995), for example, islands, mound springs, caves, wetlands, gorges, mountain ranges and topographic isolates, ecological refuges, refuges from exotic animals, and refuges from clearing. The latter may include large areas that are not suitable for clearing because of land suitability/capability.
- Ic - areas with concentrations of disjunct populations.
- Id - areas with concentrations of taxa at the limits of their geographic ranges.
- Ie - areas with high species richness.
- If - areas with concentrations of relictual populations (ancient and primitive taxa).
- Ig - areas containing REs with distinct variation in species composition associated with geomorphology and other environmental variables.
- Ih - an artificial waterbody or managed/manipulated wetland considered by the panel/s to be of ecological significance.
- Ii - areas with a high density of hollow-bearing trees that provide habitat for animals.
- Ij - breeding or roosting sites used by a significant number of individuals.
- Ik - climate change refuge.

The following table identifies the value and extent area of the Other Essential Criteria H and I within the AOI.

Table 13: Relative importance of expert panel criteria (H and I) used to access overall biodiversity significance with respect to the AOI

Expert Panel	Very High Rating - Area (Ha)	Very High Rating - % of AOI	High Rating - Area (Ha)	High Rating - % of AOI	Medium Rating - Area (Ha)	Medium Rating - % of AOI	Low Rating - Area (Ha)	Low Rating - % of AOI
H: Core Habitat Priority Taxa	2,881.53	4.9	3,924.65	6.7	1,923.06	3.3		
Ia: Centres of Endemism	5,211.18	8.9	19,308.45	32.8	6.5			
Ib: Wildlife Refugia	21,322.20	36.3	9,660.36	16.4				
Ic: Disjunct Populations	12,212.52	20.8	11,515.56	19.6				
Id: Limits of Geographic Ranges	12,184.79	20.7	27.73					
Ie: High Species Richness	21,965.06	37.4	8,925.41	15.2				
If: Relictual Populations	4,805.83	8.2	17,159.13	29.2				
Ig: Variation in Species Composition	9,402.36	16.0	1,871.01	3.2				
Ih: Artificial Wetland								

Expert Panel	Very High Rating - Area (Ha)	Very High Rating - % of AOI	High Rating - Area (Ha)	High Rating - % of AOI	Medium Rating - Area (Ha)	Medium Rating - % of AOI	Low Rating - Area (Ha)	Low Rating - % of AOI
Ii: Hollow Bearing Trees	12,184.79	20.7	4,895.69	8.3				
Ij: Breeding or Roosting Site	14,925.47	25.4	2,134.50	3.6				
Ik: Climate Refugia	2,157.60	3.7	1,891.52	3.2				

NB. Whilst biodiversity values associated with Criteria I may be present within the site (refer to tables 12 and 15), for the New England Tableland and Central Queensland Coast BPAs, area and % area figures associated with Criteria Ia through to Ij cannot be listed in the table above (due to slight variations in data formats between BPAs).

Criteria J. Corridors: areas identified under this criterion qualify either because they are existing vegetated corridors important for contiguity, or cleared areas that could serve this purpose if revegetated. Some examples of corridors include riparian habitats, transport corridors and "stepping stones".

Bioregional and subregional conservation corridors have been identified in the more developed bioregions of Queensland through the BPAs, using an intensive process involving expert panels. Map 3 displays the location of corridors as identified under the Statewide Corridor network. The Statewide Corridor network incorporates BPA derived corridors and for bioregions where no BPA has been assessed yet, corridors derived under other planning processes. *Note: as a result of updating and developing a statewide network, the alignment of corridors may differ slightly in some instances when compared to those used in individual BPAs.*

The functions of these corridors are:

- **Terrestrial** Bioregional corridors, in conjunction with large tracts of remnant vegetation, maintain ecological and evolutionary processes at a landscape scale, by:

  • Maintaining long term evolutionary/genetic processes that allow the natural change in distributions of species and connectivity between populations of species over long periods of time;

  • Maintaining landscape/ecosystems processes associated with geological, altitudinal and climatic gradients, to allow for ecological responses to climate change;

  • Maintaining large scale seasonal/migratory species processes and movement of fauna;

  • Maximising connectivity between large tracts/patches of remnant vegetation;

  • Identifying key areas for rehabilitation and offsets; and

- **Riparian** Bioregional Corridors also maintain and encourage connectivity of riparian and associated ecosystems.

The location of the corridors is determined by the following principles:

- Terrestrial

  • Complement riparian landscape corridors (i.e. minimise overlap and maximise connectivity);

  • Follow major watershed/catchment and/or coastal boundaries;

  • Incorporate major altitudinal/geological/climatic gradients;

  • Include and maximise connectivity between large tracts/patches of remnant vegetation;

  • Include and maximise connectivity between remnant vegetation in good condition; and

- Riparian

  • Located on the major river or creek systems within the bioregion in question.

The total extent of remnant vegetation triggered as being of "State", "Regional" or "Local" significance due to the presence of an overlying BPA derived terrestrial or riparian corridor within the AOI, is provided in the following table. For further information on how remnant vegetation is triggered due to the presence of an overlying BPA derived corridor, refer to the relevant landscape BPA expert panel report(s).

Table 14: Extent of triggered remnant vegetation due to the presence of BPA derived corridors with respect to the AOI

Biodiversity Significance	Area (Ha)	% of AOI
State	12,029.09	20.46
Regional	166.02	0.28
Local	0.0	0.0

NB: area figures associated with the extent of corridor triggered remnant vegetation are only available for those bioregions where a BPA has been undertaken.

Refer to **Map 3** for further information.

Threatening process/condition (Criteria K) - areas identified by experts under this criterion may be used to amend (upgrade or downgrade) biodiversity significance arising from the "first-cut" analysis. The condition of remnant vegetation is affected by threatening processes such as weeds, ferals, grazing and burning regime, selective timber harvesting/removal, salinity, soil erosion, and climate change.

Assessment of Criteria K with respect to the AOI is not currently included in the "Biodiversity and Conservation Values" report, as it has not been applied to the majority of Queensland due to data/information limitations and availability.

Special Area Decisions

Expert panel derived "Special Area Decisions" are used to assign values to Other Essential Criteria. The specific decisions which relate to the AOI in question are listed in the table below.

Table 15: Expert panel decisions for assigning levels of biodiversity significance with respect to the AOI

Decision Number	Description	Panel Recommended Significance	Criteria Values
eiu_fa_10	Upper Mitchell-Brooklyn	State	Ib (wildlife refugia): VERY HIGH Ie (high species richness): VERY HIGH
eiu_fa_24	Eastern ecotone	State	Ia (centre of endemism): HIGH Ib (wildlife refugia): VERY HIGH Ic (disjunct populations): VERY HIGH Id (taxa at the limits of their ranges): VERY HIGH Ie (high species richness): VERY HIGH Ii (high density of hollow-bearing trees): VERY HIGH Ij (significant breeding or roosting sites): VERY HIGH
eiu_fa_27	Areas of Regional significance for invertebrates	Regional	Ia (centre of endemism): HIGH Ib (wildlife refugia): HIGH Ic (disjunct populations): HIGH Ie (high species richness): HIGH If (relictual populations): HIGH
eiu_fa_28	High precision records for priority taxa of State significance are contained within the remnant.	State	Criterion H: VERY HIGH
eiu_fa_30	High precision records for priority taxa of Regional significance are contained within the remnant.	Regional	Criterion H: HIGH
eiu_fa_31	Low precision records for priority taxa of Regional significance are contained within the remnant.	None	Criterion H: MEDIUM
eiu_fl_08	Bakers Blue and nearby granite areas	Regional	Ib (wildlife refugia): HIGH Ic (disjunct populations): HIGH Ie (high species richness): VERY HIGH
eiu_fl_24	High precision records for priority taxa of State significance are contained within the remnant.	State	Criterion H: VERY HIGH
eiu_fl_25	Low precision records for priority taxa of State significance are contained within the remnant.	None	Criterion H: MEDIUM
eiu_fl_26	High precision records for priority taxa of Regional significance are contained within the remnant.	Regional	Criterion H: HIGH

Decision Number	Description	Panel Recommended Significance	Criteria Values
eiu_fl_27	Low precision records for priority taxa of Regional significance are contained within the remnant.	None	Criterion H: MEDIUM
eiu_l_03	Riparian ecosystems and associated areas.	State	Ib (wildlife refugia): VERY HIGH Ie (high species richness): VERY HIGH Ig (RE's with distinct variation): VERY HIGH Ii (high density of hollow-bearing trees): HIGH Ij (significant breeding or roosting sites): VERY HIGH
eiu_l_06	Wetlands	Regional	Ib (wildlife refugia): HIGH Ie (high species richness): HIGH Ii (high density of hollow-bearing trees): HIGH Ij (significant breeding or roosting sites): HIGH
eiu_l_11	Vine Thickets	State	Ia (centre of endemism): VERY HIGH Ib (wildlife refugia): VERY HIGH Ic (disjunct populations): VERY HIGH Id (taxa at the limits of their ranges): HIGH Ie (high species richness): VERY HIGH If (relictual populations): HIGH
eiu_l_15	Ecosystems with a Biodiversity status of Endangered or Of Concern and a current extent of less than 10,000ha	State	Ib (wildlife refugia): HIGH Ig (RE's with distinct variation): VERY HIGH
eiu_l_22	Corridor Special Management Areas	State	J (corridors): State (all remnant, and disturbed Wet Tropics vegetation)
eiu_l_32	Bioregional Terrestrial Corridors	State or Regional	J (corridors): State or Regional
eiu_l_33	Bioregional Riparian Corridors	State	J (corridors): State
eiu_l_34	Corridor Special Management Areas (non-remnant)	Regional	J (corridors): Regional (non remnant, excluding disturbed Wet Tropics vegetation)
wet_fa_21	Instream fauna - Mt Lewis, upper Mitchell creek, Mt Molloy, McLeod River riparian system	Local	Ia (endemic richness): M Ii (hollows and habitat): H Ik (climate change refugia): H
wet_fa_22	High 'rainforest vertebrate' taxa richness	State	Ie) (species richness): VH
wet_fa_23	High 'rainforest vertebrate' WET endemic taxa richness	State	Ia) endemics: VH
wet_l_04	Upland climate refugia	State	Ia (endemic richness): VH Ib (refugia): VH Ic (disjunct populations): VH Id (range limits): VH Ie (species richness): VH If (relictual taxa): VH Ii (hollows and habitat): VH Ij (aggregation site): VH Ik (climate change refugia): VH
wet_l_15	Sclerophyll forest west of rainforest - tall open forest	State	Ia (endemic richness): VH Ib (refugia): VH Ic (disjunct populations): VH Id (range limits): VH Ie (species richness): VH Ig (ecosystem variation): H Ii (hollows and habitat): VH Ij (aggregation site): H Ik (climate change refugia): H
wet_l_16	Wet Tropics endemic BVGs of simple to complex upland mesophyll and notophyll vine forests.	State	Ia (endemic richness):VH
wet_l_22	Wet Tropics World Heritage Area Outstanding Universal Values - Relictual and important evolutionary Areas	State	If (relictual taxa): VH

Decision Number	Description	Panel Recommended Significance	Criteria Values
wet_l_23	Wet Tropics World Heritage Area Outstanding Universal Values - Concentrations of endemism	State	Ia (endemics): VH
wet_l_24	Wet Tropics World Heritage Area Outstanding Universal Values - Habitats for conserving biodiversity and rare and threatened species of flora and fauna	State	Ib (refugia): VH Ie (species richness): VH
wet_l_25	Core areas	Regional	Ib (refugia): H
wet_l_28	Carbine uplands including Mount Spurgeon	State	Ia (endemic richness): VH Ib (refugia): VH Ic (disjunct populations): VH Id (range limits): VH Ie (species richness): VH If (relictual taxa): VH Ig (ecosystem variation): VH Ii (hollows and habitat): VH Ij (aggregation site): VH Ik (climate change refugia): VH
wet_l_30a	Terrestrial bioregional corridors (landscape connections) .	State	Criterion J (terrestrial corridor): STATE
wet_l_31a	Riparian bioregional corridors (landscape connections)	State	Criterion J (riparian corridor): STATE

Expert panel decision descriptions:

eiu_fa_10

Includes upper tributaries of the Mitchell River, downstream to near Hurricane Station. An extensive rain fed system draining the western margin of the Wet Tropics bioregion, including numerous permanent waterholes. Supports high fish diversity, including disjunct populations of the coal grunter (**Hephaestus carbo**) and other fish species, and the sooty grunter (**Hephaestus fuliginosus**). Also supports the Mitchell river prawn (**Macrobrachium rosenberghii**). Rifle creek is the upper most permanent creek in the upper Mitchell. Includes Font Hills, the source of genetic stock of redclaw (**Cherax quadricarinatus**) aquaculture worldwide. Area includes 500m buffer from riparian zone.

eiu_fa_24

The Eastern ecotone of the Einasleigh Uplands is a band of eucalypt forest separating the rainforest of the Wet Tropics from the dry tropical woodlands that characterize the bioregion. These better developed forests support a number of species that are endemic to the ecotone, or are isolated populations of species more widely distributed in the wet sclerophyll forest of south-east Queensland. These species include the northern bettong (**Bettongia tropica**), eastern yellow robin (**Eopsaltria australis**), yellow thornbill (**Acanthiza nana**), greater glider (**Petauroides volans**), Squirrel glider (**Petaurus norfolcensis**), crested shrike-tit (**Falcunculus frontatus**) and the yellow-faced honeyeater (**Lichenostomus chrysops**). Disjunct tree species that have the major part of their North Queensland distribution in the ecotone include **Eucalyptus resinifera, E. pellita, E. grandis, E. moluccana, E. reducta, E. cloeziana, E. citriodora** and **Angophora floribunda.**

eiu_fa_27

Between Carbine and McLeod River: Endemic Buprestidae (**Casturinia** spp.).

Irvinebank/Watsonville Area: Endemic Scarabidae (including **Blackburnium** sp. and Tesserodon sp.) and Bolbocertideae.

SW of Mt. Molloy: Endemic population of Macropenesthie spp (burrowing cockroach).

Southern Hann Tableland: Endemic Scarabidae, Histeridae spp. This area was incorporated into landscape decision eiu_l_12 and removed from here.

Well wooded country on the Newcastle Range: Rich variety of spp. in the Scarabidae (with at least one endemic Buprestid).

eiu_fa_28

Remnant contains Core Habitat for Priority taxa with high precision records.

eiu_fa_30

Remnant contains Core Habitat for Priority taxa with high precision records.

eiu_fa_31

Remnant contains Core Habitat for Priority taxa with low precision records.

eiu_fl_08

Biotite granite hills north-west of Mareeba. These hills and ranges are surrounded by low sedimentary hills and plains, forming small biogeographic isolates near the western boundary of the Wet Tropics bioregion. All have skeletal soils and coarse sands and are characterized by species with disjunct populations and unusual species assemblages, as well as some R T species. Ecosystems include Wet Tropics outliers as well as drier vine thickets, woodlands and heaths.

Although poorly known, plants of conservation significance known to occur include **Brachychiton albidus** (R), Pimelea sp. (Bakers Blue Mt D.G.Fell DF1588) and Tephrosia gaudium-solis.

Note: the Hann Tableland part of this decision was removed and included in Landscape Decision eiu_l_12.

eiu_fl_24

Remnant contains Core Habitat for Priority taxa with high precision records.

eiu_fl_25

Remnant contains Core Habitat for Priority taxa with low precision records.

eiu_fl_26

Remnant contains Core Habitat for Priority taxa with high precision records.

eiu_fl_27

Remnant contains Core Habitat for Priority taxa with low precision records.

eiu_l_03

Most of the Einasleigh Uplands is dominated by open vegetation on shallow or skeletal soils. Riparian RE's associated with the larger river systems function as important refuges for many species of flora and fauna because of the relatively high nutrient levels associated with most of these areas, their better moisture balance and their generally well developed vegetation. These mesic ribbons of habitat provide an important seasonal refuge and resources for a variety of species, in particular arboreal mammals, woodland birds, hollow-roosting species and amphibians. Many raptor species preferentially nest in tall riparian trees.

Riparian areas are also biogeographically significant habitat as they allow inland incursions of many east coast species into drier areas on the edge of their geographic range.

Riparian areas were given a 200m buffer with the same significance rating to ensure that adjacent habitat used opportunistically by species using the riparian areas was also included.

This decision includes Landscape decision 4.

eiu_l_06

- Wetlands have a range of biodiversity values, both in their own right, and for the role they play in maintaining water quality, protecting downstream aquatic ecosystems, and as part of the wetland ecosystem continuum where they are periodically connected with other aquatic ecosystems. Wetlands act as refugia for many species, and play a vital role in the life cycle of others.
- Wetlands were given a 200m buffer with the same significance rating to ensure that all areas adjacent to them, and the areas most likely to have higher values, were also included.

eiu_l_11

The bioregion has a wide variety of dry vine thickets across a number of different substrates. Vine thickets have been largely cleared from the Brigalow Belt, and the Einasleigh Uplands is of state significance in the protection of these ecosystems and their values. Vine thickets are refugia for a large number of plants and animals, many of which are disjunct populations, or at the limits of their geographic ranges. Although species combinations vary with substrate, EVR and other priority species are present in many occurrences and endemism of invertebrate species is common.

Mapped vine thickets were buffered by 500m to allow for species that shelter in the vine thicket but use resources in the surrounding woodlands.

Some occurrences are at risk from weed invasions (particularly lantana **Lantana camara**), pig damage and adverse fire regimes.

This decision combines and replaces Flora decision 22 and Fauna decision 23.

eiu_l_15

Einasleigh Upland regional ecosystems with a remaining extent that is less than 10,000ha have a naturally restricted distribution, and their threatened status is a reflection of this. They are susceptible to what would normally be viewed as local threats or impacts, and are therefore most vulnerable of all ecosystems to rapid and potentially total loss of natural values. In most cases their restricted distribution relates to geomorphic and/or micro-climatic settings that are also restricted and these areas therefore have particular ecological and scientific values. These values relate to the unique combination of ecological characteristics, and to the unusual habitat conditions they provide for particular species or genotypes. Where the status has been upgraded to Endangered due to the impact of threatening processes their susceptibility to further loss of values is extreme.

eiu_l_22

Corridor Special Management Areas (SMAs) are areas where there are gaps or weaknesses (such as disturbed, cleared or regrowth areas) in habitat continuity in a significant corridor or special biodiversity area, and there is an ecological relationship with the corridor or biodiversity area, or it has similar ecological values to those areas. These areas therefore have significant values in their own right. They also provide a focus for protecting existing vegetation, for consolidating habitat and for increasing habitat connectivity across areas of identified weakness. Focussed planning, management and rehabilitation can play a significant role in enhancing the special ecological values associated with these areas.

The objectives for the corridor SMAs are to limit land use intensification, promote compatible uses, and retain all remaining remnant, disturbed and regrowth vegetation. The restoration of habitat and habitat continuity in cleared parts of the SMAs should be facilitated through detailed planning and negotiation.

Disturbed or regrowth vegetation are not differentiated from cleared areas in the EIU but are in the Wet Tropics. Disturbed Wet Tropics vegetation in SMAs is of State significance, otherwise non-remnant vegetation in SMAs is of Regional Significance (see decision eiu_l_34).

eiu_l_32

This terrestrial corridors decision identifies major themes of habitat connectivity across the bioregion. They identify north/south and east/west links that cover higher altitude areas along watersheds and mountain ranges, and areas characterised by a relative continuity of similar or related habitats, using the methodology outlined in EPA 2008. Identified corridor centrelines are buffered according to the significance of the centreline and the landscape context within which it occurs

Decision eiu_l_22 Corridor Special Management Areas identifies areas where values associated with landscape scale habitat connectivity have been compromised.

eiu_l_33

Riparian corridors in the Einasleigh Uplands are particularly significant for biodiversity, both as a climatic refuge and as a major element of habitat continuity. This decision is based on the bioregional corridor values of major riparian areas. The refugial and other values of riparian areas are covered by decision eiu_l_03.

The watercourse centrelines were buffered by 200m to indicate the general location of this habitat continuity theme, in line with the state-wide approach for riparian corridors in undeveloped bioregions.

eiu_l_34

Corridor Special Management Areas (SMAs) are areas where there are gaps or weaknesses (such as disturbed, cleared or regrowth areas) in habitat continuity in a significant corridor or special biodiversity area, and there is an ecological relationship with the corridor or biodiversity area, or it has similar ecological values to those areas. These areas therefore have significant values in their own right. They also provide a focus for protecting existing vegetation, for consolidating habitat and for increasing habitat connectivity across areas of identified weakness. Focussed planning, management and rehabilitation can play a significant role in enhancing the special ecological values associated with the area.

The objectives for the corridor SMAs are to limit land use intensification, promote compatible uses, and retain all remaining remnant, disturbed and regrowth vegetation. The restoration of habitat and habitat continuity in cleared parts of the SMAs should be facilitated through detailed planning and negotiation.

Disturbed or regrowth vegetation are not differentiated from cleared areas in the EIU but are in the Wet Tropics. Disturbed Wet Tropics vegetation in SMAs is of State significance (see decision eiu_l_22) otherwise non-remnant vegetation in SMAs is of Regional Significance

wet_fa_21

Upper watercourses of the Mitchell River catchment whose sources lies in the Wet Tropics are westward flowing unlike all of the other waterways in the bioregion. This area encompasses Mt Lewis which provides cold water habitat due to its higher elevation. Many of the terrestrial values for the highest part of the mountain are given in wet_fa_12. Other endemics from lower altitudes include: **Uperoleia altissima, Carlia rubrigularis, Glaphyromorphus mjobergi, Xanthotis macleayanus, Arses kaupi, Ptiloris victoriae, Antechinus adustus, Uromys hadrourus** and **Cercartetus caudatus.**

Significant stream-dependent fauna include **Litoria lorica, Euastacus fleckeri** and **Cherax wasselli.**

This area provides suitable habitat for unique Wet Tropics fish fauna, where these taxa are more typical of the Gulf of Carpentaria, e.g. **Scortum ogilbyi, Hephaestus carbo, Ambassis macleayi, Brachirus selheimi** and **Zenarchopterus novaeguineae.**

wet_fa_22

Areas of WET remnant vegetation modelled as being of either high richness for rainforest dependent/partly dependent amphibian, avian, mammalian, or reptile taxa.

This special area representation is derived from research produced through a collaborative fauna modelling project (Williams 2006). Part of the project resulted in the construction of approximately 170 rainforest vertebrate species distribution models. Additionally, species richness, diversity and endemic richness maps were subsequently produced. Rainforest taxa were defined as those species which were obligate to periodic users of Wet Tropic rainforests.

For the purpose of the current special area representation, the extent shown in the adjoining thumbnail captures remnant vegetation which overlapped areas modelled as being of either high amphibian, avian, mammal, or reptile richness. For each taxonomic group, the area of high rainforest taxa richness was defined as the highest modelled 10% area (limited to areas within remnant vegetation) within the WET. The resultant outputs, were then combined to provide a flattened extent area capturing the four major vertebrate taxonomic faunal groups of modelled high species richness.

wet_fa_23

Areas of WET remnant vegetation modelled as being of either high richness for rainforests dependent/partly dependent amphibian, avian, mammalian, or reptile taxa, which are endemic to the WET.

This special area representation is based upon research produced through a collaborative fauna modelling project (Williams 2006). Distribution models were constructed for approximately 170 rainforest vertebrate species as art of this project. Additionally, species richness, diversity and endemic richness maps were also produced. Rainforest taxa were defined as those species which were obligate to periodic users of Wet Tropic rainforests.

For the purpose of the current special area, the extent depicted in the adjoining thumbnail captures the highest modelled 10% area of remnant vegetation which overlaps areas modelled as being of high endemic taxa richness.

wet_l_04

High elevation areas identified as important refugia areas, both currently and in the future (Reside et al. 2013). A comparison of different modelling techniques reveal a consistent result with respect to the upland areas being significant refugia for a high diversity of flora and fauna species (Reside et al. 2013). These high altitude areas include the Carbine, Windsor and Thornton Uplands in the north; Lamb and Herberton Ranges, and Bartle Frere/Bellenden Ker in the centre of the bioregion; and Mt Spec and Mt Elliot in the south.

All are recognised as being biodiversity hotspots, attributed as containing a plethora of upland rainforest-restricted vertebrates and invertebrates. Of these key areas, the highest priority refugia is possibly the upland intact rainforest of the Atherton Uplands possessing high species endemism and high numbers of unique lineages. A study by Graham et al. (2010) showed models predicted that rainforest persisted south of the Black Mountain corridor and that coastal refugia areas which comprise Bellenden-Ker and Thomson Ranges, and the Thornton and Finnegan Uplands, had high historical stability relative to their current extent. Regions of greatest stability for wet sclerophyll forest were the western edge of the Atherton to Kirrama to Paluma uplands and Mt Elliot (VanDerWal et al. 2009).

It is important to note, that whilst mountainous areas will likely provide a refugia for some species currently present at lower altitude, many species currently restricted to cool high altitude areas with narrow environmental niches, may similarly be at increased risk due either to displacement, or limited retreat options (Reside et al. 2013).

wet_l_15

Predominantly situated at the Western margins of the WET and extending from Mt Windsor south to Mt Zero, the feature also incorporates Einasleigh elements. The transition from dry, moist through to tall wet sclerophyll up to the rainforest margin is a highly dynamic zone influenced by climate and fire regimes (and is one of the few WET landscape systems that can carry a crown fire). The considerable environmental heterogeneity associated with the transition often incorporates the tension zone between lowland and upland species, resulting in a high diversity of vertebrate taxa, including many endemics. The largest

contiguous remaining tracts of wet sclerophyll adjacent to rainforest occur along western margin of Coane, Seaview and Cardwell ranges and in upper Daintree area (Stanton et al. 2014). Reduced fire exposure is considered a significant threat to the wet sclerophyll communities from rainforest incursion (Stanton et al. 2014).

The panel noted that the system has an adaptive capacity to climate change with potential movement of vegetation communities along an elevation gradient. This feature also acts as an important corridor along the western bioregion boundary, and areas with the greatest long-term climatic stability for wet sclerophyll forest have been identified as the sections encompassing the western edge of the Atherton, Kirrama and Paluma uplands (VanDerWal et al. 2009).

A number of threatened fauna inhabit this ecotone including **Delma mitella**, **Dasyurus hallucatus**, **Dasyurus maculatus gracilis**, **Bettongia tropica**, **Petauroides volans** and **Petaurus australis** unnamed subsp. (NQ). Disjunct taxa also occur, e.g. **Cormobates leucophaea minor**, **Falcunculus frontatus**, **Antechinus flavipes** and **Isoodon obesulus peninsulae**.

Presence of widespread endemics, e.g. **Bolemoreus frenatus, Xanthotis macleayanus** and **Arses kaupi**. The snail **Steorra estherlilleyae** is narrowly restricted to this habitat west of Paluma. Other invertebrates associated with wet sclerophyll forest include **Temnoplectron cooki**, **Onthophagus pinaroo**, **Pamborus elegans** and **Anomalomorpha monteithi** (Yeates Monteith 2008). Many WET taxa also reach their western and southern limits in this community. Tall eucalypts provide hollows for gliders, possums and large cockatoos, e.g. **Calyptorhynchus lathami**. This habitat is also important for winter feeding by **Pteropus conspicillatus**.

With respect to flora, some of the threatened species present include: **Prostanthera clotteniana**, **Tylophora rupicola**, **Corymbia leptoloma**, **Corymbia rhodops**, **Parsonsia wildensis**, **Plectranthus amoenus**,

Calochlaena villosa, and **Dodonaea uncinata**.

Examples of Wet Tropic endemic flora include: **Actephila flavescens, Acrothamnus spathaceus, Alpinia arctiflora, Argyrodendron peralatum, Athertonia diversifolia, Brackenridgea australiana, Bulbophyllum gadgarrense, Comesperma rhyoliticum, Corymbia leptoloma, Desmos goezeanus, Elaeocarpus carolinae, Endiandra bessaphila, Gmelina fasciculiflora, Hibbertia melhanioides var. baileyana, Lastreopsis tinarooensis, Medicosma glandulosa, Myrsine smithii, Persoonia tropica, Sarcochilus borealis, Solanum magnifolium** and **Symplocos glabra**. Examples of disjunct flora include: **Acacia ulicifolia, Alectryon semicinereus, Archidendron hendersonii, Boletellus emodensis, Cantharellus concinnus, Fistulinella mollis, Hibiscus diversifolius, Knoxia sumatrensis, Lomandra laxa, Notelaea ovata** and **Platycerium superbum.**

wet_l_16

The special area encompasses the broad vegetation groups 1b and 5c (at the 1:1,000,000 scale). BVG 1b refers to - Complex mesophyll to notophyll vine forests usually on basalt tablelands whilst the BVG 5c refers to - Simple to complex notophyll vine forests, often with **Agathis** spp. on ranges and uplands of the WET.

Both these BVGs are unique and endemic to the Wet Tropics and exhibit a unique combination of vegetation communities that only exist within the bioregion.

wet_l_22

The WET contains one of the most complete and diverse living records of the major stages in the evolutionary history of land plants. This is primarily as a result of the rainforests persisting through time since Gondwana. It also provides one of the most important living records of the history of the world's marsupials and songbirds as they originated in the rainforest ecosystems of the Wet Tropics.

The special feature depicted reflects taxa rich "hot spots" derived from known records, and for taxa considered to be of relictual of evolutionary importance (DES 2018). For the purpose of this implementation, the highest ranked 10% area of remnant vegetation within the bioregion was extracted.

Nb. spatial representation not restricted to the WTWHA.

wet_l_23

The Wet Tropics is regarded as a centre of endemism (second only to New Caledonia in the number of endemic genera per unit area), and provides critical insights into the evolutionary patterns both within and outside the rainforests, including the evolutionary history with the surrounding sclerophyll forests. It also provides outstanding examples of important ongoing ecological processes and biological evolution.

The special feature depicted reflects taxa rich "hot spots" derived from known records, and for taxa considered to be endemic to the bioregion (DES 2018). For the purpose of this implementation, the highest ranked 10% area of remnant vegetation within the bioregion was extracted.

Nb. spatial representation not restricted to the WTWHA.

wet_l_24

The Wet Tropics harbours a significant amount of biological diversity and provides a plethora of habitats for many rare and threatened species of outstanding universal significance. Within Australia, it contains relatively high proportions of fern, cycad, conifer, orchid, butterfly, freshwater fish, mammal, bird and herpetofauna species. In addition, many of these species are endemic to the Wet Tropics and have restricted distributions. As a result of this, many fauna species are subsequently rare and/or threatened (e.g. one third of endemic frog species are endangered across the Wet Tropics).

This world heritage criterion has two important features with regards to the emphasis on 'habitats' conserving populations and the importance of biodiversity in terms of the emphasis on interrelationships between individual populations and their habitats. The attributes of this OUV include habitat and plant diversity, rare and threatened flora (threatened taxa habitats), fauna diversity and, rare and threatened fauna (threatened taxa habitats).

The special feature depicted reflects "hot spots" of areas containing a combination of high ecosystem diversity, areas rich in flora and fauna taxa and areas containing concentrations of threatened taxa (DES 2018). For the purpose of this implementation, the highest ranked 10% area of remnant vegetation within the bioregion was extracted.

Nb. spatial representation not restricted to the WTWHA.

wet_l_25

Tracts are defined as patches of continuous remnant vegetation. The size of any tract is a major indicator of ecological significance and is strongly correlated with the long-term viability of biodiversity values. Larger tracts are less susceptible to ecological edge effects and are more likely to sustain viable populations of native flora and fauna than smaller tracts. These areas can be considered core nodes/refugia in which a large proportion of the bioregions biodiversity is represented.

A modified tract size analysis (Criterion C) (EHP 2014) was used to identify and delineate discrete tracts of remnant vegetation at a bioregion scale. For the purpose of the assessment, a core area was identified as a relatively contiguous area of remnant vegetation (disregarding small perforations, or linear breaks) and which was generally greater than 5km in width (based upon the minimum width of the terrestrial corridor network). Tracts of greater than 2,000ha were included.

wet_l_28

In the northern half of the WET, the Carbine uplands encompasses a substantial area of important high altitude forested habitats for a plethora of species. The uplands contain Notophyll and microphyll rainforest above 900m altitude on granite. Compared to other areas in the bioregion, the area has had less impact from cyclones and historical wood harvesting, and is relatively intact. The high rainfall area, with its eastern margins which incorporate steep slopes, facilitate species movement over relatively small distances across environmental gradients. Similarly, this mosaic of environmental gradients is thought to be a factor in driving significant changes in species turnover within regional ecosystems.

The entire tableland forms a significant upland refugia especially towards the centre of the range. The prevalence of boulders and diversity of micro habitats within the landscape facilitate a high resilience to climate change. The area is considered to house a number of disjunct populations and there is some shared species with the western foothills of Mt Bartle Frere.

Flora: The area exhibits very high species richness, and includes concentrations of endemic and relictual taxa. Examples of endemic taxa include: Aceratium ferrugineum, Acronychia chooreechillum, Aglaia brassii, Apodytes brachystylis, Athertonia diversifolia, Bubbia queenslandiana subsp. queenslandiana, Catalepidia heyana, Cryptocarya leucophylla, Elaeocarpus carolinae, Endiandra jonesii, Garcinia brassii, Goniothalamus australis, Helicia lewisensis , Lenbrassia australiana var. Australiana, Medicosma glandulosa, Motherwellia haplosciadea, Niemeyera sp. (Mt Lewis A.K.Irvine 1402), Paphia meiniana, Pilidiostigma sessile, Pittosporum trilobum, Polyosma rigidiuscula, Psychotria sp. (Mt Lewis V.K.Moriarty 2445), Rhododendron lochiae, Sarcopteryx montana, Sphalmium racemosum, Symplocos graniticola, Triunia montana, Wilkiea angustifolia. Relictual taxa examples include: Phlegmariurus filiformis, Phlegmariurus lockyeri, Tmesipteris truncate, Podocarpus smithii and Prumnopitys ladei (Mt Spurgeon black pine). The panel also noted the area as being rich in upland palm species including Laccospadix australasicus (Atherton palm), Archontophoenix purpurea and Oraniopsis appendiculata.

Similar to its eastern face, the Carbine Tableland is globally significant for its lycophytes, epiphyte orchids and ferns and epiphytes in general, however, has the highest diversity of terrestrial ferns in Australia. Fern species include: Diplopterygium longissimum (giant scrambling fern), Gleichenia dicarpa (pouched coral fern), Phlegmariurus filiformis, Sticherus flabellatus var. compactus. In addition, the area has one of the highest concentration of species with big-seeded fruit relative to elevation (Lauraceae), upon which a number of fauna are dependent, including the iconic southern cassowary.

Fauna: The peaks within this area are high in richness of both total number and number of endemic low vagility invertebrates (Yeates Monteith 2008; Staunton et al. 2014). Examples of invertebrates confined to the high altitude include snails (Koreelahropa plowmanae, Hedleya montlewis, Montanopoma carbine and Nitor reisi); crustaceans (Euastacus fleckeri); spiders (Carbinea breviscapa, C. longiscapa, C. robertsi, Centrothele spurgeon, Heteropoda spurgeon, Megateg spurgeon and Maxanapis mossman); odonates (Lestoidea lewisiana, Eusynthemis barbarae and E. netta), bug (Grosshygia nigra) and beetles (Apterotheca astraphes, A. chloros, A. pecticrinis, A. trichopectoris, Philipis laevigata, P. spurgeoni and P. geoffreyi). Chlamydopsis trichonota is a relictual taxon known to occur in the area.

The area is home to narrow range endemic frogs such as Mixophyes carbinensis and Cophixalus hosmeri. Other endemic taxa, several of which are threatened, also occur in the area and these including Cophixalus aenigma, Litoria nannotis, L. lorica, L. rheocola, L. serrata, L. nyakalensis, Taudactylus rheophilus, Lampropholis robertsi, Saproscincus czechurai, Oreoscopus gutturalis, Acanthiza katherina, Heteromyias cinereifrons, Amblyornis newtonianus, Scenopoeetes dentirostris, Hemibelideus lemuroides, Pseudochirops archeri and Antechinus adustus.

Disjunct taxa found in these mesic environs include Tyto tenebricosa multipunctata, Cormobates leucophaea minor, Sericornis citreogularis, Ailuroedus melanotis and Concinnia frerei. This area is also considered a stronghold for Dasyurus maculatus gracilis, particularly in the upland rainforest habitat (i.e. above 900m) around Mt Lewis and Mt Spurgeon. Various records over the past 15 or so years of the threatened Bettongia tropica are known from the Mt Spurgeon area.

Threatened species known to occur include Casuarius Casuarius and Erythrura trichroa. Being relatively rich in specialist and endemic bird species, the area has been identified as part of the Daintree Key Biodiversity Area (Birdlife Australia 2018). The area is also a noted refugium for flightless insects (Yeates et al. 2002).

wet_l_30a

The broad purpose of landscape-scale connections, is to provide for ecological and evolutionary processes at a bioregional scale. Maintaining connectivity across a landscape, either through "continuous linkages" or via "stepping-stones" of remnant vegetation, is important for the long-term conservation of biodiversity.

Corridor triggered remnant vegetation is focused upon areas between core tracts/nodes (as identified under the special area decision wet_l_25) within the bioregion. For further information regarding the broad principles and intent, as well as more specific information relating to the Wet Tropics terrestrial corridor network, refer to Section 3.3.2.1 and Table 14.

wet_l_31a

Riparian corridors encompass some of the most diverse, dynamic and complex habitats incorporating both environmental and topographic gradients. Comparatively, such areas tend to exhibit high species richness with respect to both flora and fauna, provide important resources in terms of water, food, shelter, nesting and nursery sites and act as a refugia during periods of drought, or in response to longer terms impacts associated with climatic change.

At the landscape scale, networks of major and minor riparian linkages are a significant element of habitat continuity and provide important migratory and dispersal pathways for a substantial number of species (especially birds, insects and flora, but also for many arboreal mammals and reptiles). In some areas of fragmented landscapes, watercourses often provide the only remaining habitat connectivity due to the extensive clearing and surrounding modified landscape.

Within the WET, the panel determined that remnant vegetation within 200m and 100m of major and minor waterways should be designated as being of State and Regional significance respectively. The significance of selected riverine systems were also modified in some instances (Table 16). Corridor triggered remnant vegetation focuses upon identifying key connections between remaining core tracts/nodes (as identified under the special area decisions wet_l_25) within the bioregion. For further information regarding the broad principles and intent, as well as more specific information relating to the Wet Tropics riparian corridor network, refer to Section 3.3.2.2.

Aquatic Conservation Assessments

Introduction

The Aquatic Biodiversity Assessment and Mapping Method or AquaBAMM (Clayton *et al.* 2006), was developed to assess conservation values of wetlands in queensland, and may also have application in broader geographical contexts. It is a comprehensive method that uses available data, including data resulting from expert opinion, to identify relative wetland conservation/ecological values within a specified study area (usually a catchment). The product of applying this method is an Aquatic Conservation Assessment (ACA) for the study area.

An ACA using AquaBAMM is non-social, non-economic and identifies the conservation/ecological values of wetlands at a user-defined scale. It provides a robust and objective conservation assessment using criteria, indicators and measures that are founded upon a large body of national and international literature. The criteria, each of which may have variable numbers of indicators and measures, are naturalness (aquatic), naturalness (catchment), diversity and richness, threatened species and ecosystems, priority species and ecosystems, special features, connectivity and representativeness. An ACA using AquaBAMM is a powerful decision support tool that is easily updated and simply interrogated through a geographic information system (GIS).

Where they have been conducted, ACAs can provide a source of baseline wetland conservation/ecological information to support natural resource management and planning processes. They are useful as an independent product or as an important foundation upon which a variety of additional environmental and socio-economic elements can be added and considered (i.e. an early input to broader 'triple-bottom-line' decision-making processes). An ACA can have application in:

- determining priorities for protection, regulation or rehabilitation of wetlands and other aquatic ecosystems
- on-ground investment in wetlands and other aquatic ecosystems
- contributing to impact assessment of large-scale development (e.g. dams)
- water resource and strategic regional planning prcesses

For a detailed explanation of the methodology please refer to the summary and expert panel reports relevant to the ACA utilised in this assessment. These reports can be accessed at Wetland *Info*:

http://wetlandinfo.des.qld.gov.au/wetlands/assessment/assessment-methods/aca

The GIS results can be downloaded from the Queensland Spatial Catalogue at:

http://qspatial.information.qld.gov.au/geoportal/

Explanation of Criteria

Under the AquaBAMM, eight criteria are assessed to derive an overall conservation value. Similar to the Biodiversity Assessment and Mapping Methodology, the criteria may be primarily diagnostic (quantitative) or primarily expert opinion (qualitative) in nature. The following sections provide a brief description of each of the 8 criteria.

Criteria 1. Naturalness - Aquatic: This attribute reflects the extent to which a wetland's (riverine, non-riverine, estuarine) aquatic state of naturalness is affected through relevant influencing indicators which include: presence of exotic flora and fauna; presence of aquatic communities; degree of habitat modification and degree of hydrological modification.

Criteria 2. Naturalness - Catchment: The naturalness of the terrestrial systems of a catchment can have an influence on many wetland characteristics including: natural ecological processes e.g. nutrient cycling, riparian vegetation, water chemistry, and flow. The indicators utilised to assess this criterion include: presence of exotic flora and/or fauna; riparian, catchment and flow modification.

Criteria 3. Naturalness - Diversity and Richness: This criterion is common to many ecological assessment methods and can include both physical and biological features. It includes such indicators as species richness, riparian ecosystem richness and geomorphological diversity.

Criteria 4. Threatened Species and Ecosystems: This criterion evaluates ecological rarity characteristics of a wetland. This includes both species rarity and rarity of communities / assemblages. The communities and assemblages are best represented by regional ecosystems. Species rarity is determined by NCA and EPBC status with Endangered, Vulnerable or Near-threatened species being included in the evaluation. Ecosystem rarity is determined by regional ecosystem biodiversity status i.e. Endangered, Of Concern, or Not of Concern.

Criteria 5. Priority Species and Ecosystems: Priority flora and fauna species lists are expert panel derived. These are aquatic, semi-aquatic and riparian species which exhibit at least 1 particular trait in order to be eligible for consideration. For

flora species the traits included:

- It forms significant macrophyte beds (in shallow or deep water).
- It is an important food source.
- It is important/critical habitat.
- It is implicated in spawning or reproduction for other fauna and/or flora species.
- It is at its distributional limit or is a disjunct population.
- It provides stream bank or bed stabilisation or has soil binding properties.
- It is a small population and subject to threatening processes.

Fauna species are included if they meet at least one of the following traits:

- It is endemic to the study area (>75 per cent of its distribution is in the study area/catchment).
- It has experienced, or is suspected of experiencing, a serious population decline.
- It has experienced a significant reduction in its distribution and has a naturally restricted distribution in the study area/catchment.
- It is currently a small population and threatened by loss of habitat.
- It is a significant disjunct population.
- It is a migratory species (other than birds).
- A significant proportion of the breeding population (>one per cent for waterbirds, >75 per cent other species) occurs in the waterbody (see Ramsar criterion 6 for waterbirds).
- Limit of species range.

See the individual expert panel reports for the priority species traits specific to an ACA.

Criteria 6. Special Features: Special features are areas identified by flora, fauna and ecology expert panels which exhibit characteristics beyond those identified in other criteria and which the expert panels consider to be of the highest ecological importance. Special feature traits can relate to, but are not solely restricted to geomorphic features, unique ecological processes, presence of unique or distinct habitat, presence of unique or special hydrological regimes e.g. spring-fed streams. Special features are rated on a 1 - 4 scale (4 being the highest).

Criteria 7. Connectivity: This criterion is based on the concept that appropriately connected aquatic ecosystems are healthy and resilient, with maximum potential biodiversity and delivery of ecosystem services.

Criteria 8. Representativeness: This criterion applies primarily to non-riverine assessments, evaluates the rarity and uniqueness of a wetland type in relation to specific geographic areas. Rarity is determined by the degree of wetland protection within "protected Areas" estate or within an area subject to the *Fisheries Act 1994*, *Coastal Protection and Management Act 1995*, or *Marine Parks Act 2004*. Wetland uniqueness evaluates the relative abundance and size of a wetland or wetland management group within geographic areas such as catchment and subcatchment.

Riverine Wetlands

Riverine wetlands are all wetlands and deepwater habitats within a channel. The channels are naturally or artificially created, periodically or continuously contain moving water, or connecting two bodies of standing water. AquaBAMM, when applied to riverine wetlands uses a discrete spatial unit termed subsections. A subsection can be considered as an area which encompasses discrete homogeneous stream sections in terms of their natural attributes (i.e. physical, chemical, biological and utilitarian values) and natural resources. Thus in an ACA, an aquatic conservation significance score is calculated for each subsection and applies to all streams within a subsection, rather than individual streams as such.

Please note, the area figures provided in Tables 16 and 17, are derived using the extent of riverine subsections within the AOI. Refer to **Map 5** for further information. A summary of the conservation significance of riverine wetlands within the AOI is provided in the following table.

Table 16: Overall level/s of riverine aquatic conservation significance

Aquatic conservation significance (riverine wetlands)	Area (Ha)	% of AOI
Very High	58,719.59	99.9

Aquatic conservation significance (riverine wetlands)	Area (Ha)	% of AOI
High	41.66	0.07
Medium	18.04	0.03
Low	0.0	0.0
Very Low	0.0	0.0

The individual aquatic conservation criteria ratings for riverine wetlands within the AOI are listed below.

Table 17: Level/s of riverine aquatic conservation significance based on selected criteria

Criteria	Very High Rating - Area (Ha)	Very High Rating - % of AOI	High Rating - Area (Ha)	High Rating - % of AOI	Medium Rating - Area (Ha)	Medium Rating - % of AOI	Low Rating - Area (Ha)	Low Rating - % of AOI
1. Naturalness aquatic			58,779.31	100.0				
2. Naturalness catchment			39,536.64	67.3	19,242.67	32.7		
3. Diversity and richness	58,719.60	99.9	59.71	0.1				
4. Threatened species and ecosystems	58,737.64	99.9	41.67	0.1				
5. Priority species and ecosystems	45,148.06	76.8	13,571.54	23.1	40.37	0.1		
6. Special features	58,719.60	99.9						
7. Connectivity			53,108.18	90.4				
8. Representative-ness								

The table below lists and describes the relevant expert panel decisions used to assign conservation significance values to riverine wetlands within the AOI.

Table 18: Expert panel decisions for assigning overall levels of riverine aquatic conservation significance

Decision number	Special feature	Catchment	Criteria/Indicator/Measure	Conservation rating (1-4)
ml_r_ec_06	Perennial waterholes in active streams	Mitchell	5.2.1, 6.1.1, 6.2.1, 6.3.1, 6.3.4, 6.4.1, 7.1.2	3, 3, 3, 4, 3, 3, 3
ml_r_ec_16	Wet Tropics rainforests and associated riverine habitats across the upper Mitchell basin	Mitchell	5.2.1, 6.1.1, 6.2.1, 6.3.1, 6.3.3, 6.3.4, 6.4.1	4, 4, 4, 4, 4, 4, 4
ml_r_ec_18	Priority refugia for freshwater fish	Mitchell	6.2.1, 6.3.1, 6.3.3, 6.3.4, 6.4.1	3, 4, 4, 4, 3

4 is the highest rating/value

Expert panel decision descriptions:

ml_r_ec_06

In the seasonally dry tropics of the Eastern Gulf, perennial waterholes in active streams provide critical refugial (6.3.1) dry season habitat for obligate freshwater species including conservation dependent and listed species such as juvenile

freshwater sawfish **Pristis pristis** and snapping turtles and represent a priority aquatic ecosystems (5.2.1). They are also important for migratory fish species (7.1.2) in particular sooty grunter **Hephaestus fuliginosus** and adult phase eel tailed catfish. Permanent waterholes in active streams support a range of ecological processes that are distinct relative to the more extensive seasonal aquatic habitats that characterise the eastern Gulf (6.2.1). Within the seasonally dry climate of the eastern Gulf the presence of permanent freshwater usually owes its existence to a combination of special geomorphic features (6.1.1) and hydrological regimes (6.4.1). Within the suite of exiting perennial waterholes are subset will also have an increasingly important role as refugia within the increasingly variable rainfall and elevated temperature regimes predicted under climate change (6.4.1).

ml_r_ec_16

The Mitchell is the most bioregionally diverse basin in the eastern Gulf and is unique within all Gulf River basins in having areas of its upper catchment fall within the Wet Tropics Bioregion. Each of the sub basins of the upper Mitchel drain three different Wet Tropics Provinces including the Palmer which drains the Daintree Bloomfield Province, the Upper Mitchel which drains both the Daintree-Bloomfield and the Macalister Provinces and the Walsh which drains the Atherton Province. These areas are fully representative of the Wet Tropics and include extremely high and seasonally distributed rainfall, high cool (6.1.1) altitude mountains and tropical rainforest vegetation. This combination of biophysical features within a Gulf drainage basin generates unique hydrological conditions (6.2.1) and associated riverine (and some unmapped non riverine) wetland habitats, communities and values. High elevation areas receive regular rainfall often via cloud capture, which sustains perennial riverine habitats often via direct rainfall run off (6.4.1) rather than groundwater contributions alone which are associated with perennial streams elsewhere in the eastern Gulf. Cool water temperatures associated with high altitude (>700m) areas support habitats rich in bryophytes and mosses and endemic fauna including a large spiny crayfish **Euastacus fleckeri** restricted within the Mitchell Basin to areas draining Mt Windsor and the Hann Tableland in the adjoining Einasleigh Uplands Bioregion (Ryan et al. 2002). An area also vegetated by Wet Tropics rainforest regional ecosystem. The potential for additional **Euastacus** species to be discovered elsewhere in these upland rainforest catchments is high. Numerous frog species including at least nine that are listed as threatened (6.3.1) also characterise the fauna of the Wet Tropics upper catchments of the Mitchell (Tait et al. 2015). These high altitude areas also include flat tablelands likely to host a number of unmapped non-riverine wetland types including springs and soaks associated with past alluvial deposits. Another restricted crayfish species red tipped yabby **Cherax wassellii** occupies mid altitude uplands ranging from 500m adjoining Black Mountain to 350m in the lower Rifle Creek system adjoining Mt Carbine. This species occurs more widely throughout adjoining eastern drainages and is believed to be a natural translocation (Ryan et al. 2002). Perennial flows from these upland rainforest catchments sustain perennial riverine habitat into lower altitude reaches and contribute to downstream shallow aquifer recharge (6.4.1) beyond the McLeod River - Rifle Creek confluence in the upper Mitchell (Hydrobiology 2005). These perennial habitats act as refugia for aquatic species (6.3.1) including fish and crustaceans more typically associated with lower western reaches. When hosted in Wet Tropics upper catchments unique community types of Gulf basins species juxtaposed within Wet Tropics habitats are formed (Vallance and Hogan 2001, Ryan et al. 2002). Some of these perennial riverine reaches are likely to provide important climate change refugia in future years (6.3.4). Frontage communities associated with these Wet Tropics riverine reaches also include a large number of 'endangered' or 'of concern' regional ecosystems (5.2.1) (e.g. RE 7.3.23, RE 7.3.25, RE 7.3.26, RE 7.3.28, RE 7.3.49, RE 7.11.42). In many cases the threatened status of these regional ecosystems is due to impacts elsewhere within the Wet Tropics and the more limited development pressure within the upper Mitchell has thus far retained good examples of them. Ongoing emerging development pressure in these uplands of the Mitchell basin underpins the need for recognition of the conservation value of these wetland associated priority ecosystems.

ml_r_ec_18

These 'Priority Refugia for Freshwater Fish' (6.3.1) are based on those defined by Hermoso et al. (2013) (6.3.3) for the Mitchell river basin on the basis of water residency (6.4.1) assessed by satellite imagery over multiple years and considerations of fish community distribution across the basin. Fish distribution was used to prioritise candidate refugia by seeking to maximise individual species representation across the set of prioritised refugia. Individual species vagility was also assessed and incorporated in refugia selection by seeking to maximise the length of stream area accessible for colonisation (6.2.1) from refugia following their isolation by extreme droughts including those predicted to occur under future climate change scenarios (6.3.4). Two sets of priority refugia were nominated one using a baseline catchment condition and another using current conditions and projections of ecological pressure that reduce the viability of some candidate refugia. Both sets of prioritised refugia intersected with riverine spatial units have been conservatively used for this decision recognising that not all projected condition pressures have been realised and also that management intervention may have the capacity to mitigate them where they have been realised. Given the use of remote sensing in the identification of potential refugia some caution is needed in the application of identified refugia values recognising that artificial waterbodies including dams may have contributed to satellite based indications of water perenniality in the landscape.

Non-riverine Wetlands

Non-riverine wetlands include both lacustrine and palustrine wetlands, however, do not currently incorporate estuarine, marine or subterranean wetland types. A summary of the conservation significance of non-riverine wetlands within the AOI is provided in the following table. Refer to **Map 6** for further information.

Table 19: Overall level/s of non-riverine aquatic conservation significance

Aquatic conservation significance (non-riverine wetlands)	Area (Ha)	% of AOI
Very High	5.07	0.01
High	0.0	0.0
Medium	283.9	0.48
Low	0.0	0.0
Very Low	0.0	0.0

The following table provides an assessment of non-riverine wetlands within the AOI and associated aquatic conservation criteria values.

Table 20: Level/s of non-riverine aquatic conservation significance based on selected criteria

Criteria	Very High Rating - Area (Ha)	Very High Rating - % of AOI	High Rating - Area (Ha)	High Rating - % of AOI	Medium Rating - Area (Ha)	Medium Rating - % of AOI	Low Rating - Area (Ha)	Low Rating - % of AOI
1. Naturalness aquatic	159.89	0.3			4.2		124.87	0.2
2. Naturalness catchment			262.47	0.4	26.49			
3. Diversity and richness	88.79	0.2	200.17	0.3				
4. Threatened species and ecosystems	200.17	0.3	88.79	0.2				
5. Priority species and ecosystems	288.96	0.5						
6. Special features	5.07							
7. Connectivity								
8. Representative-ness					125.8	0.2	74.37	0.1

The table below lists and describes the relevant expert panel decisions used to assign conservation significance values to non-riverine wetlands within the AOI.

Table 21: Expert panel decisions for assigning overall levels of non-riverine aquatic conservation significance.

Decision number	Special feature	Catchment	Criteria/Indicator/Measure	Conservation rating (1-4)
ml_nr_ec_22	Clear to turbid or turbid perennial off river waterholes	Mitchell	5.2.1, 6.1.1, 6.2.1, 6.3.1, 6.3.3, 6.3.4, 6.4.1	4, 3, 4, 4, 3, 4, 4

4 is the highest rating/value

Expert panel decision descriptions:

ml_nr_ec_22

Within the seasonally dry climate of the eastern Gulf perennial waterholes are a limited asset and have high values as aquatic refugia (6.3.1) particularly considering the spectre of increasing rainfall variability due to climate change (6.3.4). Perennial off river waterholes owe their existence to a combination of special geomorphic features (6.1.1) and hydrological regimes (6.4.1) These include greater waterhole depth associated with prior channels and/or flood scouring and groundwater supplementation. Groundwater is often supplied from shallow alluvial aquifers associated with interbedded sands in quaternary alluvium. Such aquifers are recharged by a combination of rainfall, overbank flood flows and connectivity to within channel flows in adjoining rivers channels as occurs in mid reaches of the Mitchell River, or via supplementation from fractured rock aquifers as occurs in some upper Gilbert Basin waterholes (Batlle-Aguilar et al. 2014; CSIRO 2009; Petheram et al. 2013a). Direct supplementation of waterholes from fractured rock and deeper groundwater aquifers also occurs in upper catchment areas of the Mitchell, Staaten and Gilbert basins (CSIRO 2009; Petheram et al. 2013a). Water clarity regimes within perennial waterholes are a key driver of their ecology and can also be an indicator of their condition. Mitchell, Staaten and Gilbert basin waterhole perenniality and clarity has been assessed by reference to multiple years of satellite TM imagery (Lymburner and Burrows 2008). Such imagery is not capable of detecting smaller sized or heavily vegetated waterholes which may not be included in this value decision. Such smaller perennial wetlands will share equivalent values to larger sites particularly where they occur in aggregations. While clear waterholes are often associated with high values, e.g. instream productivity, aquatic plant and fish diversity, water turbidity is often a natural water quality feature of eastern Gulf drainages. However in some cases it is indicative of land use pressure or other disturbances including cattle access, elevated soil erosion and pig wallowing particularly in the Mitchell, Staaten and Gilbert Basins where good water clarity is associated with baseline conditions in these typically sand bedded and groundwater supplemented systems. Consequently waterholes that don't exhibit sustained clarity have been valued less than their clear counterparts for these basins. Regardless of water clarity priority aquatic ecosystems are commonly associated with non-clear perennial waterholes including RE 2.3.16 lagoons on Quaternary alluvial plain. This RE is recognised as important breeding and feeding sites (6.3.1) for waterbirds and have an 'of concern' biodiversity status (Sattler and Williams 1999). The significant value of non-permanently clear and or turbid perennial waterholes are still recognised in a number (6.3.3) of national and regional assessments (Kennard et al. 2011; Hermoso et al. 2013). They also underpin key refugia and nursery habitat values nominated for several National Directory listed (6.3.2) wetlands including the Mitchell River Fan, Smithburne-Gilbert Fan and Dorunda Lakes aggregations (Blackman et al. 1999).

Threatened and Priority Species

Introduction

This chapter contains a list of threatened and priority flora and/or fauna species that have been recorded on, or within 4km of the Assessment Area.

The information presented in this chapter with respect to species presence is derived from compiled databases developed primarily for the purpose of BPAs and ACAs. Data is collated from a number of sources and is updated periodically.

It is important to note that the list of species provided in this report, may differ when compared to other reports generated from other sources such as the State government's WildNet, Herbrecs or the federal government's EPBC database for a number of reasons.

Records for threatened and priority species are filtered and checked based on a number of rules including:

- Taxonomic nomenclature - current scientific names and status,
- Location - cross-check co-ordinates with location description,
- Taxon by location - requires good knowledge of the taxon and history of the record,
- Duplicate records - identify and remove,
- Expert panels - check records and provide new records,
- Flora cultivated records excluded,
- Use precise records less than or equal to 2000m,
- Use recent records greater than or equal to 1975 animals, greater than or equal to 1950 plants.

Threatened Species

Threatened species are those species classified as "Endangered" or "Vulnerable" under the *Environment Protection and Biodiversity Conservation Act 1999* or "Endangered", "Vulnerable" or "Near threatened" under the *Nature Conservation Act 1992*.

The following threatened species have been recorded on, or within approximately 4km of the AOI.

Table 22: Threatened species recorded on, or within 4km of the AOI

Species	Common name	NCA status	EPBC status	Back on Track rank	Migratory species*	Wetland species**	Identified flora/fauna
Acacia guymeri		V		Low			FL
Acanthophis antarcticus	common death adder	V		Medium			FA
Aceratium ferrugineum	rusty carabeen	NT		Low			FL
Aglaia brassii		NT		Low			FL
Amyema plicatula		C	E				FL
Austrobuxus megacarpus		NT		Low			FL
Austrocallerya pilipes		NT					FL
Austromuellera valida		V		Low			FL
Boea kinnearii		E		Low			FL
Bubbia queenslandiana subsp. queenslandiana		NT		Low			FL
Bulbophyllum windsorense		V		Data deficient			FL
Calidris ferruginea	curlew sandpiper	CE	CE	Low	Y	I	FA
Calidris tenuirostris	great knot	CE	CE	Low	Y	I	FA
Carex breviscapa		V		Low			FL

Species	Common name	NCA status	EPBC status	Back on Track rank	Migratory species*	Wetland species**	Identified flora/fauna
Casuarius casuarius johnsonii (southern population)	southern cassowary (southern population)	E	E	Critical			FA
Cophixalus aenigma	tapping nurseryfrog	NT	E	Low			FA
Cophixalus hosmeri	rattling nurseryfrog	CE	CE	Low			FA
Cophixalus monticola	mountain nurseryfrog	CE	CE	Low			FA
Corymbia rhodops	red-throated bloodwood	V	V	Low			FL
Crocodylus porosus	estuarine crocodile	V		Low	Y	I	FA
Ctenotus monticola	Atherton ctenotus	V		Low			FA
Cyclopsitta diophthalma macleayana	Macleay's fig-parrot	V		Low			FA
Dasyurus hallucatus	northern quoll	C	E	Medium			FA
Dasyurus maculatus gracilis	spotted-tailed quoll (northern subspecies)	E	E	Critical			FA
Dendrobium bigibbum	Cooktown orchid	V	V	High			FL
Dendrolagus bennettianus	Bennett's tree-kangaroo	NT		Low			FA
Dendrolagus lumholtzi	Lumholtz's tree-kangaroo	NT		Low			FA
Diospyros granitica		NT		Low			FL
Egernia rugosa	yakka skink	V	V	Medium			FA
Ehretia microphylla		V					FL
Elaphoglossum callifolium		NT		Low			FL
Endiandra jonesii		V		Low			FL
Endiandra phaeocarpa		V		Low			FL
Erythrura trichroa	blue-faced parrot-finch	NT		Low			FA
Gastrodia urceolata		V		Low			FL
Glochidion pungens		NT		Low			FL
Grammitis reinwardtii		V	V	Low			FL
Grantiella picta	painted honeyeater	V	V	High			FA
Graptophyllum excelsum		NT		Low			FL
Grevillea glossadenia		V	V	Low			FL
Habenaria chlorosepala		E					FL
Helicia grayi		V		Low			FL
Helicia lewisensis		V		Low			FL
Helicia recurva		NT		Low			FL
Hipposideros diadema reginae	diadem leaf-nosed bat	NT		Low			FA
Hymenophyllum digitatum		V		Low			FL
Hymenophyllum pallidum		NT					FL
Lastreopsis tinarooensis		V		Low			FL
Lindsaea terrae-reginae		E		Low			FL
Linospadix palmerianus		NT		Low			FL

Species	Common name	NCA status	EPBC status	Back on Track rank	Migratory species*	Wetland species**	Identified flora/fauna
Litoria dayi	Australian lacelid	V	V	Low		I	FA
Litoria nannotis	waterfall frog	E		Low		I	FA
Litoria nyakalensis	mountain mistfrog	CE	CE	Low			FA
Litoria rheocola	common mistfrog	E		Low		I	FA
Litoria serrata	tapping green eyed frog	V		Low		I	FA
Litsea granitica		V		Low			FL
Macropteranthes montana		V	V	Low			FL
Medicosma glandulosa		NT		Low			FL
Mesembriomys gouldii	black-footed tree-rat	C	V	Low			FA
Parsonsia bartlensis		V		Low			FL
Petauroides volans	greater glider	V	V	Low			FA
Petauroides volans minor	northern greater glider	V	V				FA
Petaurus australis unnamed subsp.	yellow-bellied glider (northern subspecies)	E	V	Critical			FA
Phaleria biflora		V	V	Low			FL
Phlegmariurus creber	rat-tail tassel-fern	CE					FL
Phlegmariurus delbrueckii		V					FL
Phlegmariurus filiformis		C	E	Critical			FL
Phlegmariurus ledermannii		V					FL
Phlegmariurus lockyeri		V	V	Critical			FL
Phlegmariurus phlegmarioides		V		High			FL
Phlegmariurus squarrosus	water tassel-fern	CE	CE	Critical			FL
Phlegmariurus tetrastichoides		V	V	High			FL
Pristis pristis	freshwater sawfish		V	High	Y	D	FA
Pteridoblechnum acuminatum		NT		Low			FL
Pteropus conspicillatus	spectacled flying-fox	E	E	High			FA
Randia audasii		NT		Low			FL
Rhaphidospora cavernarum		V					FL
Rhinolophus philippinensis	greater large-eared horseshoe bat	E	V	High			FA
Rostratula australis	Australian painted snipe	E	E	Medium		I	FA
Sarcopteryx montana		NT		Low			FL
Sminthopsis archeri	chestnut dunnart	NT		Low			FA
Solanum angustum		CE		Medium			FL
Spathoglottis paulinae		NT		Low			FL
Steganthera laxiflora subsp. lewisensis		NT		Low			FL
Stylidium elachophyllum		E				I	FL
Symplocos ampulliformis		NT		Low			FL

Species	Common name	NCA status	EPBC status	Back on Track rank	Migratory species*	Wetland species**	Identified flora/fauna
Symplocos crassiramifera		V		Low			FL
Taudactylus rheophilus	northern tinkerfrog	E	E	Low		I	FA
Toechima pterocarpum	orange tamarind	E	E	Low			FL
Turnix olivii	buff-breasted button-quail	E	E	Data deficient			FA
Tyto novaehollandiae kimberli	masked owl (northern subspecies)	V	V	Low			FA
Waterhousea mulgraveana		V		Low			FL
Xylosma sp. (Mt Lewis G.Sankowsky+ 1108)		V		Low			FL
Zieria alata	Mt Lewis stink bush	CE					FL

NB. Please note that the threatened species listed in this section are based upon the most recently compiled DES internal state-wide threatened species dataset. This dataset may contain additional records that were not originally available for inclusion in the relevant individual BPAs and ACAs.

**JAMBA - Japan-Australia Migratory Bird Agreement; CAMBA - China-Australia Migratory Bird Agreement; ROKAMBA - Republic of Korea-Australia Migratory Bird Agreement; CMS - Convention on the Conservation of Migratory Species*.

***I - wetland indicator species; D - wetland dependent species*.

BPA Priority Species

A list of BPA priority species that have been recorded on, or within approximately 4km of the AOI is contained in the following table.

Table 23: Priority species recorded on, or within 4km of the AOI

Species	Common name	Back on Track rank	Identified flora/fauna
Acacia whitei	None	L	FL
Acanthiza katherina	Mountain Thornbill	L	FA
Acianthus borealis	None	None	FL
Aepyprymnus rufescens	Rufous Bettong	L	FA
Aidia gyropetala	None	None	FL
Ailuroedus maculosus	Spotted Catbird	L	FA
Amblyornis newtonianus	Golden Bowerbird	L	FA
Bonnaya tenuifolia	None	None	FL
Caladenia catenata	None	None	FL
Calanthe triplicata	christmas orchid	None	FL
Ceratopetalum hylandii	None	None	FL
Chlamydopsis trichonota	beetle	None	FA
Chlamydosaurus kingii	Frilled Lizard	L	FA
Climacteris picumnus	Brown Treecreeper	L	FA
Colluricincla boweri	Bower's Shrike-thrush	L	FA
Corybas barbarae	helmet orchid	None	FL
Crikey steveirwini	Steve Irwin's Treesnail	None	FA
Croton minimus	None	L	FL
Cryptocarya bellendenkerana	None	None	FL

Species	Common name	Back on Track rank	Identified flora/fauna
Cyathea baileyana	wig tree fern	L	FL
Dromaeschna weiskei	Ochre-tipped Darner	None	FA
Elaeocarpus linsmithii	None	None	FL
Euastacus fleckeri	freshwater crayfish	L	FA
Eucalyptus atrata	Herberton ironbark	L	FL
Eucalyptus tardecidens	None	L	FL
Eugenia reinwardtiana	beach cherry	None	FL
Garcinia brassii	None	L	FL
Gossia lewisensis	None	L	FL
Grammitis wurunuran	None	None	FL
Gynochthodes podistra	None	None	FL
Heliotropium collinum	None	L	FL
Heliotropium peninsulare	None	None	FL
Hemibelideus lemuroides	Lemuroid Ringtail Possum	L	FA
Heteromyias cinereifrons	Grey-headed Robin	L	FA
Heteromyias cinereifrons	Grey-headed robin	L	FA
Hibbertia longifolia	None	None	FL
Koreelahropa plowmanae	Plowman's Pinwheel Snail	None	FA
Leptospermum wooroonooran	None	None	FL
Linospadix apetiolatus	None	L	FL
Lomandra longifolia	None	None	FL
Lomandra multiflora	None	None	FL
Lomandra multiflora subsp. multiflora	None	None	FL
Melaleuca dealbata	swamp tea-tree	None	FL
Melaleuca leucadendra	broad-leaved tea-tree	None	FL
Melaleuca monantha	None	L	FL
Melaleuca quinquenervia	swamp paperbark	None	FL
Melaleuca viridiflora	None	None	FL
Melaleuca viridiflora var. viridiflora	None	None	FL
Mixophyes carbinensis	Carbine Barred Frog	L	FA
Mogurnda mogurnda	Northern Purplespotted Gudgeon	L	FA
Monteithium storeyi	beetle	None	FA
Nitor reisi	Mount Lewis Glass-snail	None	FA
Oreokera cumulus	Odhner's Pinwheel Snail	None	FA
Oreoscopus gutturalis	Fernwren	L	FA
Orthonyx spaldingii	Chowchilla	L	FA
Peperomia hunteriana	None	None	FL
Phlegmariurus phlegmaria	None	H	FL
Phyllanthus carpentariae	None	None	FL
Phyllanthus collinus	None	None	FL

Species	Common name	Back on Track rank	Identified flora/fauna
Phyllanthus lamprophyllus	None	None	FL
Phyllanthus maderaspatensis	None	None	FL
Phyllanthus minutiflorus	None	None	FL
Phyllanthus similis	None	None	FL
Phyllanthus simplex	None	None	FL
Phyllanthus virgatus	None	None	FL
Pimelea chlorina	None	None	FL
Podocarpus smithii	None	None	FL
Polyosma reducta	None	L	FL
Polyosma sp. (Mt Lewis B.P.Hyland RFK25241)	None	L	FL
Polyscias willmottii	None	None	FL
Portulaca bicolor	None	None	FL
Pseudochirops archeri	Green Ringtail Possum	L	FA
Pseudochirulus herbertensis	Herbert River Ringtail Possum	L	FA
Psydrax montigena	None	None	FL
Pterostylis depauperata	None	None	FL
Ptiloris victoriae	Victoria's Riflebird	L	FA
Rhodamnia spongiosa	None	None	FL
Rhodomyrtus pervagata	None	None	FL
Santalum lanceolatum	None	L	FL
Scenopoeetes dentirostris	Tooth-billed Bowerbird	L	FA
Sericornis keri	Atherton Scrubwren	L	FA
Setoturbinata taylori	Spiny Turban Pinwheel Snail	None	FA
Solanum dimorphispinum	None	L	FL
Stylidium diffusum	None	None	FL
Stylidium rotundifolium	None	None	FL
Stylidium tenerum	None	L	FL
Tephrosia filipes	None	None	FL
Tephrosia filipes subsp. filipes	None	None	FL
Tephrosia filipes var. latifolia	None	None	FL
Tephrosia gaudium-solis	None	None	FL
Tephrosia juncea	None	None	FL
Tephrosia leptoclada	None	None	FL
Tephrosia macrostachya	None	None	FL
Tephrosia varians	None	None	FL
Thelymitra aristata	great sun orchid	None	FL
Uromyrtus metrosideros	None	None	FL
Uromys hadrourus	Pygmy White-tailed Rat	L	FA
Xanthorrhoea johnsonii	None	None	FL
Zieria alata	None	None	FL

NB. Please note that the list of priority species is based on those species identified in the BPAs, however records for these species may be more recent than the originals used. furthermore, the BPA priority species databases are updated from time to time. At each update, the taxonomic details for all species are amended as necessary to reflect current taxonomic name and/or status changes.

ACA Priority Species

A list of ACA priority species used in riverine and non-riverine ACAs that have been recorded on, or within approximately 4km of the AOI are contained in the following tables.

Table 24: Priority species recorded on, or within 4 km of the AOI - riverine

Species	Common name	Back on Track rank	Identified flora/fauna
Acrostichum speciosum	mangrove fern	Low	FL
Actitis hypoleucos	Common Sandpiper	None	FA
Austrothelphusa agassizi	None	None	FA
Austrothelphusa wasselli	None	None	FA
Calidris ferruginea	Curlew Sandpiper	None	FA
Cherax wasselli	None	None	FA
Eleocharis philippinensis	None	None	FL
Euastacus fleckeri	freshwater crayfish	None	FA
Eucalyptus camaldulensis	None	None	FL
Eucalyptus tereticornis	None	None	FL
Gallinago hardwickii	Latham's Snipe	None	FA
Gallinago megala	Swinhoe's Snipe	None	FA
Gelochelidon nilotica	Gull-billed Tern	None	FA
Hephaestus fuliginosus	Sooty Grunter	None	FA
Hydroprogne caspia	Caspian Tern	None	FA
Leersia hexandra	swamp rice grass	None	FL
Leiopotherapon unicolor	Spangled Perch	None	FA
Lepidosperma laterale	None	None	FL
Limnophila brownii	None	None	FL
Lomandra longifolia	None	None	FL
Melaleuca bracteata	None	None	FL
Melaleuca fluviatilis	None	None	FL
Melaleuca leucadendra	broad-leaved tea-tree	None	FL
Melaleuca viminalis	None	Low	FL
Nauclea orientalis	Leichhardt tree	None	FL
Neosilurus ater	Black Catfish	None	FA
Neosilurus hyrtlii	Hyrtl's Catfish	None	FA
Nymphaea violacea	None	None	FL
Ornithorhynchus anatinus	Platypus	None	FA
Oryza rufipogon	None	None	FL
Pandanus spiralis	None	None	FL
Pandion cristatus	Eastern Osprey	None	FA
Plegadis falcinellus	Glossy Ibis	None	FA

Species	Common name	Back on Track rank	Identified flora/fauna
Pristis pristis	Freshwater Sawfish	None	FA
Scleria mackaviensis	None	None	FL
Scortum ogilbyi	Gulf Grunter	None	FA
Tringa stagnatilis	Marsh Sandpiper	None	FA

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

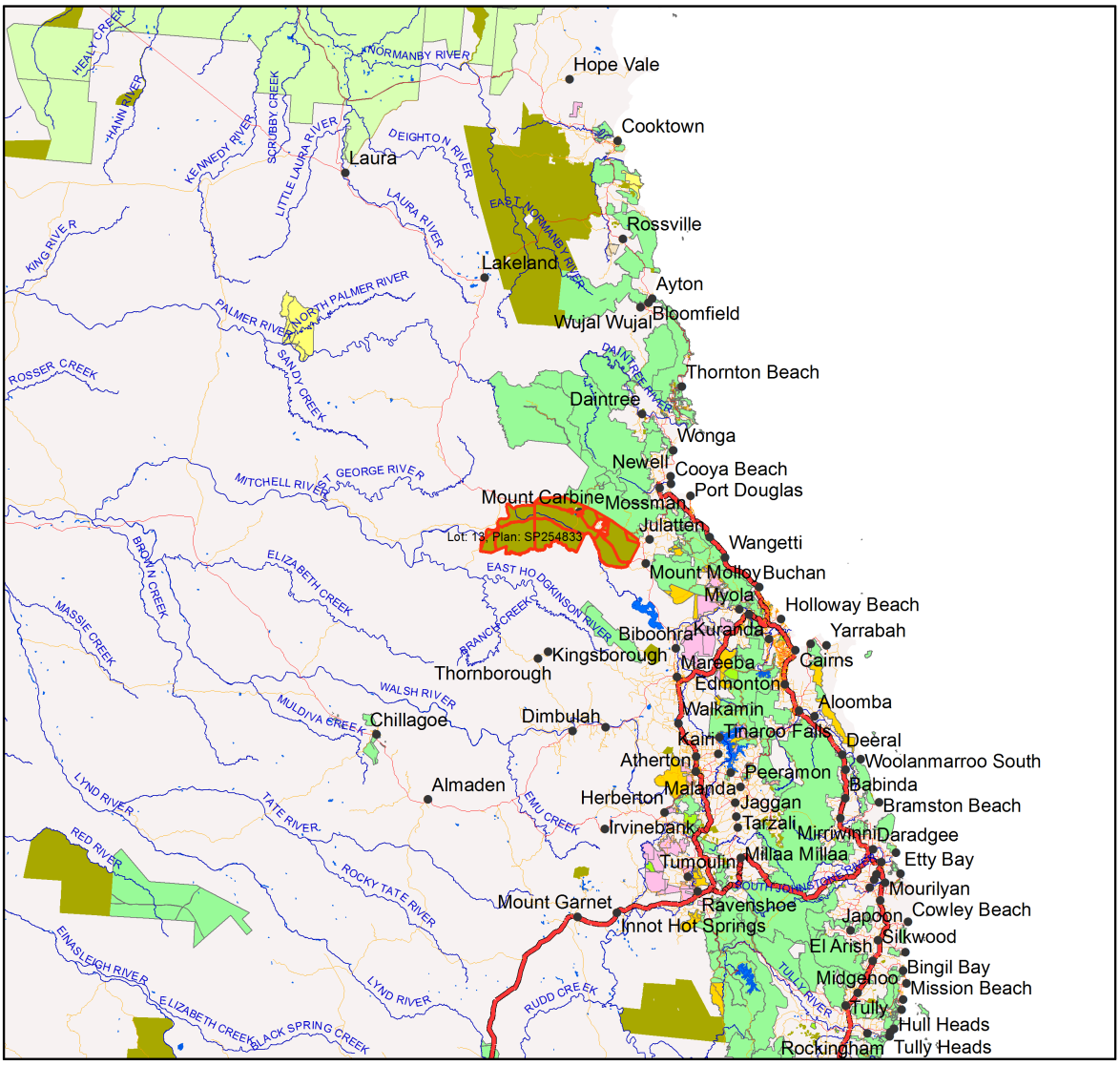
Species	Common name	Back on Track rank	Identified flora/fauna
Acrostichum speciosum	mangrove fern	Low	FL
Baumea rubiginosa	soft twigrush	None	FL
Bonnaya tenuifolia	None	None	FL
Calidris acuminata	Sharp-tailed Sandpiper	None	FA
Calidris ferruginea	Curlew Sandpiper	None	FA
Calidris ruficollis	Red-necked Stint	None	FA
Eleocharis atropurpurea	None	None	FL
Eleocharis brassii	None	None	FL
Eleocharis philippinensis	None	None	FL
Eleocharis spiralis	None	None	FL
Eleocharis tetraquetra	None	None	FL
Eucalyptus camaldulensis	None	None	FL
Eucalyptus tereticornis	None	None	FL
Gallinago hardwickii	Latham's Snipe	None	FA
Gallinago megala	Swinhoe's Snipe	None	FA
Gelochelidon nilotica	Gull-billed Tern	None	FA
Hephaestus fuliginosus	Sooty Grunter	None	FA
Hydroprogne caspia	Caspian Tern	None	FA
Leersia hexandra	swamp rice grass	None	FL
Leiopotherapon unicolor	Spangled Perch	None	FA
Lepidosperma laterale	None	None	FL
Limnophila brownii	None	None	FL
Marsilea crenata	None	None	FL
Melaleuca bracteata	None	None	FL
Melaleuca leucadendra	broad-leaved tea-tree	None	FL
Melaleuca viminalis	None	Low	FL
Monochoria cyanea	None	None	FL
Neosilurus ater	Black Catfish	None	FA
Neosilurus hyrtlii	Hyrtl's Catfish	None	FA
Nymphaea violacea	None	None	FL
Ornithorhynchus anatinus	Platypus	None	FA
Oryza australiensis	None	None	FL
Oryza rufipogon	None	None	FL
Pandanus spiralis	None	None	FL

Species	Common name	Back on Track rank	Identified flora/fauna
Pandion cristatus	Eastern Osprey	None	FA
Plegadis falcinellus	Glossy Ibis	None	FA
Pluvialis fulva	Pacific Golden Plover	None	FA
Pristis pristis	Freshwater Sawfish	None	FA
Pseudoraphis spinescens	spiny mudgrass	None	FL
Scleria mackaviensis	None	None	FL
Scortum ogilbyi	Gulf Grunter	None	FA
Tringa stagnatilis	Marsh Sandpiper	None	FA

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

Maps

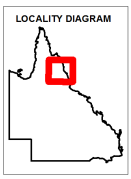
Map 1 - Locality Map



Locality Map

Legend

- Selected Lot and Plan
- Towns
- Highway
- Connector
- Street/Local Road
- Reservoirs
- Lakes
- National Park (Scientific)
- National Park
- National Park (CYPAL)
- Conservation Park
- Resources Reserve
- Forest Reserve
- State Forest
- Timber Reserve
- Nature Refuges
- Coordinated Conservation Areas
- Major rivers/creeks
- Queensland



N

0 18000 36000 54000 72000 90000 m

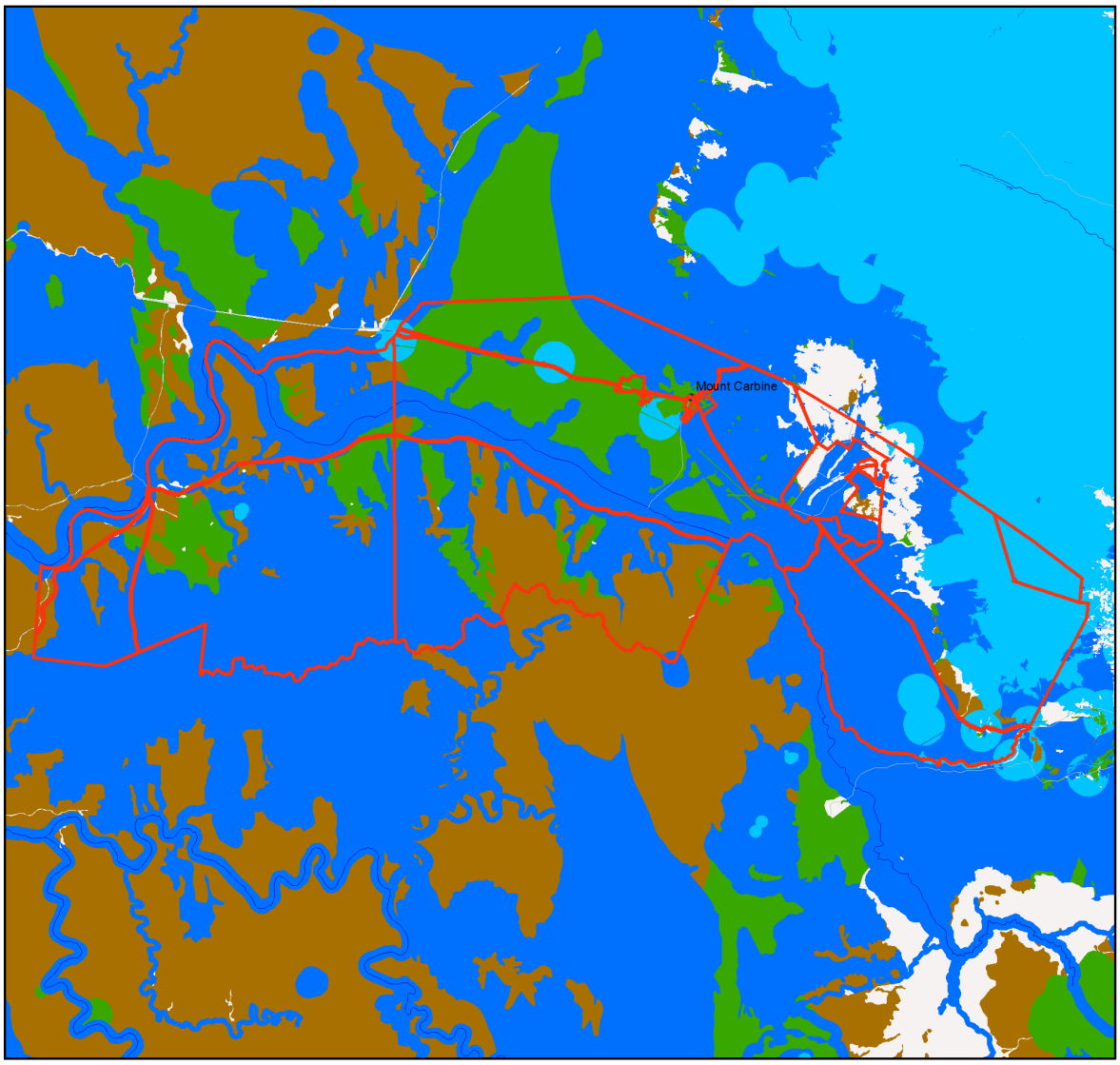
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Map 2 - Biodiversity Planning Assessment (BPA)



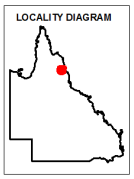
Biodiversity Planning Assessments

Legend

- Selected Lot and Plan
- Towns
- Roads
- Major rivers/creeks
- Queensland

Biodiversity Planning Assessment

- State Habitat for EVNT taxa
- State
- Regional
- Local or Other Values
- Non Bioregion Ecosystem



N

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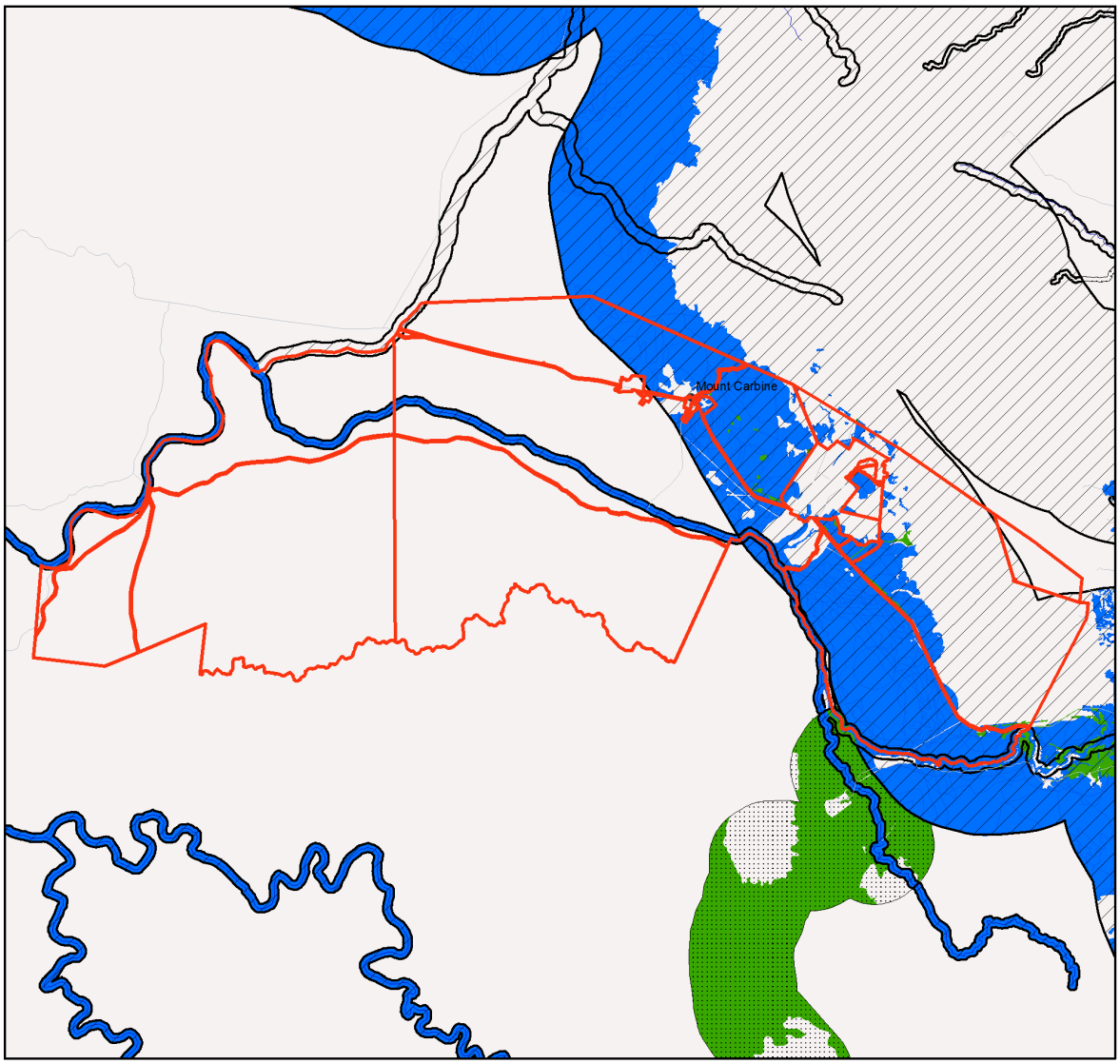
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0 2800 5600 8400 11200 14000 m

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Map 3 - Corridors



Corridors

Legend

- Selected Lot and Plan
- Towns
- Roads
- Major rivers/creeks
- Queensland

Corridors

- State
- Regional

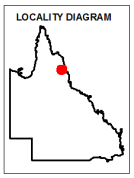
Corridor Triggered Vegetation

- State
- Regional
- Local

Core Area Vegetation

- Brigalow Belt only

LOCALITY DIAGRAM



N

0 2800 5600 8400 11200 14000 m

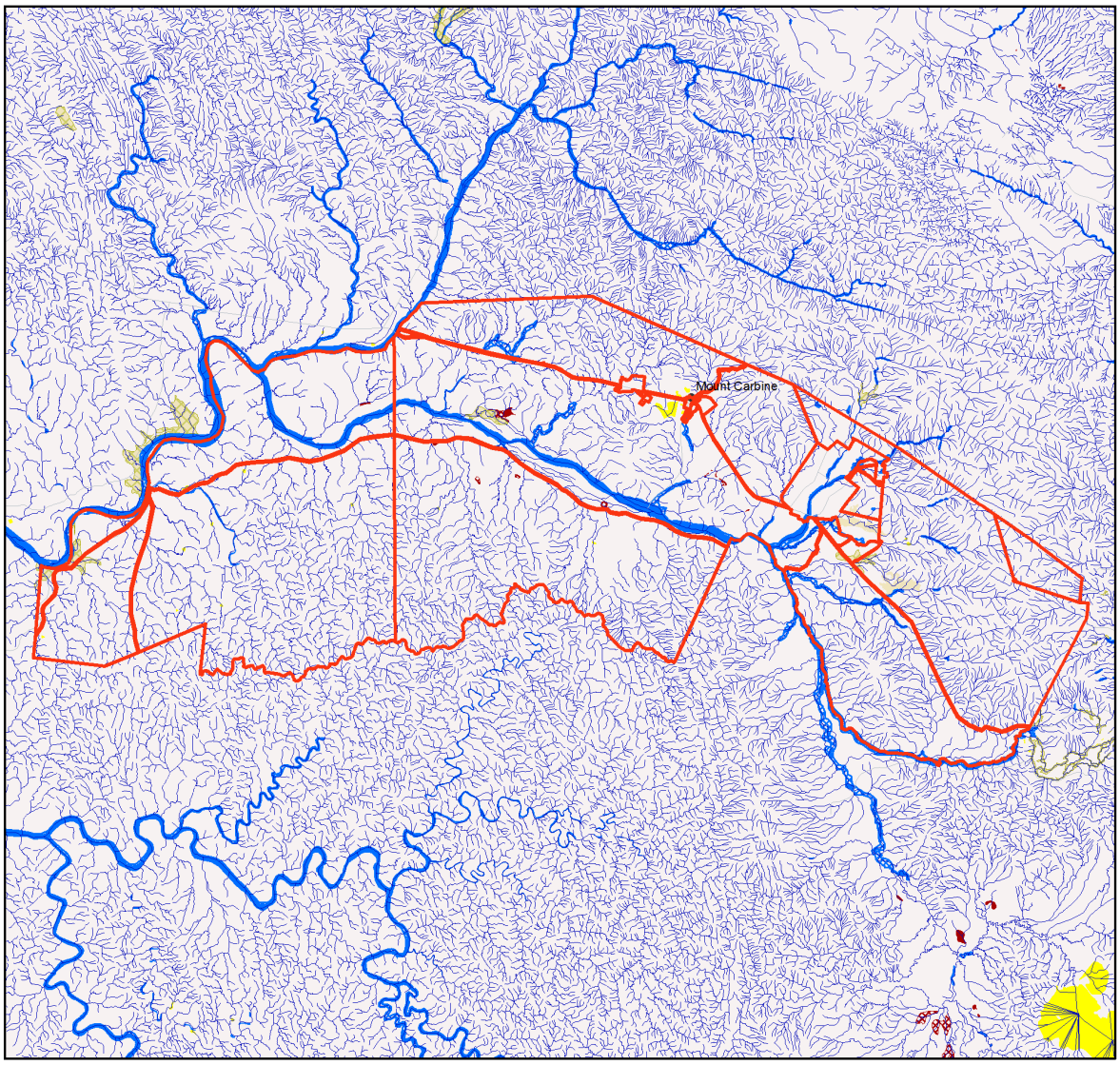
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Map 4 - Wetlands and waterways



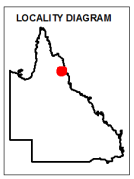
Wetlands and Waterways

Legend

- Selected Lot and Plan
- Towns
- Roads
- Springs
- Rivers/Creeks
- Directory of Important Wetlands
- Ramsar Sites - QLD
- Queensland

Wetland Type

- Marine Waterbodies
- Estuarine Waterbodies
- Riverine Waterbodies
- Lacustrine Waterbodies
- Palustrine Waterbodies
- Marine RE
- Estuarine RE
- Riverine RE
- Lacustrine RE
- Palustrine RE
- RE 51-80% wetland (mosaic units)
- RE 1-50% wetland (mosaic units)



N

0 2800 5600 8400 11200 14000 m

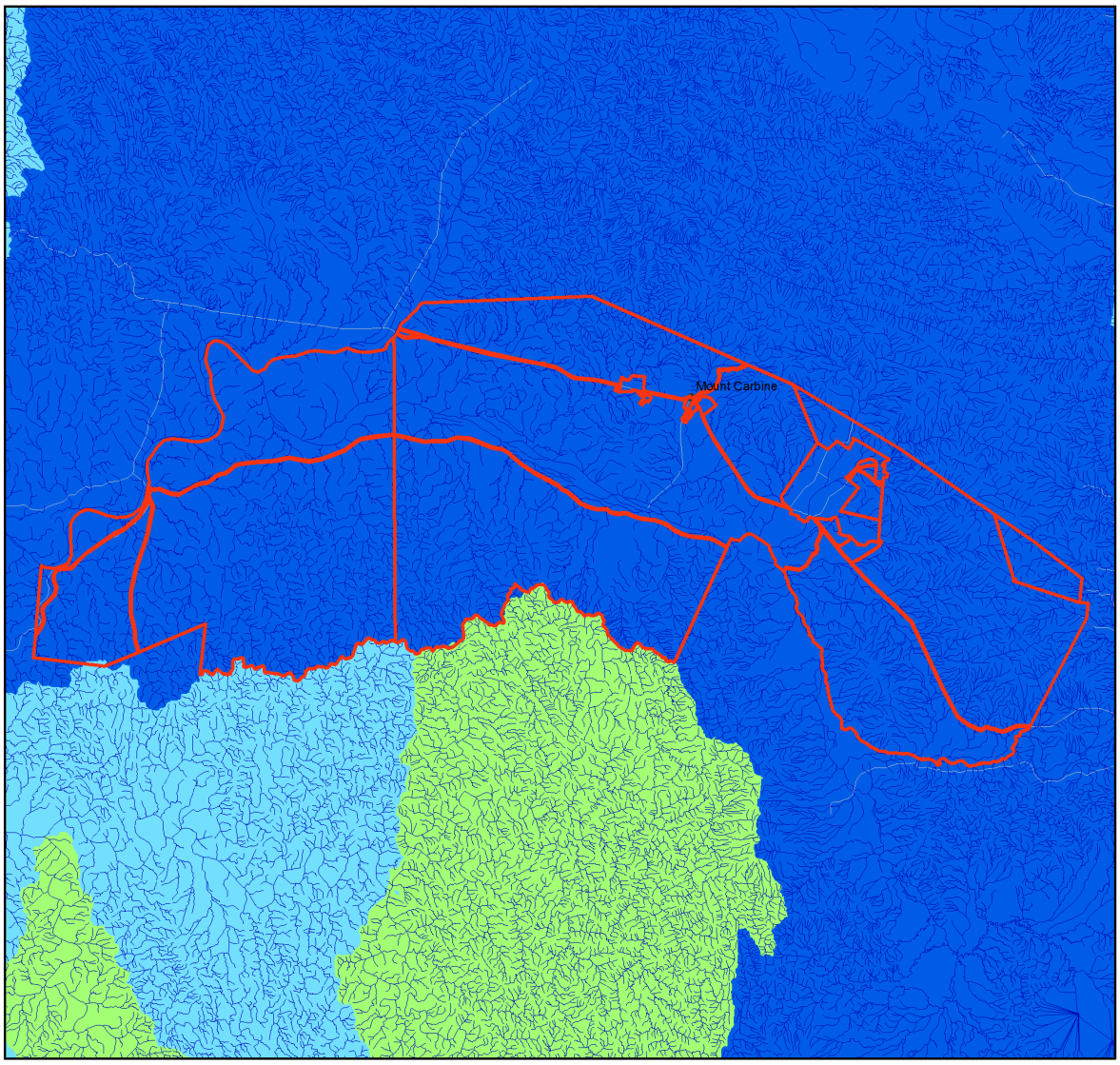
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Map 5 - Aquatic Conservation Assessment (ACA) - riverine



Aquatic Conservation Assessment (ACA) - riverine

Legend

- Selected Lot and Plan
- Towns
- Roads
- Rivers/Creeks
- Queensland

ACA Riverine - Subcatchment Significance

- Very High
- High
- Medium
- Low
- Very Low

LOCALITY DIAGRAM

N

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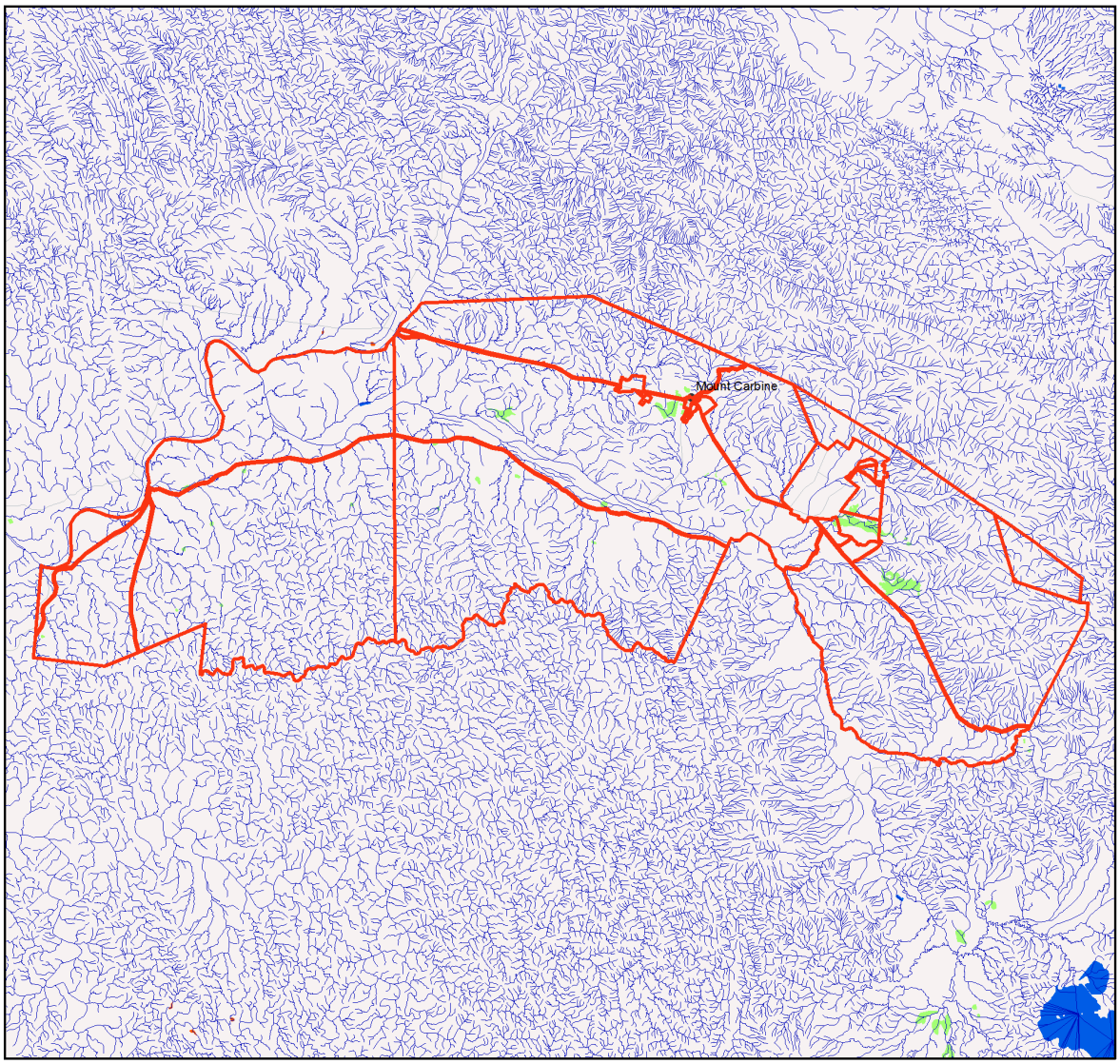
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0 2800 5600 8400 11200 14000 m

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



Aquatic Conservation Assessment (ACA) - nonriverine

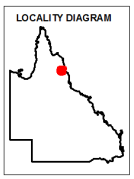
Legend

- Selected Lot and Plan
- Towns
- Roads
- Rivers/Creeks
- Queensland

ACA Non-riverine

- Very High
- High
- Medium
- Low
- Very Low

LOCALITY DIAGRAM



N

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Appendices

Appendix 1 - Source Data

Theme	Datasets
Aquatic Conservation Assessments Non-riverine*	Combination of the following datasets: Cape York Peninsula Non-riverine v1.1 Eastern Gulf of Carpentaria v1.1 Great Barrier Reef Catchment Non-riverine v1.3 Lake Eyre and Bulloo Basins v1.1 QMDB Non-riverine ACA v1.4 Southeast Queensland ACA v1.1 WBB Non-riverine ACA v1.1 Southern Gulf Catchments Non-riverine ACA v1.1
Aquatic Conservation Assessments Riverine*	Combination of the following datasets: Cape York Peninsula Riverine v1.1 Eastern Gulf of Carpentaria v1.1 Great Barrier Reef Catchment Riverine v1.1 Lake Eyre and Bulloo Basins v1.1 QMDB Riverine ACA v1.4 Southeast Queensland ACA v1.1 WBB Riverine ACA v1.1 Southern Gulf Catchments Riverine ACA v1.1
Biodiversity Planning Assessments*	Combination of the following datasets: Brigalow Belt BPA v2.1 Cape York Peninsula BPA v1.1 Central Queensland Coast BPA v1.3 Channel Country BPA v1.1 Desert Uplands BPA v1.3 Einasleigh Uplands BPA v1.1 Gulf Plains BPA v1.1 Mitchell Grass Downs BPA v1.1 Mulga Lands BPA v1.4 New England Tableland v2.3 Northwest Highlands v1.1 Southeast Queensland v4.1 Wet Tropics v1.1
Statewide BPA Corridors*	Statewide corridors v1.6
Threatened Species	An internal DES database compiled from Wildnet, Herbrecs, Corveg, the QLD Museum, as well as other incidental sources.
BPA Priority Species	An internal DES database compiled from Wildnet, Herbrecs, Corveg, the QLD Museum, as well as other incidental sources.
ACA Priority Species	An internal DES database compiled from Wildnet, Herbrecs, Corveg, the QLD Museum, as well as other incidental sources.

***These datasets are available at:**

http://dds.information.qld.gov.au/DDS

Appendix 2 - Acronyms and Abbreviations

AOI	- Area of Interest
ACA	- Aquatic Conservation Assessment
AQUABAMM	- Aquatic Biodiversity Assessment and Mapping Methodology
BAMM	- Biodiversity Assessment and Mapping Methodology
BoT	- Back on Track
BPA	- Biodiversity Planning Assessment
CAMBA	- China-Australia Migratory Bird Agreement
DES	- Department of Environment and Science
EPBC	- *Environment Protection and Biodiversity Conservation Act 1999*
EVNT	- Endangered, Vulnerable, Near Threatened
GDA94	- Geocentric Datum of Australia 1994
GIS	- Geographic Information System
JAMBA	- Japan-Australia Migratory Bird Agreement
NCA	- *Nature Conservation Act 1992*
RE	- Regional Ecosystem
REDD	- Regional Ecosystem Description Database
ROKAMBA	- Republic of Korea-Australia Migratory Bird Agreement

Queensland Government

Department of Environment and Science

Environmental Reports

Matters of State Environmental Significance

For the selected area of interest
Lot: 13 Plan: SP254833

Environmental Reports - General Information

The Environmental Reports portal provides for the assessment of selected matters of interest relevant to a user specified location, or area of interest (AOI). All area and derivative figures are relevant to the extent of matters of interest contained within the AOI unless otherwise stated. Please note, if a user selects an AOI via the "central coordinates" option, the resulting assessment area encompasses an area extending for a 2km radius from the point of interest.

All area and area derived figures included in this report have been calculated via reprojecting relevant spatial features to Albers equal-area conic projection (central meridian = 146, datum Geocentric Datum of Australia 1994). As a result, area figures may differ slightly if calculated for the same features using a different co-ordinate system.

Figures in tables may be affected by rounding.

The matters of interest reported on in this document are based upon available state mapped datasets. Where the report indicates that a matter of interest is not present within the AOI (e.g. where area related calculations are equal to zero, or no values are listed), this may be due either to the fact that state mapping has not been undertaken for the AOI, that state mapping is incomplete for the AOI, or that no values have been identified within the site.

The information presented in this report should be considered as a guide only and field survey may be required to validate values on the ground.

Please direct queries about these reports to: Planning.Support@des.qld.gov.au

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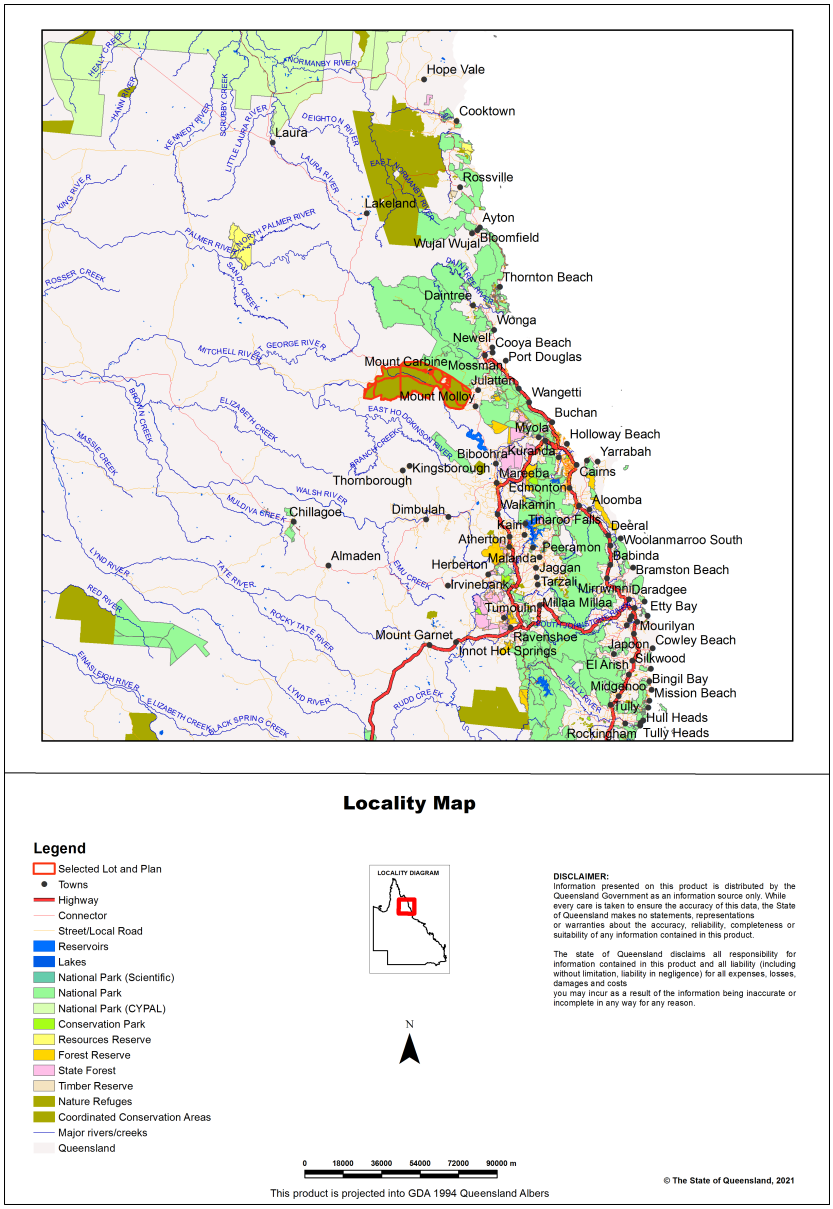
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Assessment Area Details

The following table provides an overview of the area of interest (AOI) with respect to selected topographic and environmental values.

Table 1: Summary table, details for AOI Lot: 13 Plan: SP254833

Size (ha)	58,779.14
Local Government(s)	Mareeba Shire
Bioregion(s)	Einasleigh Uplands, Wet Tropics
Subregion(s)	Hodgkinson Basin, Macalister, Daintree - Bloomfield
Catchment(s)	Mitchell



Matters of State Environmental Significance (MSES)

MSES Categories

Queensland's State Planning Policy (SPP) includes a biodiversity State interest that states:

'The sustainable, long-term conservation of biodiversity is supported. Significant impacts on matters of national or state environmental significance are avoided, or where this cannot be reasonably achieved; impacts are minimised and residual impacts offset.'

The MSES mapping product is a guide to assist planning and development assessment decision-making. Its primary purpose is to support implementation of the SPP biodiversity policy. While it supports the SPP, the mapping does not replace the regulatory mapping or environmental values specifically called up under other laws or regulations. Similarly, the SPP biodiversity policy does not override or replace specific requirements of other Acts or regulations.

The SPP defines matters of state environmental significance as:

- Protected areas (including all classes of protected area except coordinated conservation areas) under the *Nature Conservation Act 1992* ;

- Marine parks and land within a 'marine national park', 'conservation park', 'scientific research', 'preservation' or 'buffer' zone under the *Marine Parks Act 2004* ;

- Areas within declared fish habitat areas that are management A areas or management B areas under the Fisheries Regulation 2008;

- Threatened wildlife under the *Nature Conservation Act 1992* and special least concern animals under the Nature Conservation (Wildlife) Regulation 2006;

- Regulated vegetation under the *Vegetation Management Act 1999* that is:

    • Category B areas on the regulated vegetation management map, that are 'endangered' or 'of concern' regional ecosystems;

    • Category C areas on the regulated vegetation management map that are 'endangered' or 'of concern' regional ecosystems;

    • Category R areas on the regulated vegetation management map;

    • Regional ecosystems that intersect with watercourses identified on the vegetation management watercourse and drainage feature map;

    • Regional ecosystems that intersect with wetlands identified on the vegetation management wetlands map;

- Strategic Environmental Areas under the *Regional Planning Interests Act 2014* ;

- Wetlands in a wetland protection area of wetlands of high ecological significance shown on the Map of Queensland Wetland Environmental Values under the Environment Protection Regulation 2019;

- Wetlands and watercourses in high ecological value waters defined in the Environmental Protection (Water) Policy 2009, schedule 2;

- Legally secured offset areas.

MSES Values Present

The MSES values that are present in the area of interest are summarised in the table below:

Table 2: Summary of MSES present within the AOI

1a Protected Areas- estates	0.0 ha	0.0 %
1b Protected Areas- nature refuges	58412.12 ha	99.4%
1c Protected Areas- special wildlife reserves	0.0 ha	0.0 %
2 State Marine Parks- highly protected zones	0.0 ha	0.0 %
3 Fish habitat areas (A and B areas)	0.0 ha	0.0 %
4 Strategic Environmental Areas (SEA)	0.0 ha	0.0 %
5 High Ecological Significance wetlands on the map of Referable Wetlands	155.0 ha	0.3%
6a High Ecological Value (HEV) wetlands	0.0 ha	0.0 %
6b High Ecological Value (HEV) waterways **	0.0 km	Not applicable
7a Threatened (endangered or vulnerable) wildlife	10293.25 ha	17.5%
7b Special least concern animals	1491.14 ha	2.5%
7c i Koala habitat area - core (SEQ)	0.0 ha	0.0 %
7c ii Koala habitat area - locally refined (SEQ)	0.0 ha	0.0 %
8a Regulated Vegetation - Endangered/Of concern in Category B (remnant)	2187.24 ha	3.7%
8b Regulated Vegetation - Endangered/Of concern in Category C (regrowth)	6.23 ha	0.0%
8c Regulated Vegetation - Category R (GBR riverine regrowth)	0.0 ha	0.0 %
8d Regulated Vegetation - Essential habitat	10794.17 ha	18.4%
8e Regulated Vegetation - intersecting a watercourse **	1435.4 km	Not applicable
8f Regulated Vegetation - within 100m of a Vegetation Management Wetland	465.15 ha	0.8%
9a Legally secured offset areas- offset register areas	0.0 ha	0.0 %
9b Legally secured offset areas- vegetation offsets through a Property Map of Assessable Vegetation	0.0 ha	0.0 %

Additional Information with Respect to MSES Values Present

MSES - State Conservation Areas

1a. Protected Areas - estates

(no results)

1b. Protected Areas - nature refuges

Name
Brooklyn Nature Refuge

1c. Protected Areas - special wildlife reserves

(no results)

2. State Marine Parks - highly protected zones

(no results)

3. Fish habitat areas (A and B areas)

(no results)

Refer to **Map 1 - MSES - State Conservation Areas** for an overview of the relevant MSES.

MSES - Wetlands and Waterways

4. Strategic Environmental Areas (SEA)

(no results)

5. High Ecological Significance wetlands on the Map of Queensland Wetland Environmental Values

Natural wetlands that are 'High Ecological Significance' (HES) on the Map of Queensland Wetland Environmental Values are present.

6a. Wetlands in High Ecological Value (HEV) waters

(no results)

6b. Waterways in High Ecological Value (HEV) waters

(no results)

Refer to **Map 2 - MSES - Wetlands and Waterways** for an overview of the relevant MSES.

MSES - Species

7a. Threatened (endangered or vulnerable) wildlife

Values are present

7b. Special least concern animals

Values are present

7c i. Koala habitat area - core (SEQ)

Not applicable

7c ii. Koala habitat area - locally refined (SEQ)

Not applicable

Threatened (endangered or vulnerable) wildlife habitat suitability models

Species	Common name	NCA status	Presence
Boronia keysii		V	None
Calyptorhynchus lathami	Glossy black cockatoo	V	None
Casuarius casuarius johnsonii	Sthn population cassowary	E	Core
Crinia tinnula	Wallum froglet	V	None
Denisonia maculata	Ornamental snake	V	None
Litoria freycineti	Wallum rocketfrog	V	None
Litoria olongburensis	Wallum sedgefrog	V	None
Melaleuca irbyana		E	None
Petaurus gracilis	Mahogany Glider	E	None
Petrogale persephone	Proserpine rock-wallaby	E	None
Phascolarctos cinereus	Koala - outside SEQ*	V	None
Pezoporus wallicus wallicus	Eastern ground parrot	V	None
Taudactylus pleione	Kroombit tinkerfrog	E	None
Xeromys myoides	Water Mouse	V	None

**For koala model, this includes areas outside SEQ. Check 7c SEQ koala habitat for presence/absence.*

Threatened (endangered or vulnerable) wildlife species records

Scientific name	Common name	NCA status	EPBC status	Migratory status
Helicia grayi		V		
Egernia rugosa	yakka skink	V	V	
Phlegmariurus squarrosus		E	CE	
Cophixalus monticola	mountain nurseryfrog	V	CE	
Acanthophis antarcticus	common death adder	V		
Corymbia rhodops	red-throated bloodwood	V	V	
Rhaphidospora cavernarum		V		
Acacia guymeri		V		
Litoria nannotis	waterfall frog	E	E	

Scientific name	Common name	NCA status	EPBC status	Migratory status
Solanum angustum		E		
Toechima pterocarpum	orange tamarind	E	E	
Rostratula australis	Australian painted snipe	E	E	
Lindsaea terrae-reginae		V		
Turnix olivii	buff-breasted button-quail	E	E	
Tyto novaehollandiae kimberli	masked owl (northern subspecies)	V	V	
Phlegmariurus phlegmarioides		V		
Helicia lewisensis		V		
Gastrodia urceolata		V		
Crocodylus porosus	estuarine crocodile	V		M-B/E
Litoria serrata	tapping green eyed frog	V		
Ehretia microphylla		V		
Symplocos crassiramifera		V		
Macropteranthes montana		V	V	
Calidris ferruginea	curlew sandpiper	E	CE	M-C/J/R/B/E
Parsonsia bartlensis		V		
Litoria rheocola	common mistfrog	E	E	
Dasyurus maculatus gracilis	spotted-tailed quoll (northern subspecies)	E	E	
Petauroides volans	greater glider	V	V	
Xylosma sp. (Mt Lewis G.Sankowsky+ 1108)		V		
Phlegmariurus tetrastichoides		V	V	
Grantiella picta	painted honeyeater	V	V	PM
Macroderma gigas	ghost bat	E	V	
Taudactylus rheophilus	northern tinkerfrog	E	E	
Lastreopsis tinarooensis		V		
Bulbophyllum windsorense		V		
Litoria nyakalensis	mountain mistfrog	E	CE	
Litoria dayi	Australian lacelid	E	V	
Grammitis reinwardtii		V	V	

Special least concern animal species records

Scientific name	Common name	Migratory status
Tachyglossus aculeatus	short-beaked echidna	
Ornithorhynchus anatinus	platypus	
Rhipidura rufifrons	rufous fantail	M-B/E
Gallinago megala	Swinhoe's snipe	M-C/J/R/B/E
Tringa nebularia	common greenshank	M-C/J/R/B/E
Gallinago hardwickii	Latham's snipe	M-J/R/B/E

Scientific name	Common name	Migratory status
Actitis hypoleucos	common sandpiper	M-C/J/R/B/E
Calidris acuminata	sharp-tailed sandpiper	M-C/J/R/B/E
Calidris ruficollis	red-necked stint	M-C/J/R/B/E
Pluvialis fulva	Pacific golden plover	M-C/J/R/B/E
Tringa stagnatilis	marsh sandpiper	M-C/J/R/B/E

**Nature Conservation Act 1992 (NCA) Status- Endangered (E), Vulnerable (V) or Special Least Concern Animal (SL). Environment Protection and Biodiversity Conservation Act 1999 (EPBC) status: Critically Endangered (CE) Endangered (E), Vulnerable (V)*

Migratory status (M) - China and Australia Migratory Bird Agreement (C), Japan and Australia Migratory Bird Agreement (J), Republic of Korea and Australia Migratory Bird Agreement (R), Bonn Migratory Convention (B), Eastern Flyway (E)

To request a species list for an area, or search for a species profile, access Wildlife Online at:
https://www.qld.gov.au/environment/plants-animals/species-list/

Refer to **Map 3a - MSES - Species - Threatened (endangered or vulnerable) wildlife and special least concern animals** and **Map 3b - MSES - Species - Koala habitat area (SEQ)** for an overview of the relevant MSES.

MSES - Regulated Vegetation

For further information relating to regional ecosystems in general, go to:
https://www.qld.gov.au/environment/plants-animals/plants/ecosystems/
For a more detailed description of a particular regional ecosystem, access the regional ecosystem search page at:
https://environment.ehp.qld.gov.au/regional-ecosystems/

8a. Regulated Vegetation - Endangered/Of concern in Category B (remnant)

Regional ecosystem	Vegetation management polygon	Vegetation management status
7.3.49a	O-dom	rem_oc
7.12.57a	O-dom	rem_oc
9.3.2/9.3.4/9.3.3c	O-subdom	rem_oc
7.12.66a	O-dom	rem_oc
7.12.58	O-dom	rem_oc
7.12.9	O-dom	rem_oc
7.12.57	O-dom	rem_oc
7.11.44	O-dom	rem_oc
7.3.28d	O-dom	rem_oc
7.12.62c	O-dom	rem_oc
7.12.69b	O-dom	rem_oc
7.12.5c	O-dom	rem_oc
9.3.4	O-dom	rem_oc
7.12.48	O-dom	rem_oc
7.12.37i	O-dom	rem_oc
7.12.66b	O-dom	rem_oc

Regional ecosystem	Vegetation management polygon	Vegetation management status
9.3.4/9.5.9c	O-dom	rem_oc
9.12.43b/9.12.43a	O-dom	rem_oc
9.12.2/9.12.43b/9.12.43a	O-subdom	rem_oc
7.3.14a	O-dom	rem_oc
9.12.17/7.12.34/9.12.43a	O-subdom	rem_oc

8b. Regulated Vegetation - Endangered/Of concern in Category C (regrowth)

Regional ecosystem	Vegetation management polygon	Vegetation management status
9.3.4	O-dom	hvr_oc
9.3.2/9.3.4/9.3.3c	O-subdom	hvr_oc

8c. Regulated Vegetation - Category R (GBR riverine regrowth)

Not applicable

8d. Regulated Vegetation - Essential habitat

Values are present

8e. Regulated Vegetation - intersecting a watercourse**

A vegetation management watercourse is mapped as present

8f. Regulated Vegetation - within 100m of a Vegetation Management wetland

Regulated vegetation map category	Map number
B	7964
C	7964
B	7864

Refer to **Map 4 - MSES - Regulated Vegetation** for an overview of the relevant MSES.

MSES - Offsets

9a. Legally secured offset areas - offset register areas

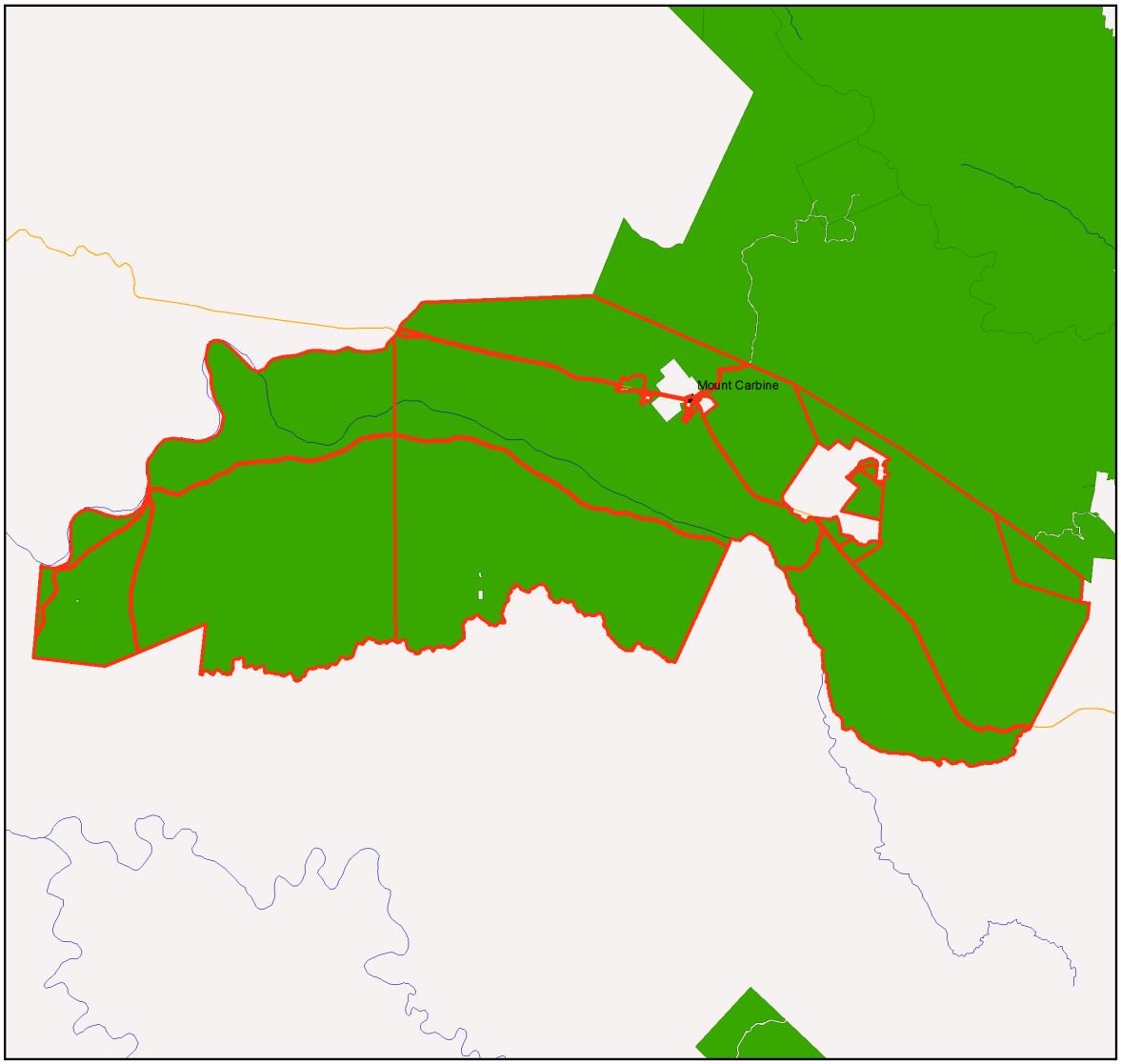
(no results)

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

(no results)

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

Map 1 - MSES - State Conservation Areas

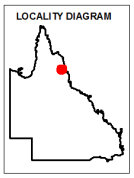


MSES - State Conservation Areas

Area of Interest

- Selected Lot and Plan
- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Protected area (estates, nature refuges, special wildlife reserves)
- Declared fish habitat area (A and B areas)
- Marine park (highly protected)

LOCALITY DIAGRAM



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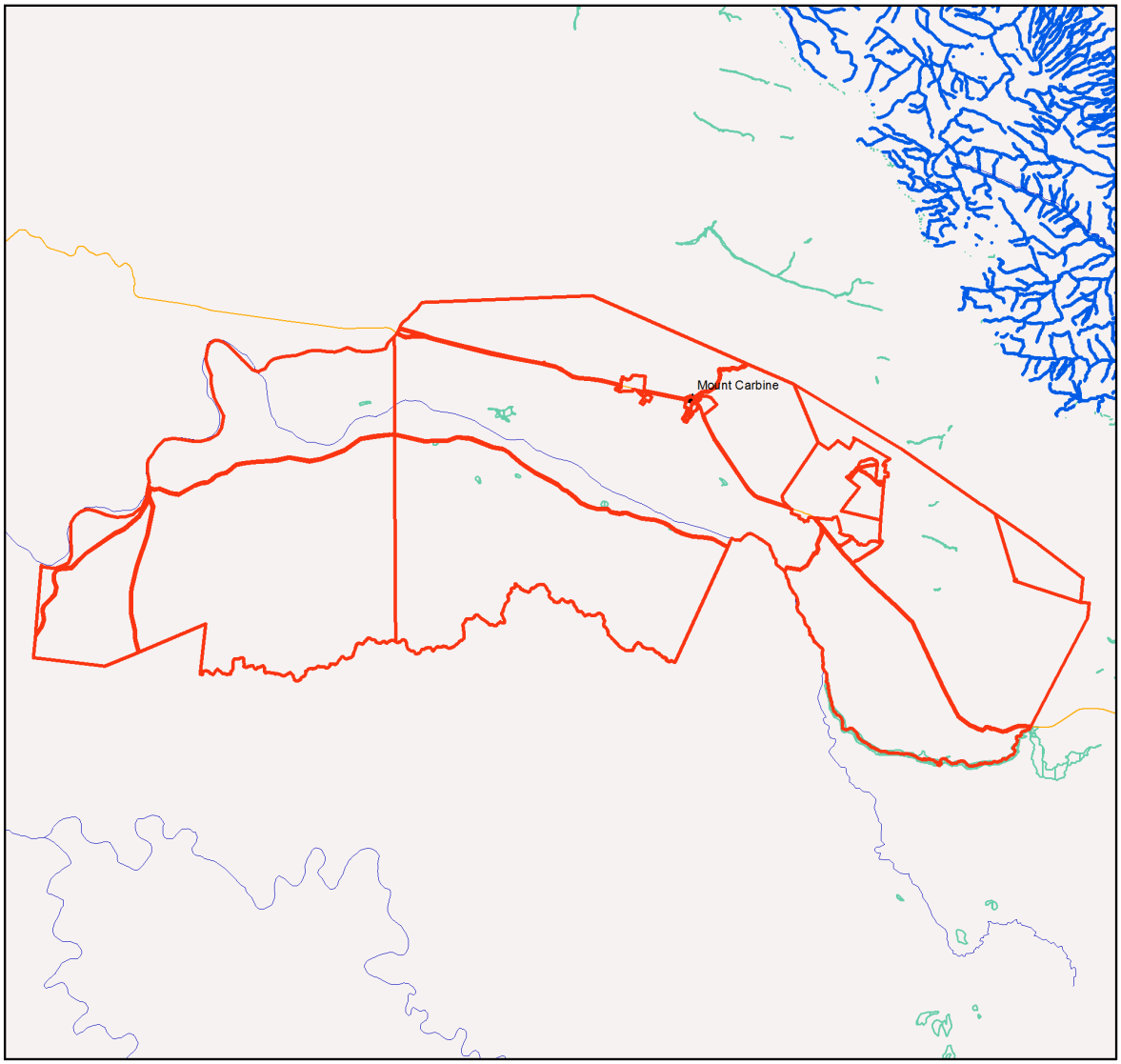
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Map 2 - MSES - Wetlands and Waterways

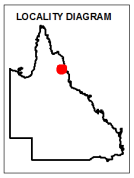


MSES - Wetlands and Waterways

Area of Interest

- Selected Lot and Plan
- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Declared high ecological value waters (watercourse)
- Strategic environmental area (designated precinct)
- Declared high ecological value waters (wetland)
- High ecological significance wetlands

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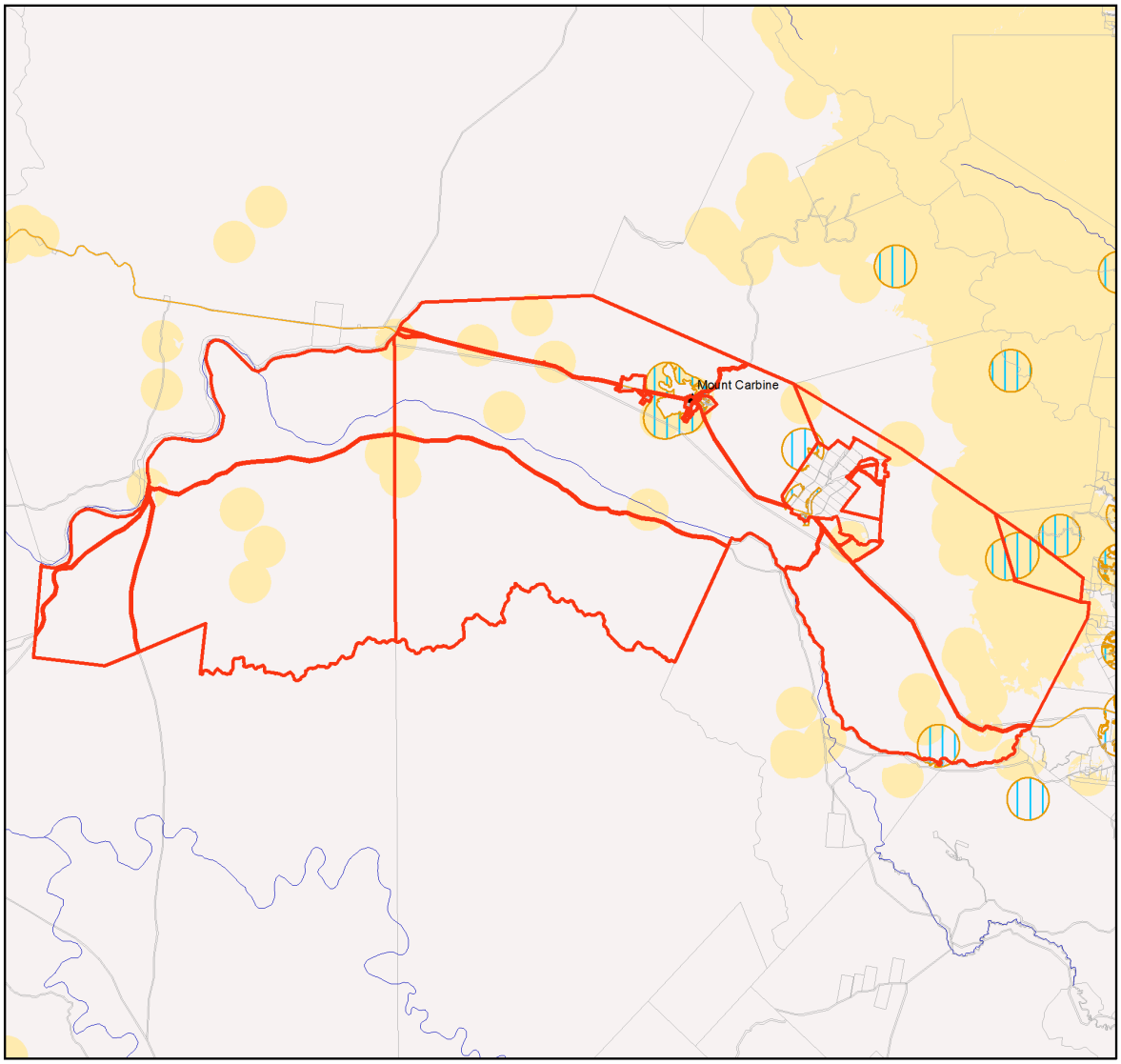
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Map 3a - MSES - Species - Threatened (endangered or vulnerable) wildlife and special least concern animals

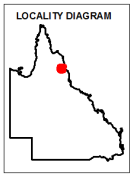


MSES - Species
Threatened (endangered or vulnerable) wildlife and special least concern animals

Area of Interest

- Selected Lot and Plan
- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Wildlife habitat (special least concern)
- Wildlife habitat (endangered or vulnerable)

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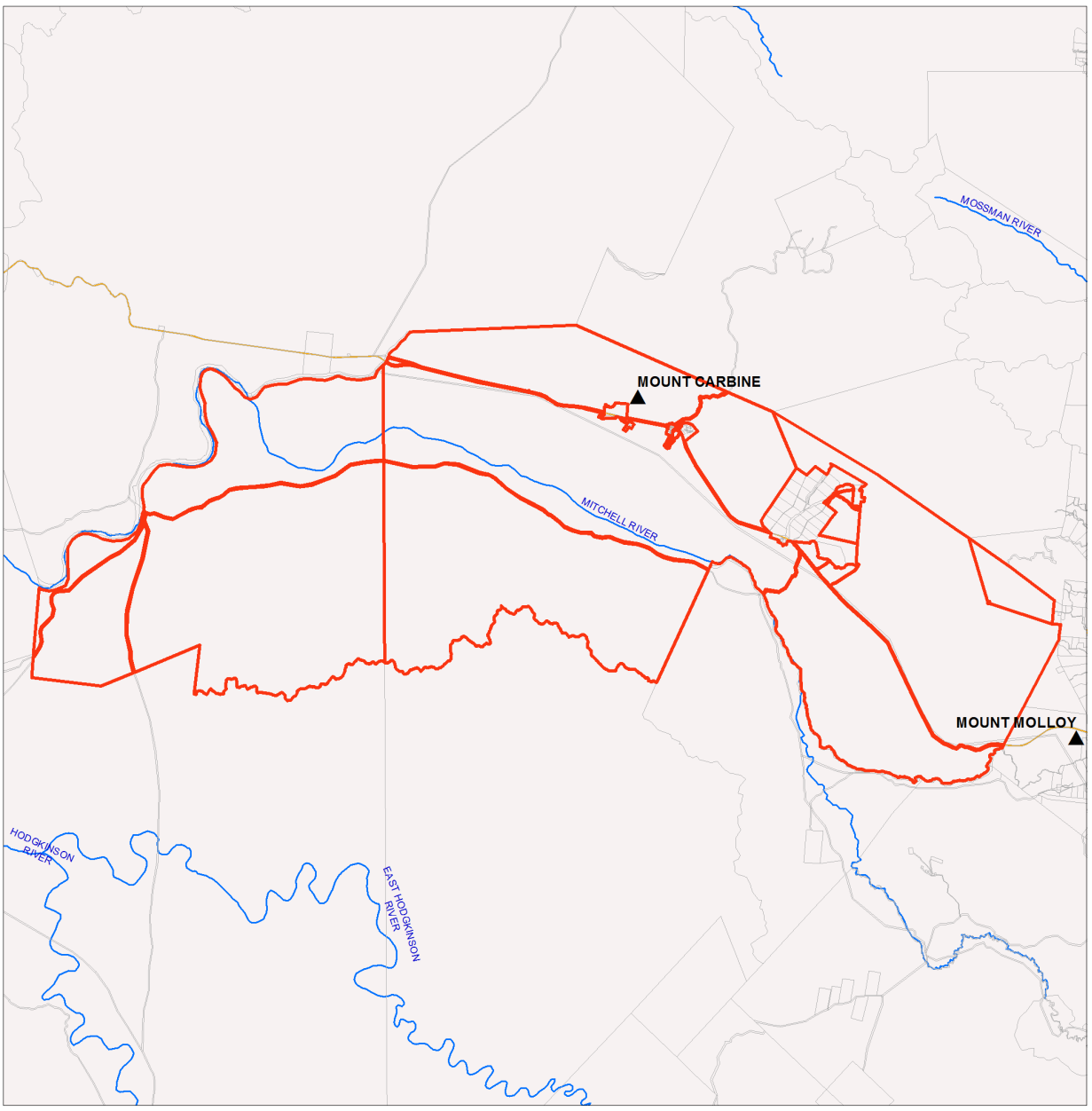
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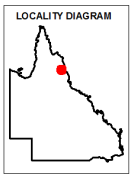
Map 3b - MSES - Species - Koala habitat area (SEQ)



MSES - Species
Koala habitat area (SEQ)

Area of Interest
- Selected Lot and Plan
- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Koala habitat area (core)
- Koala habitat area (locally refined)

LOCALITY DIAGRAM



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The represented layers for SEQ 'koala habitat area-core' and 'koala habitat area- locally refined' in MSES are sourced directly from the regulatory mapping under the Nature Conservation (Koala) Conservation Plan 2017. Whilst every effort is made to ensure the information remains current, there may be delays between updating versions. Please refer to the original mapping for the most recent version. See https://environment.des.qld.gov.au/wildlife/animals/living-with/koalas/mapping

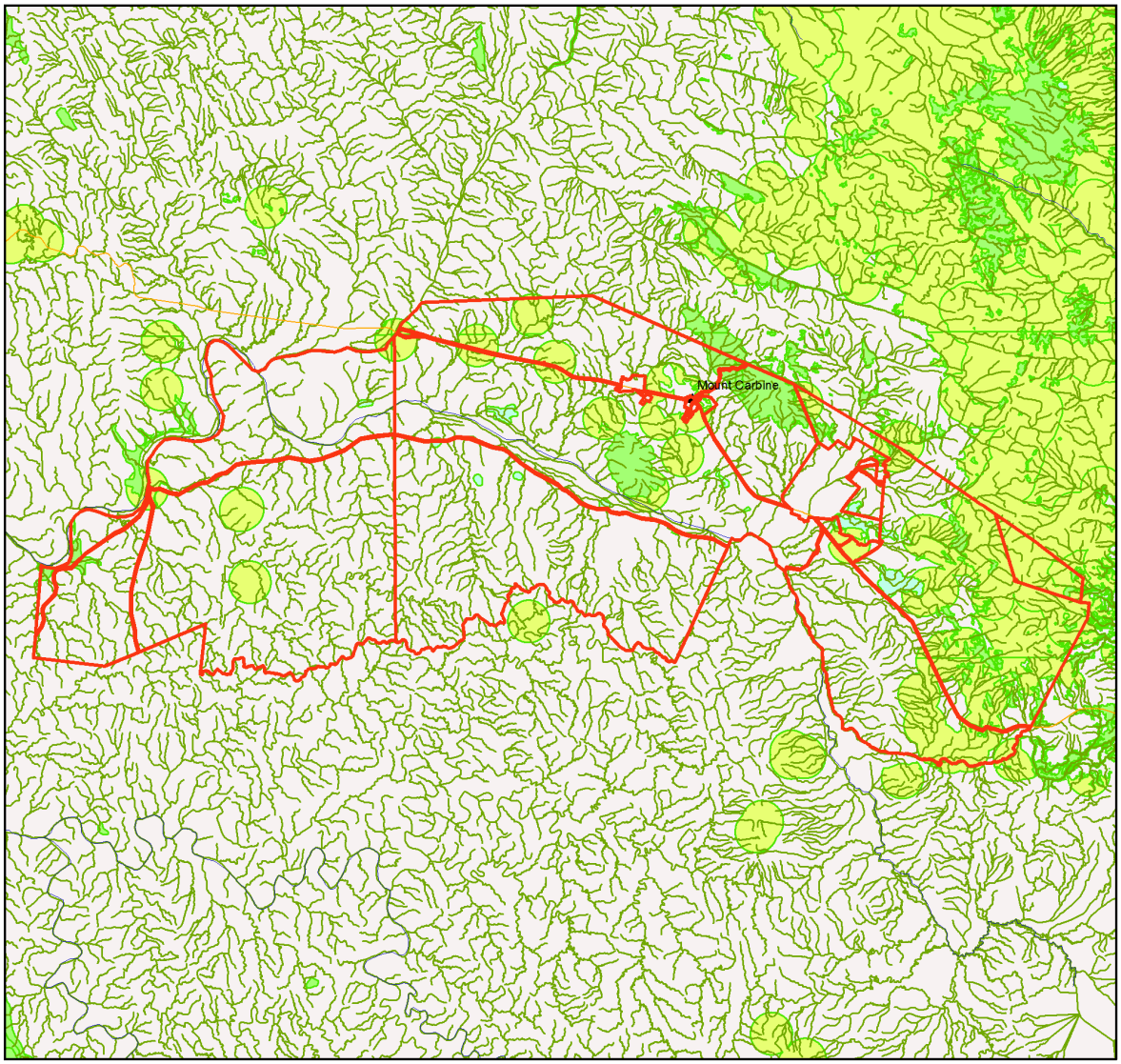
The koala habitat mapping within South East Queensland uses regional ecosystem linework compiled at a scale varying from 1:25,000 to 1:100,000. Linework should be used as a guide only. The positional accuracy of regional ecosystem data mapped at a scale of 1:100,000 is +/- 100 metres.

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0 2,700 5,400 8,100 10,800 13,500 m

This product is projected into GDA 1994 Queensland Albers

Map 4 - MSES - Regulated Vegetation

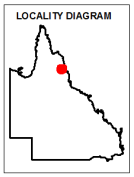


MSES - Regulated Vegetation

Area of Interest

- Selected Lot and Plan
- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Regulated vegetation (intersecting a watercourse)
- Regulated vegetation (100m from wetland)
- Regulated vegetation (category B - endangered or of concern)
- Regulated vegetation (category C - endangered or of concern)
- Regulated vegetation (category R - GBR riverine)
- Regulated vegetation (essential habitat)

LOCALITY DIAGRAM



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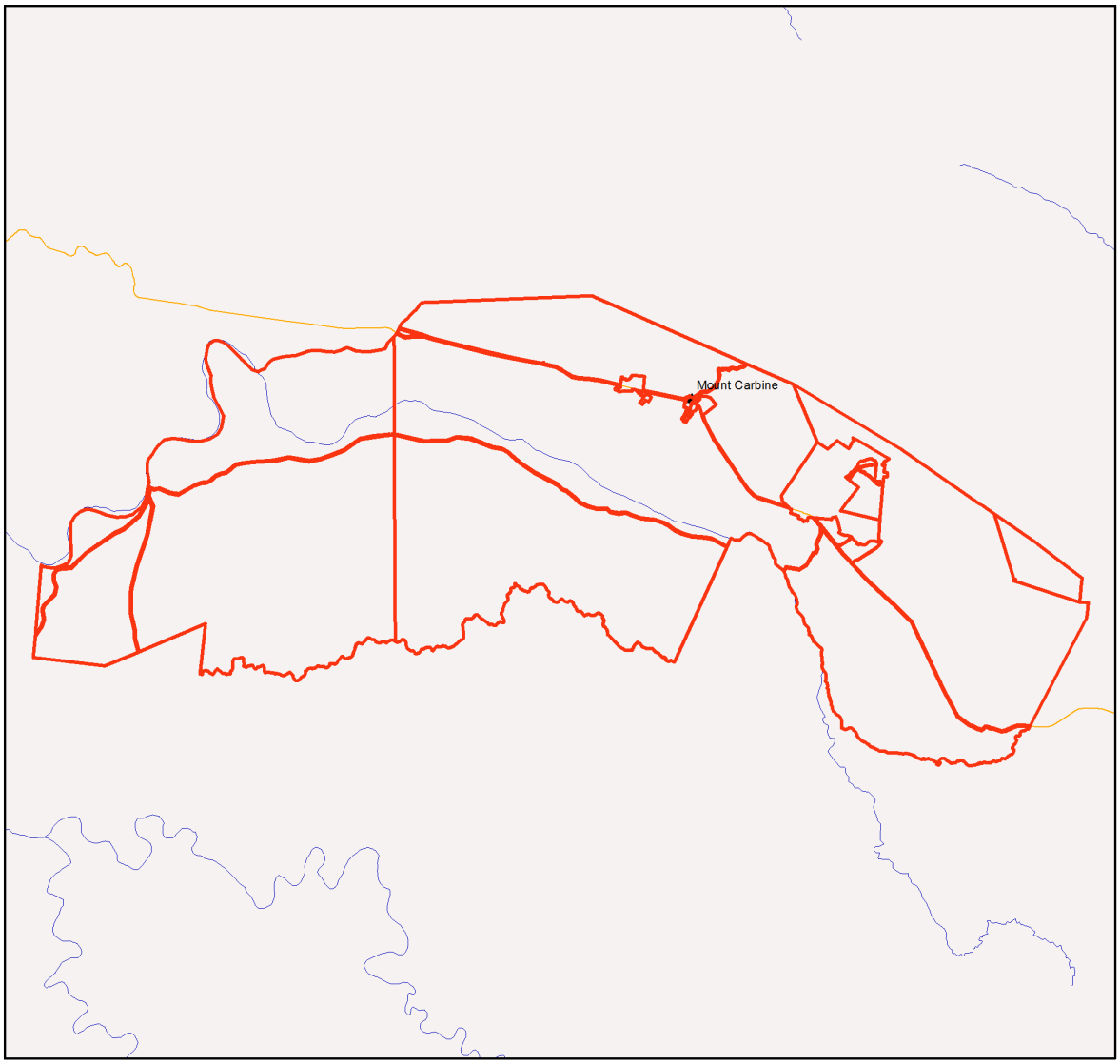
N

0 2800 5600 8400 11200 14000 m

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Map 5 - MSES - Offset Areas

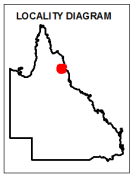


MSES - Offsets

Area of Interest

- Selected Lot and Plan
- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Legally secured offset area (offset register)
- Legally secured offset area (vegetation offsets)

LOCALITY DIAGRAM



N

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0 2800 5600 8400 11200 14000 m

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Appendices

Appendix 1 - Matters of State Environmental Significance (MSES) methodology

MSES mapping is a regional-scale representation of the definition for MSES under the State Planning Policy (SPP). The compiled MSES mapping product is a guide to assist planning and development assessment decision-making. Its primary purpose is to support implementation of the SPP biodiversity policy. While it supports the SPP, the mapping does not replace the regulatory mapping or environmental values specifically called up under other laws or regulations. Similarly, the SPP biodiversity policy does not override or replace specific requirements of other Acts or regulations.

The Queensland Government's "Method for mapping - matters of state environmental significance for use in land use planning and development assessment" can be downloaded from:

http://www.ehp.qld.gov.au/land/natural-resource/method-mapping-mses.html .

Appendix 2 - Source Data

The datasets listed below are available on request from:

http://qldspatial.information.qld.gov.au/catalogue/custom/index.page

- Matters of State environmental significance

Note: MSES mapping is not based on new or unique data. The primary mapping product draws data from a number of underlying environment databases and geo-referenced information sources. MSES mapping is a versioned product that is updated generally on a twice-yearly basis to incorporate the changes to underlying data sources. Several components of MSES mapping made for the current version may differ from the current underlying data sources. To ensure accuracy, or proper representation of MSES values, it is strongly recommended that users refer to the underlying data sources and review the current definition of MSES in the State Planning Policy, before applying the MSES mapping.

Individual MSES layers can be attributed to the following source data available at QSpatial:

MSES layers	**current QSpatial data (http://qspatial.information.qld.gov.au)**
Protected Areas-Estates, Nature Refuges, Special Wildlife Reserves	- Protected areas of Queensland - Nature Refuges - Queensland - Special Wildlife Reserves- Queensland
Marine Park-Highly Protected Zones	Moreton Bay marine park zoning 2008
Fish Habitat Areas	Queensland fish habitat areas
Strategic Environmental Areas-designated	Regional Planning Interests Act - Strategic Environmental Areas
HES wetlands	Map of Queensland Wetland Environmental Values
Wetlands in HEV waters	HEV waters: - EPP Water intent for waters Source Wetlands: - Queensland Wetland Mapping (Current version 5) Source Watercourses: - Vegetation management watercourse and drainage feature map (1:100000 and 1:250000)
Wildlife habitat (threatened and special least concern)	-WildNet database species records - habitat suitability models (various) - SEQ koala habitat areas under the Koala Conservation Plan 2019
VMA regulated regional ecosystems	Vegetation management regional ecosystem and remnant map
VMA Essential Habitat	Vegetation management - essential habitat map
VMA Wetlands	Vegetation management wetlands map
Legally secured offsets	Vegetation Management Act property maps of assessable vegetation. For offset register data-contact DES
Regulated Vegetation Map	Vegetation management - regulated vegetation management map

Appendix 3 - Acronyms and Abbreviations

AOI	- Area of Interest
DES	- Department of Environment and Science
EP Act	- *Environmental Protection Act 1994*
EPP	- Environmental Protection Policy
GDA94	- Geocentric Datum of Australia 1994
GEM	- General Environmental Matters
GIS	- Geographic Information System
MSES	- Matters of State Environmental Significance
NCA	- *Nature Conservation Act 1992*
RE	- Regional Ecosystem
SPP	- State Planning Policy
VMA	- *Vegetation Management Act 1999*

Queensland Government

Department of Environment and Science

Environmental Reports

Regional Ecosystems

Biodiversity Status

For the selected area of interest
Lot: 13 Plan: SP254833

Environmental Reports - General Information

The Environmental Reports portal provides for the assessment of selected matters of interest relevant to a user specified location, or area of interest (AOI). All area and derivative figures are relevant to the extent of matters of interest contained within the AOI unless otherwise stated. Please note, if a user selects an AOI via the "central coordinates" option, the resulting assessment area encompasses an area extending for a 2km radius from the input coordinates.

All area and area derived figures included in this report have been calculated via reprojecting relevant spatial features to Albers equal-area conic projection (central meridian = 146, datum Geocentric Datum of Australia 1994). As a result, area figures may differ slightly if calculated for the same features using a different co-ordinate system.

Figures in tables may be affected by rounding.

The matters of interest reported on in this document are based upon available state mapped datasets. Where the report indicates that a matter of interest is not present within the AOI (e.g. where area related calculations are equal to zero, or no values are listed), this may be due either to the fact that state mapping has not been undertaken for the AOI, that state mapping is incomplete for the AOI, or that no matters of interest have been identified within the site.

The information presented in this report should be considered as a guide only and field survey may be required to validate values on the ground.

Important Note to User

Information presented in this report is based upon the Queensland Herbarium's Regional Ecosystem framework. The Biodiversity Status has been used to depict the extent of "Endangered", "Of Concern" and "No Concern at Present" regional ecosystems in all cases, rather than the classes used for the purposes of the *Vegetation Management Act 1999* (VMA). Mapping and figures presented in this document reflect the Queensland Herbarium's Remnant and Pre-clearing Regional Ecosystem Datasets, and not the certified mapping used for the purpose of the VMA.

For matters relevant to vegetation management under the VMA, please refer to the Department of Resources website https://www.dnrme.qld.gov.au/

Please direct queries about these reports to: Queensland.Herbarium@qld.gov.au

Disclaimer

Whilst every care is taken to ensure the accuracy of the information provided in this report, the Queensland Government makes no representations or warranties about its accuracy, reliability, completeness, or suitability, for any particular purpose and disclaims all responsibility and all liability (including without limitation, liability in negligence) for all expenses, losses, damages (including indirect or consequential damage) and costs which the user may incur as a consequence of the information being inaccurate or incomplete in any way and for any reason.



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Summary Information

The following table provides an overview of the AOI with respect to selected topographic and environmental themes. Refer to **Map 1** for locality information.

Table 1: Area of interest details: Lot: 13 Plan: SP254833

Size (ha)	58,779.14
Local Government(s)	Mareeba Shire
Bioregion(s)	Einasleigh Uplands, Wet Tropics
Subregion(s)	Hodgkinson Basin, Macalister, Daintree - Bloomfield
Catchment(s)	Mitchell

The table below summarizes the extent of remnant vegetation classed as "Endangered", "Of concern" and "No concern at present" regional ecosystems classified by Biodiversity Status within the area of interest (AOI).

Table 2: Summary table, biodiversity status of regional ecosystems within the AOI

Biodiversity Status	Area (Ha)	% of AOI
Endangered	619.09	1.05
Of concern	4,516.50	7.68
No concern at present	52,370.06	89.1
Total remnant vegetation	57,505.66	97.83

Refer to **Map 2** for further information.

Regional Ecosystems

1. Introduction

Regional ecosystems are vegetation communities in a bioregion that are consistently associated with particular combinations of geology, landform and soil (Sattler and Williams 1999). Descriptions of Queensland's Regional ecosystems are available online from the Regional Ecosystem Description Database (REDD). Descriptions are compiled from a broad range of information sources including vegetation, land system and geology survey and mapping and detailed vegetation site data. The regional ecosystem classification and descriptions are reviewed as new information becomes available. A number of vegetation communities may form a single regional ecosystem and are usually distinguished by differences in dominant species, frequently in the shrub or ground layers and are denoted by a letter following the regional ecosystem code (e.g. a, b, c). Vegetation communities and regional ecosystems are amalgamated into a higher level classification of broad vegetation groups (BVGs).

A published methodology for survey and mapping of regional ecosystems across Queensland (Neldner et al 2020) provides further details on regional ecosystem concepts and terminology.

This report provides information on the type, status, and extent of vegetation communities, regional ecosystems and broad vegetation groups present within a user specified area of interest. Please note, for the purpose of this report, the Biodiversity Status is used. This report has not been developed for application of the *Vegetation Management Act 1999* (VMA). Additionally, information generated in this report has been derived from the Queensland Herbarium's Regional Ecosystem Mapping, and not the regulated mapping certified for the purposes of the VMA. If your interest/matter relates to regional ecosystems and the VMA, users should refer to the Department of Resources website.

https://www.dnrme.qld.gov.au/

With respect to the Queensland Biodiversity Status,

"Endangered" regional ecosystems are described as those where:

- remnant vegetation is less than 10 per cent of its pre-clearing extent across the bioregion; or 10-30% of its pre-clearing extent remains and the remnant vegetation is less than 10,000 hectares, or
- less than 10 per cent of its pre-clearing extent remains unaffected by severe degradation and/or biodiversity loss*, or
- 10-30 per cent of its pre-clearing extent remains unaffected by severe degradation and/or biodiversity loss and the remnant vegetation is less than 10,000 hectares; or
- it is a rare** regional ecosystem subject to a threatening process.***

"Of concern" regional ecosystems are described as those where:

- the degradation criteria listed above for 'Endangered' regional ecosystems are not met and,
- remnant vegetation is 10-30 per cent of its pre-clearing extent across the bioregion; or more than 20 per cent of its pre-clearing extent remains and the remnant extent is less than 10,000 hectares, or
- 10-30 percent of its pre-clearing extent remains unaffected by moderate degradation and/or biodiversity loss.****

and "No concern at present" regional ecosystems are described as those where:

- remnant vegetation is over 30 per cent of its pre-clearing extent across the bioregion, and the remnant area is greater than 10,000 hectares, and
- the degradation criteria listed above for 'Endangered' or 'Of concern' regional ecosystems are not met.

**Severe degradation and/or biodiversity loss is defined as: floristic and/or faunal diversity is greatly reduced but unlikely to recover within the next 50 years even with the removal of threatening processes; or soil surface is severely degraded, for example, by loss of A horizon, surface expression of salinity; surface compaction, loss of organic matter or sheet erosion.*

***Rare regional ecosystem: pre-clearing extent (1000 ha); or patch size (100 ha and of limited total extent across its range).*

****Threatening processes are those that are reducing or will reduce the biodiversity and ecological integrity of a regional ecosystem. For example, clearing, weed invasion, fragmentation, inappropriate fire regime or grazing pressure, or infrastructure development.*

*****Moderate degradation and/or biodiversity loss is defined as: floristic and/or faunal diversity is greatly reduced but unlikely to recover within the next 20 years even with the removal of threatening processes; or soil surface is moderately degraded.*

2. Remnant Regional Ecosystems

The following table identifies the remnant regional ecosystems and vegetation communities mapped within the AOI and provides their short descriptions, Biodiversity Status, and remnant extent within the selected AOI. Please note, where heterogeneous vegetated patches (mixed patches of remnant vegetation mapped as containing multiple regional ecosystems) occur within the AOI, they have been split and listed as individual regional ecosystems (or vegetation communities where present) for the purposes of the table below. In such instances, associated area figures have been generated based upon the estimated proportion of each regional ecosystem (or vegetation community) predicted to be present within the larger mixed patch.

Table 3: Remnant regional ecosystems, description and status within the AOI

Regional Ecosystem	Short Description	BD Status	Area (Ha)	% of AOI
7.11.1a	Simple to complex mesophyll to notophyll vine forest on moderately to poorly drained metamorphics (excluding amphibolites) of moderate fertility of the moist and wet lowlands, foothills and uplands	No concern at present	0.21	less than 0.01
7.11.44	Eucalyptus tereticornis open forest to woodland on coastal metamorphic foothills	Of concern	2.5	less than 0.01
7.11.51a	Corymbia clarksoniana and/or Eucalyptus drepanophylla open forest to woodland on metamorphics	Of concern	0.75	less than 0.01
7.12.16a	Simple to complex notophyll vine forest, including small areas of Araucaria bidwillii, of cloudy wet and moist uplands and highlands on granites and rhyolites	No concern at present	1,782.68	3.03
7.12.16b	Simple to complex notophyll vine forest, including small areas of Araucaria bidwillii, of cloudy wet and moist uplands and highlands on granites and rhyolites	No concern at present	1.79	less than 0.01
7.12.16c	Simple to complex notophyll vine forest, including small areas of Araucaria bidwillii, of cloudy wet and moist uplands and highlands on granites and rhyolites	No concern at present	8.14	0.01
7.12.19a	Simple microphyll vine-fern forest with Balanops australiana, Elaeocarpus spp. +/- Trochocarpa bellendenkerensis +/- Uromyrtus spp. +/- Agathis atropurpurea of cloudy wet highlands on granites and rhyolites	No concern at present	248.58	0.42
7.12.1a	Simple to complex mesophyll to notophyll vine forest of moderately to poorly-drained granites and rhyolites of moderate fertility of the moist and wet lowlands, foothills and uplands	No concern at present	626.28	1.07
7.12.1b	Simple to complex mesophyll to notophyll vine forest of moderately to poorly-drained granites and rhyolites of moderate fertility of the moist and wet lowlands, foothills and uplands	No concern at present	1.14	less than 0.01
7.12.21a	Eucalyptus grandis open forest to woodland, or Corymbia intermedia, E. pellita and E. grandis open forest to woodland, (or vine forest with these species as emergents) on granites and rhyolites	Endangered	44.68	0.08

Regional Ecosystem	Short Description	BD Status	Area (Ha)	% of AOI
7.12.21b	Eucalyptus grandis open forest to woodland, or Corymbia intermedia, E. pellita and E. grandis open forest to woodland, (or vine forest with these species as emergents) on granites and rhyolites	Endangered	19.71	0.03
7.12.22a	Eucalyptus resinifera +/- E. portuensis +/- Syncarpia glomulifera tall open forest to tall woodland (or vine forest with these species as emergents) of granite and rhyolite uplands and highlands	Endangered	403.22	0.69
7.12.22b	Eucalyptus resinifera +/- E. portuensis +/- Syncarpia glomulifera tall open forest to tall woodland (or vine forest with these species as emergents) of granite and rhyolite uplands and highlands	Endangered	76.13	0.13
7.12.24a	Eucalyptus portuensis and Corymbia intermedia open forest to woodland (or vine forest with E. portuensis and C. intermedia emergents) on foothills and uplands on granites and rhyolites	No concern at present	189.93	0.32
7.12.30a	Corymbia citriodora +/- Eucalyptus portuensis woodland to open forest on granite and rhyolite	No concern at present	1,030.42	1.75
7.12.30b	Corymbia citriodora +/- Eucalyptus portuensis woodland to open forest on granite and rhyolite	No concern at present	413.85	0.7
7.12.34	Eucalyptus portuensis and/or E. drepanophylla +/- C. intermedia +/- C. citriodora, +/- E. granitica open woodland to open forest on uplands on granite	No concern at present	723.12	1.23
7.12.37i	Rock pavements and seepage areas of wet lowlands, uplands and highlands of the eastern escarpment and central range (excluding Hinchinbrook Island and Bishop Peak) on granite and rhyolite, with Allocasuarina spp. Low woodland and/or sedgelands	Of concern	0.73	less than 0.01
7.12.48	Wind-sheared notophyll vine forest on exposed granite and rhyolite ridge crests and steep slopes	Of concern	43.73	0.07
7.12.57	Shrubland and low woodland mosaic with Syncarpia glomulifera, Corymbia abergiana, Eucalyptus portuensis, Allocasuarina littoralis and Xanthorrhoea johnsonii on uplands and highlands on granite	Of concern	31.34	0.05
7.12.57a	Shrubland and low woodland mosaic with Syncarpia glomulifera, Corymbia abergiana, Eucalyptus portuensis, Allocasuarina littoralis and Xanthorrhoea johnsonii on uplands and highlands on granite	Of concern	78.85	0.13
7.12.58	Eucalyptus reducta +/- E. granitica +/- Corymbia dimorpha +/- C. citriodora woodland to open forest on granite and rhyolite	Of concern	71.58	0.12
7.12.5c	Eucalyptus pellita +/- Corymbia intermedia open forest, or Acacia mangium and Lophostemon suaveolens open forest (or vine forest with these species as emergents), on granites and rhyolites	Endangered	74.57	0.13
7.12.61a	Eucalyptus tereticornis +/- E. granitica woodland to open forest of foothills and uplands on granite and rhyolite	Of concern	193.69	0.33
7.12.62c	Eucalyptus sp. and/or Corymbia stockeri +/- C. hylandii +/- Syncarpia glomulifera +/- E. portuensis woodland on dry granite hill slopes in the north-west of the bioregion	Of concern	13.6	0.02

Regional Ecosystem	Short Description	BD Status	Area (Ha)	% of AOI
7.12.65e	Rock pavement or areas of skeletal soil on granite and rhyolite of dry western or southern areas +/- shrublands to closed forests of Acacia spp. And/or Lophostemon suaveolens and/or Allocasuarina littoralis and/or Eucalyptus lockyeri subsp. Exuta	Of concern	33.0	0.06
7.12.65f	Rock pavement or areas of skeletal soil on granite and rhyolite of dry western or southern areas +/- shrublands to closed forests of Acacia spp. And/or Lophostemon suaveolens and/or Allocasuarina littoralis and/or Eucalyptus lockyeri subsp. Exuta	Of concern	0.2	less than 0.01
7.12.65k	Rock pavement or areas of skeletal soil on granite and rhyolite of dry western or southern areas +/- shrublands to closed forests of Acacia spp. And/or Lophostemon suaveolens and/or Allocasuarina littoralis and/or Eucalyptus lockyeri subsp. Exuta	Of concern	2.12	less than 0.01
7.12.66a	Lophostemon confertus low shrubland or low closed forest on exposed rocky slopes on granite and rhyolite	Of concern	6.6	0.01
7.12.66b	Lophostemon confertus low shrubland or low closed forest on exposed rocky slopes on granite and rhyolite	Of concern	54.84	0.09
7.12.69b	Eucalyptus drepanophylla and/or E. granitica +/- Corymbia clarksoniana +/- C. erythrophloia woodland on uplands on granite and rhyolite	Of concern	22.3	0.04
7.12.7a	Simple to complex microphyll to notophyll vine forest, often with Agathis robusta or A. microstachya, on granites and rhyolites of moist foothills and uplands	No concern at present	18.99	0.03
7.12.9	Acacia celsa open forest to closed forest on granites and rhyolites	Of concern	72.51	0.12
7.3.14a	Eucalyptus leptophleba +/- Corymbia clarksoniana +/- Melaleuca dealbata woodland to open forest on alluvium in low rainfall areas of the west and north	Of concern	0.21	less than 0.01
7.3.28d	Rivers and streams including riparian herbfield and shrubland on river and stream bed alluvium and rock within stream beds	Endangered	0.77	less than 0.01
7.3.49a	Notophyll vine forest on rubble terraces of streams	Of concern	11.01	0.02
9.11.25	Eucalyptus tardecidens or E. chlorophylla +/- Corymbia spp. +/- E. cullenii low woodland on steep to rolling metamorphic hills and rises	No concern at present	2,543.97	4.33
9.11.26a	Eucalyptus leptophleba and/or E. cullenii and/or Corymbia clarksoniana +/- E. platyphylla woodland on undulating terrain to rolling hills	No concern at present	3,337.66	5.68
9.11.3a	Eucalyptus cullenii or E. staigeriana +/- Corymbia clarksoniana woodland on skeletal soils on metamorphic hills	No concern at present	2,573.99	4.38
9.11.3b	Eucalyptus cullenii or E. staigeriana +/- Corymbia clarksoniana woodland on skeletal soils on metamorphic hills	No concern at present	15,814.95	26.91
9.11.3d	Eucalyptus cullenii or E. staigeriana +/- Corymbia clarksoniana woodland on skeletal soils on metamorphic hills	No concern at present	92.69	0.16

Regional Ecosystem	Short Description	BD Status	Area (Ha)	% of AOI
9.11.7a	Eucalyptus platyphylla and/or E. cullenii +/- Corymbia clarksoniana woodland on texture contrast soils on metamorphic hills	No concern at present	99.68	0.17
9.11.7b	Eucalyptus platyphylla and/or E. cullenii +/- Corymbia clarksoniana woodland on texture contrast soils on metamorphic hills	No concern at present	118.9	0.2
9.12.17	Eucalyptus atrata +/- Corymbia citriodora subsp. citriodora +/- E. portuensis woodland on mountains and hills on igneous rocks	No concern at present	580.56	0.99
9.12.2	Eucalyptus portuensis, Corymbia citriodora subsp. citriodora, E. granitica or E. crebra, C. intermedia or C. clarksoniana mixed woodland on steep hills and ranges on igneous hills close to Wet Tropics boundary	No concern at present	435.24	0.74
9.12.31a	Eucalyptus leptophleba, Corymbia clarksoniana and E. crebra +/- C. dallachiana woodland on igneous rocks	Of concern	20.04	0.03
9.12.43a	Granite and rhyolite boulders and pavements edged with patches of Callitris intratropica +/- vine thicket species	Of concern	157.83	0.27
9.12.43b	Granite and rhyolite boulders and pavements edged with patches of Callitris intratropica +/- vine thicket species	Of concern	85.13	0.14
9.12.7a	Eucalyptus cullenii +/- Corymbia leichhardtii +/- C. erythrophloia woodland on igneous rocks	No concern at present	339.88	0.58
9.12.7c	Eucalyptus cullenii +/- Corymbia leichhardtii +/- C. erythrophloia woodland on igneous rocks	No concern at present	679.23	1.16
9.12.8a	Semi-evergreen vine thicket on rocky outcrops and shallow soils of igneous rocks	No concern at present	0.08	less than 0.01
9.3.12a	River beds and associated waterholes on major rivers and channels	Of concern	3.56	0.01
9.3.12b	River beds and associated waterholes on major rivers and channels	Of concern	79.64	0.14
9.3.13	Melaleuca spp., Eucalyptus camaldulensis and Casuarina cunninghamiana fringing open forest on streams and channels	Of concern	227.52	0.39
9.3.14a	Melaleuca spp. +/- Acacia spp. +/- Syzygium spp. +/- Leptospermum spp. fringing woodland on channels and levees	Of concern	1,120.88	1.91
9.3.16	Eucalyptus tereticornis and/or E. platyphylla and/or Corymbia clarksoniana woodland on alluvial flats, levees and plains	Of concern	112.09	0.19
9.3.2	Eucalyptus leptophleba and/or E. chlorophylla +/- Corymbia dallachiana woodland on river levees and terraces	No concern at present	7,309.38	12.44
9.3.3c	Corymbia spp. and Eucalyptus spp. dominated mixed woodland on alluvial flats, levees and plains	Of concern	1,939.28	3.3
9.3.4	Permanent or seasonal wetlands frequently fringed by narrow bands of trees and shrubs including Eucalyptus spp. on alluvial plains	Of concern	130.98	0.22
9.3.6a	Eucalyptus platyphylla +/- Eucalyptus spp. +/- Corymbia spp. woodland on alluvial plains	No concern at present	127.18	0.22

Regional Ecosystem	Short Description	BD Status	Area (Ha)	% of AOI
9.5.12	Eucalyptus chlorophylla and/or E. tardecidens woodland on Tertiary plains	No concern at present	5,284.08	8.99
9.5.13a	Melaleuca citrolens and/or Macropteranthes montana low woodland with Eucalyptus spp. emergents on Tertiary sand sheets	No concern at present	1,056.23	1.8
9.5.15a	Melaleuca monantha +/- M. viridiflora +/- Callitris intratropica mixed low woodland on valley infill	No concern at present	1,394.07	2.37
9.5.9b	Corymbia clarksoniana and/or Eucalyptus leptophleba and/or E. platyphylla woodland on plains	No concern at present	2,322.64	3.95
9.5.9c	Corymbia clarksoniana and/or Eucalyptus leptophleba and/or E. platyphylla woodland on plains	No concern at present	3,214.51	5.47
non-remnant	None	None	1,231.73	2.1
water	None	None	42.27	0.07

Refer to **Map 2** for further information. **Map 3** also provides a visual estimate of the distribution of regional ecosystems present before clearing.

Table 4 provides further information in regards to the remnant regional ecosystems present within the AOI. Specifically, the extent of remnant vegetation remaining within the bioregion, the 1:1,000,000 broad vegetation group (BVG) classification, whether the regional ecosystem is identified as a wetland, and extent of representation in Queensland's Protected Area Estate. For a description of the vegetation communities within the AOI and classified according to the 1:1,000,000 BVG, refer to **Table 6**.

Table 4: Remnant regional ecosystems within the AOI, additional information

Regional Ecosystem	Remnant Extent	BVG (1 Million)	Wetland	Representation in protected estate
7.11.1a	Pre-clearing 146000 ha; Remnant 2019 130000 ha	2a	None	High
7.11.44	Pre-clearing 10000 ha; Remnant 2019 9000 ha	9c	None	High
7.11.51a	Pre-clearing 19000 ha; Remnant 2019 16000 ha	9c	None	High
7.12.16a	Pre-clearing 242000 ha; Remnant 2019 230000 ha	6b	None	High
7.12.16b	Pre-clearing 242000 ha; Remnant 2019 230000 ha	5d	None	High
7.12.16c	Pre-clearing 242000 ha; Remnant 2019 230000 ha	5c	None	High
7.12.19a	Pre-clearing 14000 ha; Remnant 2019 14000 ha	6b	None	High
7.12.1a	Pre-clearing 124000 ha; Remnant 2019 120000 ha	2a	None	High
7.12.1b	Pre-clearing 124000 ha; Remnant 2019 120000 ha	5d	None	High
7.12.21a	Pre-clearing 16000 ha; Remnant 2019 16000 ha	8a	None	High
7.12.21b	Pre-clearing 16000 ha; Remnant 2019 16000 ha	8a	None	High

Regional Ecosystem	Remnant Extent	BVG (1 Million)	Wetland	Representation in protected estate
7.12.22a	Pre-clearing 40000 ha; Remnant 2019 39000 ha	8a	None	High
7.12.22b	Pre-clearing 40000 ha; Remnant 2019 39000 ha	8a	None	High
7.12.24a	Pre-clearing 33000 ha; Remnant 2019 32000 ha	9d	None	High
7.12.30a	Pre-clearing 44000 ha; Remnant 2019 43000 ha	10b	None	High
7.12.30b	Pre-clearing 44000 ha; Remnant 2019 43000 ha	10b	None	High
7.12.34	Pre-clearing 53000 ha; Remnant 2019 51000 ha	9d	None	High
7.12.37i	Pre-clearing 5000 ha; Remnant 2019 5000 ha	29b	None	High
7.12.48	Pre-clearing 7000 ha; Remnant 2019 7000 ha	6b	None	High
7.12.57	Pre-clearing 4000 ha; Remnant 2019 4000 ha	9d	None	Medium
7.12.57a	Pre-clearing 4000 ha; Remnant 2019 4000 ha	9d	None	Medium
7.12.58	Pre-clearing 1000 ha; Remnant 2019 1000 ha	9d	None	High
7.12.5c	Pre-clearing 12000 ha; Remnant 2019 9000 ha	9c	None	High
7.12.61a	Pre-clearing 26000 ha; Remnant 2019 25000 ha	9c	None	High
7.12.62c	Pre-clearing 600 ha; Remnant 2019 600 ha	7b	None	High
7.12.65e	Pre-clearing 16000 ha; Remnant 2019 16000 ha	28e	None	High
7.12.65f	Pre-clearing 16000 ha; Remnant 2019 16000 ha	29b	None	High
7.12.65k	Pre-clearing 16000 ha; Remnant 2019 16000 ha	29b	None	High
7.12.66a	Pre-clearing 5000 ha; Remnant 2019 5000 ha	28e	None	High
7.12.66b	Pre-clearing 5000 ha; Remnant 2019 5000 ha	28e	None	High
7.12.69b	Pre-clearing 700 ha; Remnant 2019 700 ha	13c	None	High
7.12.7a	Pre-clearing 15000 ha; Remnant 2019 14000 ha	5c	None	High
7.12.9	Pre-clearing 5000 ha; Remnant 2019 5000 ha	5d	None	High
7.3.14a	Pre-clearing 3000 ha; Remnant 2019 2000 ha	9b	None	Medium
7.3.28d	Pre-clearing 8000 ha; Remnant 2019 8000 ha	16d	Riverine wetland or fringing riverine wetland.	High

Regional Ecosystem	Remnant Extent	BVG (1 Million)	Wetland	Representation in protected estate
7.3.49a	Pre-clearing 800 ha; Remnant 2019 800 ha	22c	Riverine wetland or fringing riverine wetland.	High
9.11.25	Pre-clearing 195000 ha; Remnant 2019 193000 ha	19d	None	Low
9.11.26a	Pre-clearing 67000 ha; Remnant 2019 66000 ha	13a	None	Low
9.11.3a	Pre-clearing 924000 ha; Remnant 2019 917000 ha	13a	None	Low
9.11.3b	Pre-clearing 924000 ha; Remnant 2019 917000 ha	13a	None	Low
9.11.3d	Pre-clearing 924000 ha; Remnant 2019 917000 ha	21b	None	Low
9.11.7a	Pre-clearing 41000 ha; Remnant 2019 39000 ha	9b	None	Low
9.11.7b	Pre-clearing 41000 ha; Remnant 2019 39000 ha	21a	None	Low
9.12.17	Pre-clearing 19000 ha; Remnant 2019 19000 ha	13c	None	Low
9.12.2	Pre-clearing 117000 ha; Remnant 2019 116000 ha	9d	None	High
9.12.31a	Pre-clearing 11000 ha; Remnant 2019 10000 ha	9b	None	No representation
9.12.43a	Pre-clearing 7000 ha; Remnant 2019 7000 ha	29b	None	Low
9.12.43b	Pre-clearing 7000 ha; Remnant 2019 7000 ha	29b	None	Low
9.12.7a	Pre-clearing 610000 ha; Remnant 2019 606000 ha	13a	None	Low
9.12.7c	Pre-clearing 610000 ha; Remnant 2019 606000 ha	13a	None	Low
9.12.8a	Pre-clearing 11000 ha; Remnant 2019 11000 ha	7a	None	High
9.3.12a	Pre-clearing 64000 ha; Remnant 2019 63000 ha	16d	Riverine wetland or fringing riverine wetland.	Low
9.3.12b	Pre-clearing 64000 ha; Remnant 2019 63000 ha	16d	Riverine wetland or fringing riverine wetland.	Low
9.3.13	Pre-clearing 95000 ha; Remnant 2019 93000 ha	22c	Riverine wetland or fringing riverine wetland.	Low
9.3.14a	Pre-clearing 18000 ha; Remnant 2019 18000 ha	22c	Riverine wetland or fringing riverine wetland.	Low
9.3.16	Pre-clearing 33000 ha; Remnant 2019 29000 ha	16c	Floodplain (other than floodplain wetlands).	Low
9.3.2	Pre-clearing 19000 ha; Remnant 2019 18000 ha	16b	None	Low
9.3.3c	Pre-clearing 150000 ha; Remnant 2019 130000 ha	16b	Floodplain (other than floodplain wetlands).	Low
9.3.4	Pre-clearing 6000 ha; Remnant 2019 5000 ha	34d	Palustrine wetland (e.g. vegetated swamp).	Medium

Regional Ecosystem	Remnant Extent	BVG (1 Million)	Wetland	Representation in protected estate
9.3.6a	Pre-clearing 20000 ha; Remnant 2019 19000 ha	16c	Contains palustrine wetland (e.g. in swales).	Medium
9.5.12	Pre-clearing 30000 ha; Remnant 2019 27000 ha	18c	None	Low
9.5.13a	Pre-clearing 31000 ha; Remnant 2019 31000 ha	21b	None	High
9.5.15a	Pre-clearing 16000 ha; Remnant 2019 12000 ha	21a	None	Low
9.5.9b	Pre-clearing 92000 ha; Remnant 2019 55000 ha	18c	None	Low
9.5.9c	Pre-clearing 92000 ha; Remnant 2019 55000 ha	9e	None	Low
non-remnant	None	None	None	None
water	None	None	None	None

Representation in Protected Area Estate: High greater than 10% of pre-clearing extent is represented; Medium 4 - 10% is represented; Low less than 4% is represented, No representation.

The distribution of mapped wetland systems within the area of interest is displayed in **Map 6**.

The following table lists known special values associated with a regional ecosystem type.

Table 5: Remnant regional ecosystems within the AOI, special values

Regional Ecosystem	Special Values
7.11.1a	Habitat for threatened plant species of 7.11.1a include: Archidendron kanisii, Archidendropsis xanthoxylon, Asplenium wildii, Austromuellera trinervia, Beilschmiedia castrisinensis, Cyclophyllum costatum, Dioclea hexandra, Endiandra grayi, Endiandra microneura, Euodia hylandii, Euodia pubifolia, Freycinetia marginata, Gardenia actinocarpa, Phlegmariurus spp., Lepiderema hirsuta, Megahertzia amplexicaulis, Microsorum membranifolium, Mitrantia bilocularis, Neostrearia fleckeri, Noahdendron nicholasii, Peripentadenia phelpsii, Samadera baileyana, Randia audasii, Ryparosa kurrangii, Sankowskya stipularis, Symplocos crassiramifera, Vrydagzynea grayi, Whyanbeelia terrae-reginae and Xanthophyllum fragrans. Also there are many locally restricted regional endemics and unusual species such as: Austrocallerya australis, Coelospermum dasylobum, Cupaniopsis diploglottoides, Mischarytera megaphylla, Storckiella australiensis, Tainia trinervis and Idiospermum australiense. Other species of local significance are Argyrodendron sp. (Whyanbeel B.P.Hyland RFK1106), Monoon patinatum and Rhodomyrtus effusa.
7.11.44	Potential habitat for NCA listed species: Randia audasii
7.11.51a	Potential habitat for NCA listed species: Grevillea glossadenia, Coleus gratus

Regional Ecosystem	Special Values
7.12.16a	Habitat of threatened plant species including: Albizia sp. (Windsor Tableland B.Gray 2181), Argophyllum cryptophlebum, Ctenopteris walleri, Eidothea zoexylocarya, Elaeocarpus thelmae, Endiandra jonesii, Endiandra phaeocarpa, Helicia grayi, Helicia lewisensis, Phlegmariurus spp., Diteilis simmondsii, Litsea granitica, Phaleria biflora, Stenocarpus davallioides, , Symplocos graniticola and Xylosma sp. (Mt Lewis G.Sankowsky+ 1108). Habitat for near threatened plant species Aceratium ferrugineum, Aglaia brassii, Austrobuxus megacarpus, Bubbia queenslandiana subsp. queenslandiana, Glochidion pungens, Goodyera viridiflora, Diospyros granitica, Polyalthia submontana subsp. submontana, Helicia recurva, Medicosma glandulosa, Pectinopitys ladei, Pteridoblechnum acuminatum, Sarcopteryx montana, Symplocos ampulliformis and Wendlandia connata. Habitat of many endemic species of fauna and flora. Other species of local significance include Diospyros hemicycloides, Elaeocarpus johnsonii, Solanum dimorphispinum and Steganthera cooperorum.
7.12.16b	Habitat of threatened plant species including: Albizia sp. (Windsor Tableland B.Gray 2181), Argophyllum cryptophlebum, Ctenopteris walleri, Eidothea zoexylocarya, Elaeocarpus thelmae, Endiandra jonesii, Endiandra phaeocarpa, Helicia grayi, Helicia lewisensis, Phlegmariurus spp., Diteilis simmondsii, Litsea granitica, Phaleria biflora, Stenocarpus davallioides, , Symplocos graniticola and Xylosma sp. (Mt Lewis G.Sankowsky+ 1108). Habitat for near threatened plant species Aceratium ferrugineum, Aglaia brassii, Austrobuxus megacarpus, Bubbia queenslandiana subsp. queenslandiana, Glochidion pungens, Goodyera viridiflora, Diospyros granitica, Polyalthia submontana subsp. submontana, Helicia recurva, Medicosma glandulosa, Pectinopitys ladei, Pteridoblechnum acuminatum, Sarcopteryx montana, Symplocos ampulliformis and Wendlandia connata. Habitat of many endemic species of fauna and flora. Other species of local significance include Diospyros hemicycloides, Elaeocarpus johnsonii, Solanum dimorphispinum and Steganthera cooperorum.
7.12.16c	Habitat of threatened plant species including: Albizia sp. (Windsor Tableland B.Gray 2181), Argophyllum cryptophlebum, Ctenopteris walleri, Eidothea zoexylocarya, Elaeocarpus thelmae, Endiandra jonesii, Endiandra phaeocarpa, Helicia grayi, Helicia lewisensis, Phlegmariurus spp., Diteilis simmondsii, Litsea granitica, Phaleria biflora, Stenocarpus davallioides, , Symplocos graniticola and Xylosma sp. (Mt Lewis G.Sankowsky+ 1108). Habitat for near threatened plant species Aceratium ferrugineum, Aglaia brassii, Austrobuxus megacarpus, Bubbia queenslandiana subsp. queenslandiana, Glochidion pungens, Goodyera viridiflora, Diospyros granitica, Polyalthia submontana subsp. submontana, Helicia recurva, Medicosma glandulosa, Pectinopitys ladei, Pteridoblechnum acuminatum, Sarcopteryx montana, Symplocos ampulliformis and Wendlandia connata. Habitat of many endemic species of fauna and flora. Other species of local significance include Diospyros hemicycloides, Elaeocarpus johnsonii, Solanum dimorphispinum and Steganthera cooperorum.

Regional Ecosystem	Special Values
7.12.19a	Threatened species include: Acrotriche baileyana, Aglaia brassii, Albizia sp. (Windsor Tableland B.Gray 2181), Austromuellera valida, Bubbia whiteana, Ceratopetalum corymbosum, Ctenopteris walleri, Eidothea zoexylocarya, Endiandra jonesii, Flindersia oppositifolia, Grammitis albosetosa, Helicia grayi, Helicia lewisensis, Phlegmariurus spp., Leionema ellipticum, Litsea granitica, Phaleria biflora, Stenocarpus davallioides, Symplocos graniticola, and Wendlandia connata. Habitat for near threatened plant species Austobuxus megacarpus, Bubbia queenslandiana subsp. queenslandiana, Chiloglottis longiclavata, Diospyros granitica, Glochidion pungens, Goodyera viridiflora, Helicia recurva, Medicosma glandulosa, Pectinopitys ladei, Sarcopteryx montana, Symplocos ampulliformis and Symplocos oresbia. Habitat of many endemic species of fauna and flora. Other species of local significance include Diospyros hemicycloides, Elaeocarpus johnsonii and Steganthera cooperorum.
7.12.1a	Habitat for threatened plant species including: Actephila foetida, Arytera dictyoneura, Citrus inodora, Cladopus queenslandicus, Cheilocostus potierae, Croton densivestitus, Dansiea elliptica, Diploglottis pedleyi, Drosera adelae, Endiandra anthropophagorum, Phlegmariurus spp., Lepiderema largiflorens, Neostrearia fleckeri and Piper mestonii. Habitat for many plant species endemic to the bioregion. The vegetation community 7.12.1c (G166) harbours many regionally endemic species such as Choriceras majus, Beilschmiedia castrisinensis, Mesua larnachiana, Dissiliaria tuckeri and Buckinghamia ferruginiflora. Endemicity levels and species number decline south of the Tully River. The unusual grass Lophatherum gracile occurs along creeks particularly in the Tully area. It is the only known habitat of Passiflora aurantioides which in Australia is confined to the Babinda-Bellenden Ker area.
7.12.1b	Habitat for threatened plant species including: Actephila foetida, Arytera dictyoneura, Citrus inodora, Cladopus queenslandicus, Cheilocostus potierae, Croton densivestitus, Dansiea elliptica, Diploglottis pedleyi, Drosera adelae, Endiandra anthropophagorum, Phlegmariurus spp., Lepiderema largiflorens, Neostrearia fleckeri and Piper mestonii. Habitat for many plant species endemic to the bioregion. The vegetation community 7.12.1c (G166) harbours many regionally endemic species such as Choriceras majus, Beilschmiedia castrisinensis, Mesua larnachiana, Dissiliaria tuckeri and Buckinghamia ferruginiflora. Endemicity levels and species number decline south of the Tully River. The unusual grass Lophatherum gracile occurs along creeks particularly in the Tully area. It is the only known habitat of Passiflora aurantioides which in Australia is confined to the Babinda-Bellenden Ker area.
7.12.21a	Habitat for arboreal mammals. Habitat for plant species of limited distribution including Bertya polystigma, Pityrodia salviifolia, Pomaderris argyrophylla, Dodonaea uncinata, Phebalium longifolium and Persoonia tropica.
7.12.21b	Habitat for arboreal mammals. Habitat for plant species of limited distribution including Bertya polystigma, Pityrodia salviifolia, Pomaderris argyrophylla, Dodonaea uncinata, Phebalium longifolium and Persoonia tropica.
7.12.22a	Important arboreal mammal habitat for species including the yellow-bellied glider (Petaurus australis). Habitat for the tropical bettong (Bettongia tropica). Habitat for plant species with restricted distribution including Bertya polystigma, Pityrodia salviifolia, Pomaderris argyrophylla, Dodonaea uncinata, Phebalium longifolium, and Persoonia tropica.

Regional Ecosystem	Special Values
7.12.22b	Important arboreal mammal habitat for species including the yellow-bellied glider (Petaurus australis). Habitat for the tropical bettong (Bettongia tropica). Habitat for plant species with restricted distribution including Bertya polystigma, Pityrodia salviifolia, Pomaderris argyrophylla, Dodonaea uncinata, Phebalium longifolium, and Persoonia tropica.
7.12.24a	Potential habitat for NCA listed species: Arytera dictyoneura, Corymbia leptoloma, Marsdenia rara, Coleus gratus
7.12.30a	Potential habitat for NCA listed species: Acacia longipedunculata, Acacia purpureopetala, Acacia tingoorensis, Corymbia rhodops, Diuris oporina, Dodonaea uncinata, Grevillea glossadenia, Homoranthus porteri, Melaleuca sylvana, Micromyrtus delicata, Coleus amoenus, Prostanthera clotteniana, Triplarina nitchaga, Zieria obovata 7.12.30d: Habitat for several locally restricted and disjunct species. Threatened plant species include Micromyrtus delicata, Melaleuca sylvana, Diuris oporina, Homoranthus porteri, Grevillea glossadenia, Acacia purpureopetala, Corymbia rhodops and Prostanthera clotteniana. Other species of local significance are Eucalyptus lockyeri.
7.12.30b	Potential habitat for NCA listed species: Acacia longipedunculata, Acacia purpureopetala, Acacia tingoorensis, Corymbia rhodops, Diuris oporina, Dodonaea uncinata, Grevillea glossadenia, Homoranthus porteri, Melaleuca sylvana, Micromyrtus delicata, Coleus amoenus, Prostanthera clotteniana, Triplarina nitchaga, Zieria obovata 7.12.30d: Habitat for several locally restricted and disjunct species. Threatened plant species include Micromyrtus delicata, Melaleuca sylvana, Diuris oporina, Homoranthus porteri, Grevillea glossadenia, Acacia purpureopetala, Corymbia rhodops and Prostanthera clotteniana. Other species of local significance are Eucalyptus lockyeri.
7.12.34	Potential habitat for NCA listed species: Acacia longipedunculata, Calochlaena villosa, Croton densivestitus, Grevillea glossadenia, Homoranthus porteri, Coleus amoenus, Solanum angustum, Zieria obovata
7.12.37i	Potential habitat for NCA listed species: Austrobuxus megacarpus, Coleus gratus, Polyalthia submontana subsp. submontana, Prostanthera albohirta, Prostanthera clotteniana, Vincetoxicum rupicola
7.12.48	Potential habitat for NCA listed species: Argophyllum cryptophlebum, Helicia grayi, Lepiderema hirsuta, Symplocos ampulliformis
7.12.57	Threatened species include Diuris oporina (NT), Homoranthus porteri (V), Melaleuca uxorum (E) and Prostanthera clotteniana (E). Other species of local significance are Eucalyptus lockyeri. 7.12.57a: Threatened species include Corymbia leptoloma (V), Homoranthus porteri (V), Marsdenia brevifolia (V), Acacia longipedunculata (NT), Dodonaea uncinata and Diuris oporina (NT). Other species of local significance are Eucalyptus lockyeri. 7.12.57c: Habitat for several locally restricted and disjunct species. Threatened species include Micromyrtus delicata (E), Melaleuca sylvana (E), Melaleuca uxorum (E), Diuris oporina (NT), Homoranthus porteri (V), Grevillea glossadenia (V), Acacia purpureopetala (V), Corymbia rhodops (V) and Prostanthera clotteniana (E). Other species of local significance are Eucalyptus lockyeri.

Regional Ecosystem	Special Values
7.12.57a	Threatened species include Diuris oporina (NT), Homoranthus porteri (V), Melaleuca uxorum (E) and Prostanthera clotteniana (E). Other species of local significance are Eucalyptus lockyeri. 7.12.57a: Threatened species include Corymbia leptoloma (V), Homoranthus porteri (V), Marsdenia brevifolia (V), Acacia longipedunculata (NT), Dodonaea uncinata and Diuris oporina (NT). Other species of local significance are Eucalyptus lockyeri. 7.12.57c: Habitat for several locally restricted and disjunct species. Threatened species include Micromyrtus delicata (E), Melaleuca sylvana (E), Melaleuca uxorum (E), Diuris oporina (NT), Homoranthus porteri (V), Grevillea glossadenia (V), Acacia purpureopetala (V), Corymbia rhodops (V) and Prostanthera clotteniana (E). Other species of local significance are Eucalyptus lockyeri.
7.12.58	Potential habitat for NCA listed species: Homoranthus porteri
7.12.5c	Potential habitat for NCA listed species: Acianthus sublestus, Marsdenia rara
7.12.61a	Potential habitat for NCA listed species: Arthraxon hispidus, Cucumis costatus, Dendrobium bigibbum, Dendrobium johannis, Dodonaea uncinata, Coleus gratus
7.12.62c	None
7.12.65e	Potential habitat for NCA listed species: Acacia purpureopetala, Buckinghamia ferruginiflora, Corymbia leptoloma, Corymbia rhodops, Diuris oporina, Dodonaea uncinata, Grevillea glossadenia, Homoranthus porteri, Melaleuca sylvana, Melaleuca uxorum, Micromyrtus delicata, Coleus amoenus, Prostanthera clotteniana, Pterostylis caligna, Zieria obovata 7.12.65k: Habitat for several locally restricted and disjunct species. Threatened species include Micromyrtus delicata, Melaleuca sylvana, Melaleuca uxorum, Diuris oporina, Homoranthus porteri, Grevillea glossadenia, Acacia purpureopetala, Corymbia rhodops and Prostanthera clotteniana. Other species of local significance are Eucalyptus lockyeri.
7.12.65f	Potential habitat for NCA listed species: Acacia purpureopetala, Buckinghamia ferruginiflora, Corymbia leptoloma, Corymbia rhodops, Diuris oporina, Dodonaea uncinata, Grevillea glossadenia, Homoranthus porteri, Melaleuca sylvana, Melaleuca uxorum, Micromyrtus delicata, Coleus amoenus, Prostanthera clotteniana, Pterostylis caligna, Zieria obovata 7.12.65k: Habitat for several locally restricted and disjunct species. Threatened species include Micromyrtus delicata, Melaleuca sylvana, Melaleuca uxorum, Diuris oporina, Homoranthus porteri, Grevillea glossadenia, Acacia purpureopetala, Corymbia rhodops and Prostanthera clotteniana. Other species of local significance are Eucalyptus lockyeri.
7.12.65k	Potential habitat for NCA listed species: Acacia purpureopetala, Buckinghamia ferruginiflora, Corymbia leptoloma, Corymbia rhodops, Diuris oporina, Dodonaea uncinata, Grevillea glossadenia, Homoranthus porteri, Melaleuca sylvana, Melaleuca uxorum, Micromyrtus delicata, Coleus amoenus, Prostanthera clotteniana, Pterostylis caligna, Zieria obovata 7.12.65k: Habitat for several locally restricted and disjunct species. Threatened species include Micromyrtus delicata, Melaleuca sylvana, Melaleuca uxorum, Diuris oporina, Homoranthus porteri, Grevillea glossadenia, Acacia purpureopetala, Corymbia rhodops and Prostanthera clotteniana. Other species of local significance are Eucalyptus lockyeri.
7.12.66a	None
7.12.66b	None
7.12.69b	Potential habitat for NCA listed species: Dendrobium bigibbum

Regional Ecosystem	Special Values
7.12.7a	Habitat for threatened plant species including: Alectryon semicinereus, Alpinia hylandii, Elaeocarpus coorangooloo, Arytera dictyoneura. Rhodamnia longisepala is endemic and confined to this RE on the Windsor Tableland.
7.12.9	None
7.3.14a	None
7.3.28d	An important component of stream ecology and structure influencing substrate types, depth gradients, flow characteristics and flooding characteristics.
7.3.49a	Potential habitat for NCA listed species: Buckinghamia ferruginiflora, Gymnostoma australianum, Hollandaea riparia, Sphaerantia chartacea
9.11.25	Potential habitat for NCA listed species: Acacia guymeri, Acacia purpureopetala, Cucumis costatus
9.11.26a	None
9.11.3a	Potential habitat for NCA listed species: Acacia guymeri, Acacia purpureopetala, Cucumis costatus, Dianella incollata, Ehretia microphylla, Euphorbia carissoides, Macropteranthes montana, Panicum chillagoanum, Stenanthemum argenteum
9.11.3b	Potential habitat for NCA listed species: Acacia guymeri, Acacia purpureopetala, Cucumis costatus, Dianella incollata, Ehretia microphylla, Euphorbia carissoides, Macropteranthes montana, Panicum chillagoanum, Stenanthemum argenteum
9.11.3d	Potential habitat for NCA listed species: Acacia guymeri, Acacia purpureopetala, Cucumis costatus, Dianella incollata, Ehretia microphylla, Euphorbia carissoides, Macropteranthes montana, Panicum chillagoanum, Stenanthemum argenteum
9.11.7a	None
9.11.7b	None
9.12.17	Potential habitat for NCA listed species: Goodenia stirlingii, Coleus amoenus
9.12.2	Old growth of this ecosystem is significant for a number of species including arboreal mammals. Habitat for vulnerable flora species including Corymbia rhodops
9.12.31a	Potential habitat for NCA listed species: Peristylus banfieldii, Spathoglottis paulinae
9.12.43a	None
9.12.43b	None
9.12.7a	Habitat for near threatened and threatened flora species. 9.12.7a: Potential habitat for the vulnerable plant species Cycas platyphylla.
9.12.7c	Habitat for near threatened and threatened flora species. 9.12.7a: Potential habitat for the vulnerable plant species Cycas platyphylla.
9.12.8a	Potential habitat for NCA listed species: Dubouzetia saxatilis, Graptophyllum excelsum, Ipomoea saintronanensis, Panicum chillagoanum
9.3.12a	Significant habitat as drought refuge, wildlife corridors and for arboreal animals.
9.3.12b	Significant habitat as drought refuge, wildlife corridors and for arboreal animals.

Regional Ecosystem	Special Values
9.3.13	Significant habitat as drought refuge, wildlife corridors and for arboreal animals.
9.3.14a	Significant habitat as drought refuge, wildlife corridors and for arboreal animals.
9.3.16	Significant habitat as drought refuge, wildlife corridors and for arboreal animals.
9.3.2	Significant habitat particularly for herbivores such as macropods and arboreal mammals
9.3.3c	Significant habitat as drought refuge, wildlife corridors and for arboreal animals.
9.3.4	Seasonal and permanent fresh water habitats significant for water bird feeding, breeding and drought refuge
9.3.6a	Includes seasonal wetlands important for water bird feeding. 9.3.6a: Includes seasonal wetlands important for water bird feeding.
9.5.12	Potential habitat for NCA listed species: Habenaria rumphii
9.5.13a	Habitat for the vulnerable plant species Macropteranthes montana.
9.5.15a	None
9.5.9b	Potential habitat for NCA listed species: Habenaria rumphii
9.5.9c	Potential habitat for NCA listed species: Habenaria rumphii
non-remnant	None
water	None

3. Remnant Regional Ecosystems by Broad Vegetation Group

BVGs are a higher-level grouping of vegetation communities. Queensland encompasses a wide variety of landscapes across temperate, wet and dry tropics and semi-arid climatic zones. BVGs provide an overview of vegetation communities across the state or a bioregion and allow comparison with other states. There are three levels of BVGs which reflect the approximate scale at which they are designed to be used: the 1:5,000,000 (national), 1:2,000,000 (state) and 1:1,000,000 (regional) scales.

A comprehensive description of BVGs is available at:

https://publications.qld.gov.au/dataset/redd/resource/

The following table provides a description of the 1:1,000,000 BVGs present and their associated extent within the AOI.

Table 6: Broad vegetation groups (1 million) within the AOI

BVG (1 Million)	Description	Area (Ha)	% of AOI
None	None	1,273.99	2.17
10b	Moist open forests to woodlands dominated by Corymbia citriodora (spotted gum). (land zones 12, 11, 9, 5, 8) (SEQ, CQC, EIU, WET)	1,444.27	2.46
13a	Woodlands and open woodlands dominated by ironbarks such Eucalyptus cullenii (Cullen's ironbark), E. staigeriana (lemon-scented ironbark) or E. melanophloia (silver-leaved ironbark) and bloodwoods such as Corymbia stockeri subsp. peninsularis, C. clarksoniana (grey bloodwood) or C. leichhardtii (rustyjacket). (land zones 11, 12, 7, 5) (EIU, CYP, GUP)	22,745.70	38.7

BVG (1 Million)	Description	Area (Ha)	% of AOI
13c	Woodlands of Eucalyptus crebra (sens. lat.) (narrow-leaved red ironbark), E. drepanophylla (grey ironbark), E. fibrosa (dusky-leaved ironbark), E. shirleyi (shirley's silver-leaved ironbark) on granitic and metamorphic ranges (land zones 12, 11, 9, [5]) (BRB, EIU, SEQ, NET, CQC)	602.86	1.03
16b	Woodlands dominated by Eucalyptus leptophleba (Molloy red box), with Corymbia tessellaris (carbeen) or C. clarksoniana (grey bloodwood) or C. dallachiana. On sandy levees. (land zones 3, 5) (GUP, EIU, CYP)	9,248.66	15.73
16c	Woodlands and open woodlands dominated by Eucalyptus coolabah (coolabah) or E. microtheca (coolabah) or E. largiflorens (black box) or E. tereticornis (blue gum) or E. chlorophylla on floodplains. Does not include alluvial areas dominated by herb and grasslands or alluvial plains that are not flooded. (land zone 3) (All bioregions except WET, principally GUP, BRB, MUL).	239.27	0.41
16d	River beds, open water or sand, or rock, frequently unvegetated. (land zone 3) (GUP, EIU, BRB, CYP, DEU, [CQC, MUL])	83.97	0.14
18c	Woodlands and open woodlands dominated by Eucalyptus chlorophylla (E. microtheca or E. leptophleba on heavy soils) frequently with Corymbia spp. (land zones 9, 5, 3, 12, [4]) (CYP, GUP, EIU, MGD, [NWH])	7,606.72	12.94
19d	Low open woodlands dominated by Eucalyptus persistens (or E. normantonensis (Normanton box), E. tardecidens, E. provecta) with Triodia spp. dominated ground layer, mainly on hills and ranges. (land zones 7, 11, 12, 5, [4, 10]) (EIU, MGD, CHC, BRB, GUP, DEU)	2,543.97	4.33
21a	Low woodlands and low open woodlands dominated by Melaleuca viridiflora (coarse-leaved paperbark) on depositional plains. (land zones 3, 5, 11, [10]) (GUP, CYP, BRB, CQC, EIU, WET, SEQ)	1,512.97	2.57
21b	Low open woodlands and tall shrublands of Melaleuca citrolens or M. stenostachya or other Melaleuca spp. (land zones 5, 3, 7, 10, 11, 12) (GUP, CYP, EIU, DEU, BRB, [SEQ])	1,148.93	1.95
22c	Open forests dominated by Melaleuca spp. (M. argentea (silver tea-tree), M. leucadendra (broad-leaved tea-tree), M. dealbata (swamp tea-tree) or M. fluviatilis), fringing major streams with Melaleuca saligna or M. bracteata (black tea-tree) in minor streams. (land zone 3) (CYP, GUP, EIU, BRB, CQC, DEU, NWH, WET, [SEQ])	1,359.40	2.31
28e	Low open forest to woodlands dominated by Lophostemon suaveolens (swamp box) (or L. confertus (brush box)) or Syncarpia glomulifera (turpentine) frequently with Allocasuarina spp. on rocky hill slopes. (land zones 12, 9, 3, 11, [10, 8]) (CQC, WET, SEQ, BRB, [CYP])	94.44	0.16
29b	Open shrublands to open heaths in montane frequently rocky locations. (land zones 7, 12, 11, 5, 8, 10) (BRB, NWH, WET, CYP, EIU, SEQ, DEU, [NET, CQC])	246.01	0.42
2a	Complex evergreen notophyll vine forest frequently with Araucaria cunninghamii (hoop pine) from foothills to ranges. (land zones 11, 12, 8) (WET, SEQ, CQC) (Tracey 1982 5a, 5b)	626.49	1.07
34d	Palustrine wetlands. Freshwater swamps/springs/billabongs on floodplains ranging from permanent and semi-permanent to ephemeral. (land zone 3) (GUP, EIU, BRB, CYP, CHC, [MGD])	130.98	0.22

BVG (1 Million)	Description	Area (Ha)	% of AOI
5c	Simple to complex notophyll vine forests, often with Agathis spp. on ranges and uplands of the Wet Tropics bioregion. (land zones 12, 11, 8, [3]) (WET) (Tracey 1982 6)	27.13	0.05
5d	Acacia celsa / A. mangium (brown salwood) / A. polystachya closed forests to open forests with mixed rainforest species understorey, includes areas regenerating after disturbance (upland and lowland areas). (land zones 12, 11, 3, 8) (CYP, WET)	75.44	0.13
6b	Simple evergreen notophyll vine forest to simple microphyll vine fern thicket on high peaks and plateaus of northern Queensland. (land zones 12, 11) (WET, CQC) (Tracey 1982 8, 9, 10)	2,074.99	3.53
7a	Semi-evergreen vine thickets on wide range of substrates. (land zones 8, 9, 11, 12, 5, 4, 3, 10, [7]) (BRB, EIU, SEQ, CQC, [WET, GUP]) (Tracey 1982 11)	0.08	less than 0.01
7b	Deciduous microphyll vine thicket on ranges and heavy clay alluvia in northern bioregions. (land zones 3, 12, 11, 10, 7) (CYP, WET)	13.6	0.02
8a	Wet tall open forest dominated by species such as Eucalyptus grandis (flooded gum) or E. saligna, E. resinifera (red mahogany), Lophostemon confertus (brush box), Syncarpia glomulifera (turpentine), E. laevopinea (silvertop stringybark). Contains a well developed understorey of rainforest components, including ferns and palms, or the understorey may be dominated by sclerophyll shrubs. (land zones 12, 8, 10, 11, 3, 5, 9) (SEQ, WET, BRB, CQC, [NET])	543.75	0.93
9b	Moist to dry woodlands dominated by Eucalyptus platyphylla (poplar gum) and/or E. leptophleba (Molloy red box). Other frequent tree species include Corymbia clarksoniana (grey bloodwood), E. drepanophylla (grey ironbark) and occasionally E. chlorophylla. (land zones 12, 11, 3, 10, 5). (CYP, CQC, BRB, WET, EIU)	119.93	0.2
9c	Open forests of Corymbia clarksoniana (grey bloodwood) (or C. intermedia (pink bloodwood) or C. novoguinensis), C. tessellaris (carbeen) +/- Eucalyptus tereticornis (blue gum) predominantly on coastal ranges. Other frequent tree species include Eucalyptus drepanophylla (grey ironbark), E. pellita (large-fruited red mahogany), E. brassiana (Cape York red gum) and Lophostemon suaveolens (swamp box). (land zones 12, 11, 8, 5). (WET, CQC, CYP, BRB)	271.51	0.46
9d	Moist to dry open forest to woodland dominated by Eucalyptus portuensis, Corymbia intermedia (pink bloodwood), E. drepanophylla, E. resinifera or E. reducta +/- Syncarpia glomulifera (turpentine) or E. cloeziana (Gympie messmate) on ranges. Also includes mixed forests with Eucalyptus pellita or Corymbia torelliana emergents and rainforest understories (land zones 12, 11, 3, 9, 5, 8). (CQC, WET, EIU)	1,530.08	2.6
9e	Open forests, woodlands and open woodlands dominated by Corymbia clarksoniana (grey bloodwood) (or C. novoguinensis or C. intermedia (pink bloodwood) or C. polycarpa (long-fruited bloodwood)) frequently with Erythrophleum chlorostachys (red ironwood) or Eucalyptus platyphylla (poplar gum) predominantly on coastal sandplains and alluvia. (land zones 3, 5, 2) (CYP, BRB, CQC, WET, EIU)	3,214.51	5.47

Refer to **Map 4** for further information. **Map 5** also provides a representation of the distribution of vegetation communities as per the 1:5,000,000 BVG believed to be present prior to European settlement.

4. Technical and BioCondition Benchmark Descriptions

Technical descriptions provide a detailed description of the full range in structure and floristic composition of regional ecosystems (e.g. 11.3.1) and their component vegetation communities (e.g. 11.3.1a, 11.3.1b). See:

http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/technical-descriptions/

The descriptions are compiled using site survey data from the Queensland Herbarium's CORVEG database. Distribution maps, representative images (if available) and the pre-clearing and remnant extent (hectares) of each vegetation community derived from the regional ecosystem mapping data are included. The technical descriptions should be used in conjunction with the fields from the regional ecosystem description database (REDD) for a full description of the regional ecosystem.

Technical descriptions include data on canopy height, canopy cover and native plant species composition of the predominant layer, which are attributes relevant to assessment of the remnant status of vegetation under the *Vegetation Management Act 1999*. However, as technical descriptions reflect the full range in structure and floristic composition across the climatic, natural disturbance and geographic range of the regional ecosystem, local reference sites should be used for remnant assessment where possible (Neldner et al. 2020 (PDF)* section 3.3 of:

https://publications.qld.gov.au/dataset/redd/resource/

The technical descriptions are subject to review and are updated as additional data becomes available.

When conducting a BioCondition assessment, these technical descriptions should be used in conjunction with BioCondition benchmarks for the specific regional ecosystem, or component vegetation community.

http://www.qld.gov.au/environment/plants-animals/biodiversity/benchmarks/

Benchmarks are based on a combination of quantitative and qualitative information and should be used as a guide only. Benchmarks are specific to one regional ecosystem vegetation community, however, the natural variability in structure and floristic composition under a range of climatic and natural disturbance regimes has been considered throughout the geographic extent of the regional ecosystem. Local reference sites should be used for this spatial and temporal (seasonal and annual) variability.

Table 7: List of remnant regional ecosystems within the AOI for which technical and biocondition benchmark descriptions are available

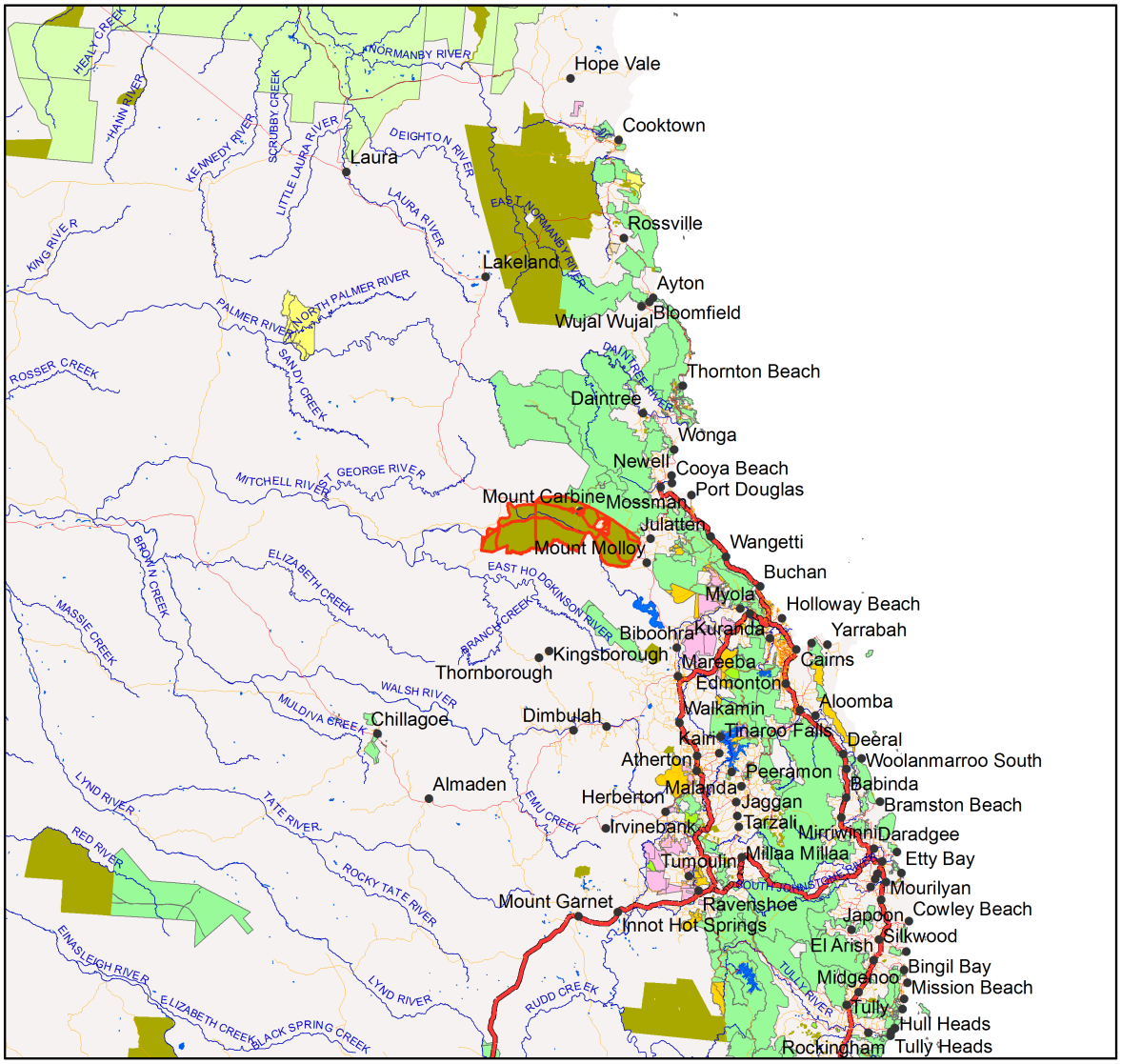
Regional ecosystems mapped as within the AOI	Technical Descriptions	Biocondition Benchmarks
7.11.1a	Not currently available	Not currently available
7.11.44	Not currently available	Not currently available
7.11.51a	Not currently available	Not currently available
7.12.16a	Not currently available	Not currently available
7.12.16b	Not currently available	Not currently available
7.12.16c	Not currently available	Not currently available
7.12.19a	Not currently available	Not currently available
7.12.1a	Not currently available	Not currently available
7.12.1b	Not currently available	Not currently available
7.12.21a	Not currently available	Not currently available
7.12.21b	Not currently available	Not currently available
7.12.22a	Not currently available	Not currently available
7.12.22b	Not currently available	Not currently available
7.12.24a	Not currently available	Not currently available
7.12.30a	Not currently available	Not currently available
7.12.30b	Not currently available	Not currently available
7.12.34	Not currently available	Not currently available

Regional ecosystems mapped as within the AOI	Technical Descriptions	Biocondition Benchmarks
7.12.37i	Not currently available	Not currently available
7.12.48	Not currently available	Not currently available
7.12.57	Not currently available	Not currently available
7.12.57a	Not currently available	Not currently available
7.12.58	Not currently available	Not currently available
7.12.5c	Not currently available	Not currently available
7.12.61a	Not currently available	Not currently available
7.12.62c	Not currently available	Not currently available
7.12.65e	Not currently available	Not currently available
7.12.65f	Not currently available	Not currently available
7.12.65k	Not currently available	Not currently available
7.12.66a	Not currently available	Not currently available
7.12.66b	Not currently available	Not currently available
7.12.69b	Not currently available	Not currently available
7.12.7a	Not currently available	Not currently available
7.12.9	Not currently available	Not currently available
7.3.14a	Not currently available	Not currently available
7.3.28d	Not currently available	Not currently available
7.3.49a	Not currently available	Not currently available
9.11.25	Available	Available
9.11.26a	Available	Not currently available
9.11.3a	Available	Available
9.11.3b	Available	Not currently available
9.11.3d	Available	Not currently available
9.11.7a	Available	Not currently available
9.11.7b	Available	Not currently available
9.12.17	Available	Not currently available
9.12.2	Available	Not currently available
9.12.31a	Available	Not currently available
9.12.43a	Not currently available	Not currently available
9.12.43b	Not currently available	Not currently available
9.12.7a	Available	Not currently available
9.12.7c	Available	Not currently available
9.12.8a	Not currently available	Not currently available
9.3.12a	Available	Not currently available
9.3.12b	Not currently available	Not currently available
9.3.13	Available	Not currently available
9.3.14a	Available	Not currently available
9.3.16	Available	Not currently available
9.3.2	Available	Not currently available
9.3.3c	Available	Not currently available

Regional ecosystems mapped as within the AOI	Technical Descriptions	Biocondition Benchmarks
9.3.4	Available	Not currently available
9.3.6a	Available	Not currently available
9.5.12	Available	Not currently available
9.5.13a	Available	Not currently available
9.5.15a	Available	Not currently available
9.5.9b	Available	Not currently available
9.5.9c	Available	Not currently available
non-remnant	Not currently available	Not currently available
water	Not currently available	Not currently available

Maps

Map 1 - Location



Locality Map

Legend

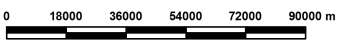
- Selected Lot and Plan
- Towns
- Highway
- Connector
- Street/Local Road
- Reservoirs
- Lakes
- National Park (Scientific)
- National Park
- National Park (CYPAL)
- Conservation Park
- Resources Reserve
- Forest Reserve
- State Forest
- Timber Reserve
- Nature Refuges
- Coordinated Conservation Areas
- Major rivers/creeks
- Queensland





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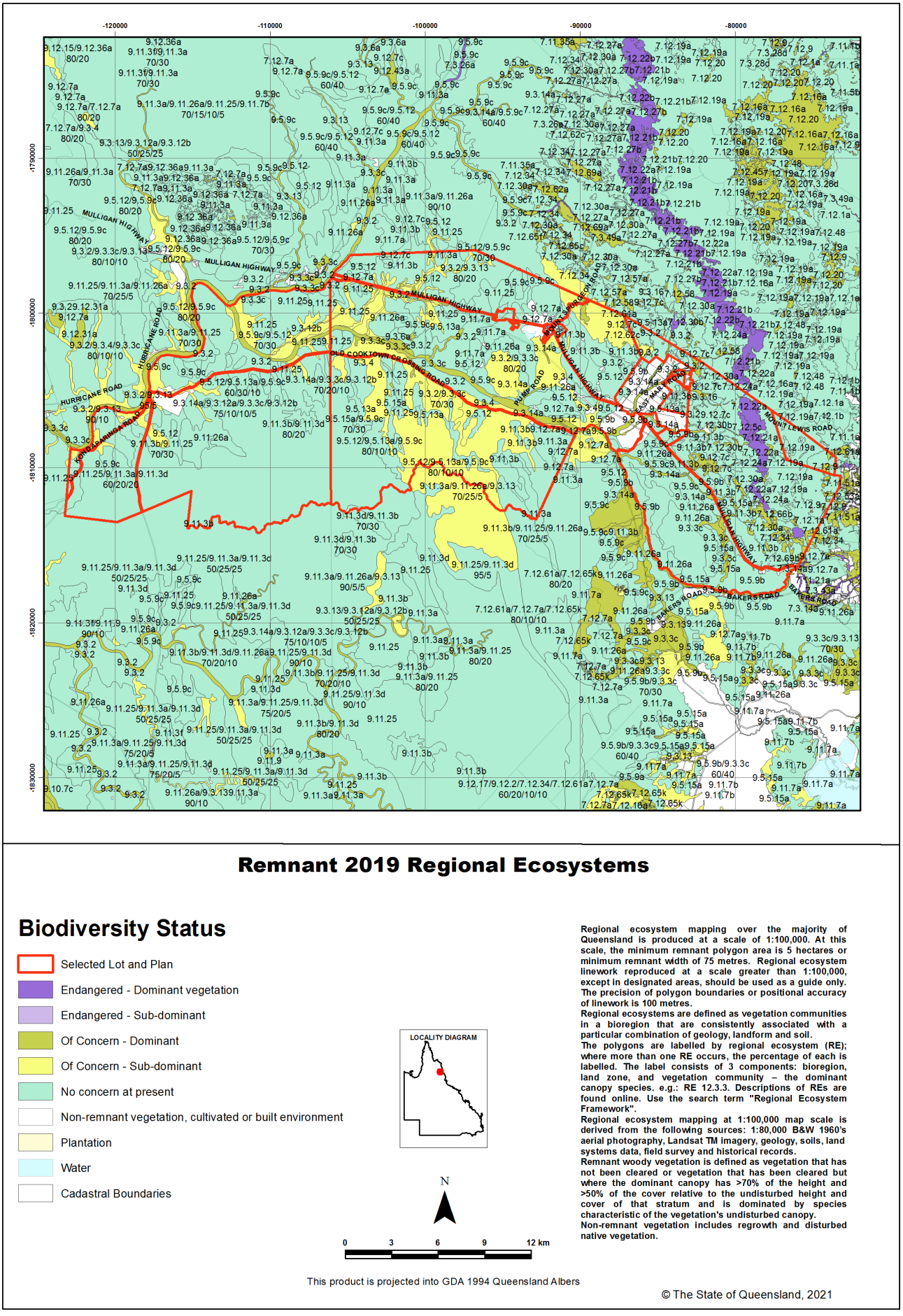
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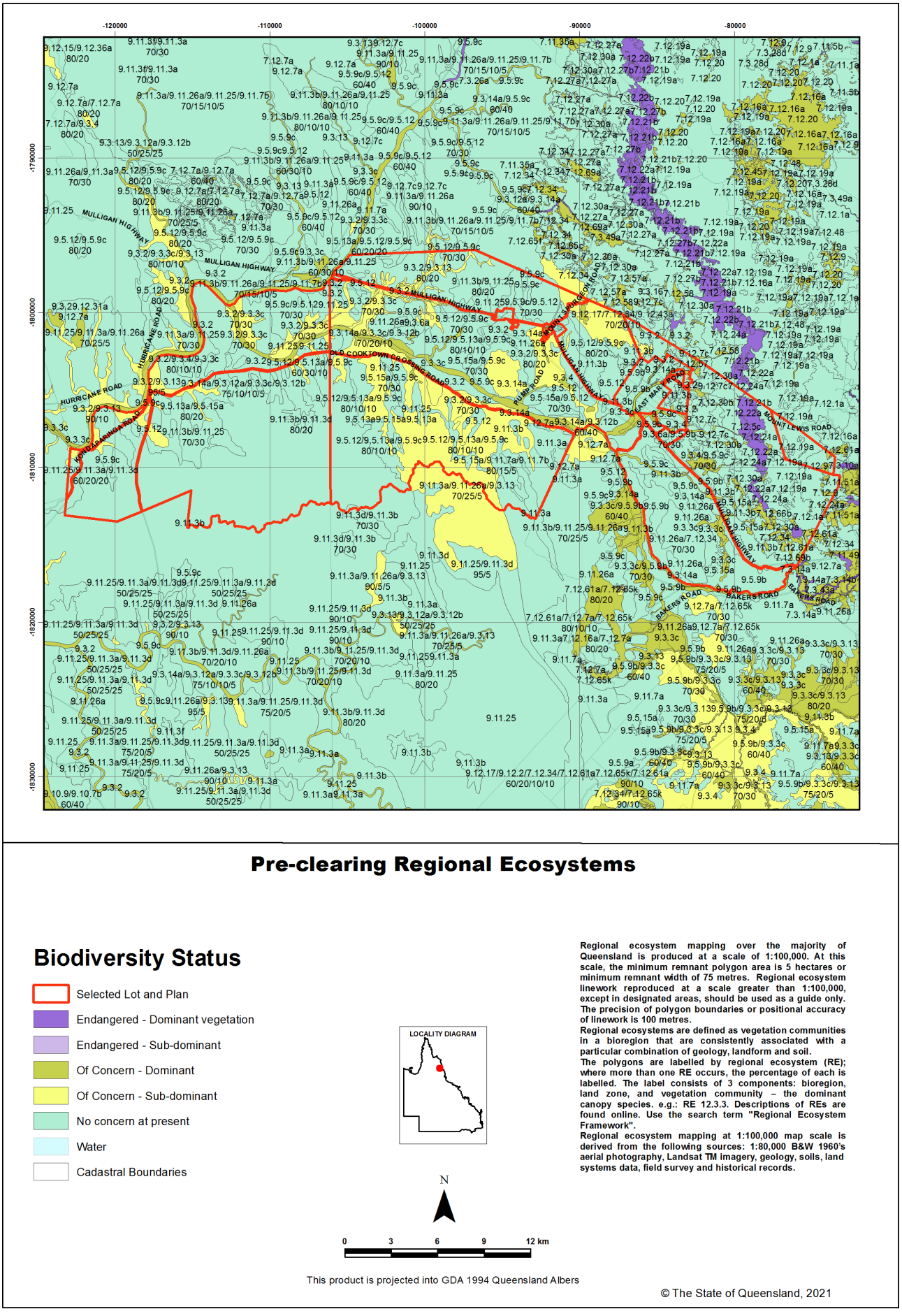
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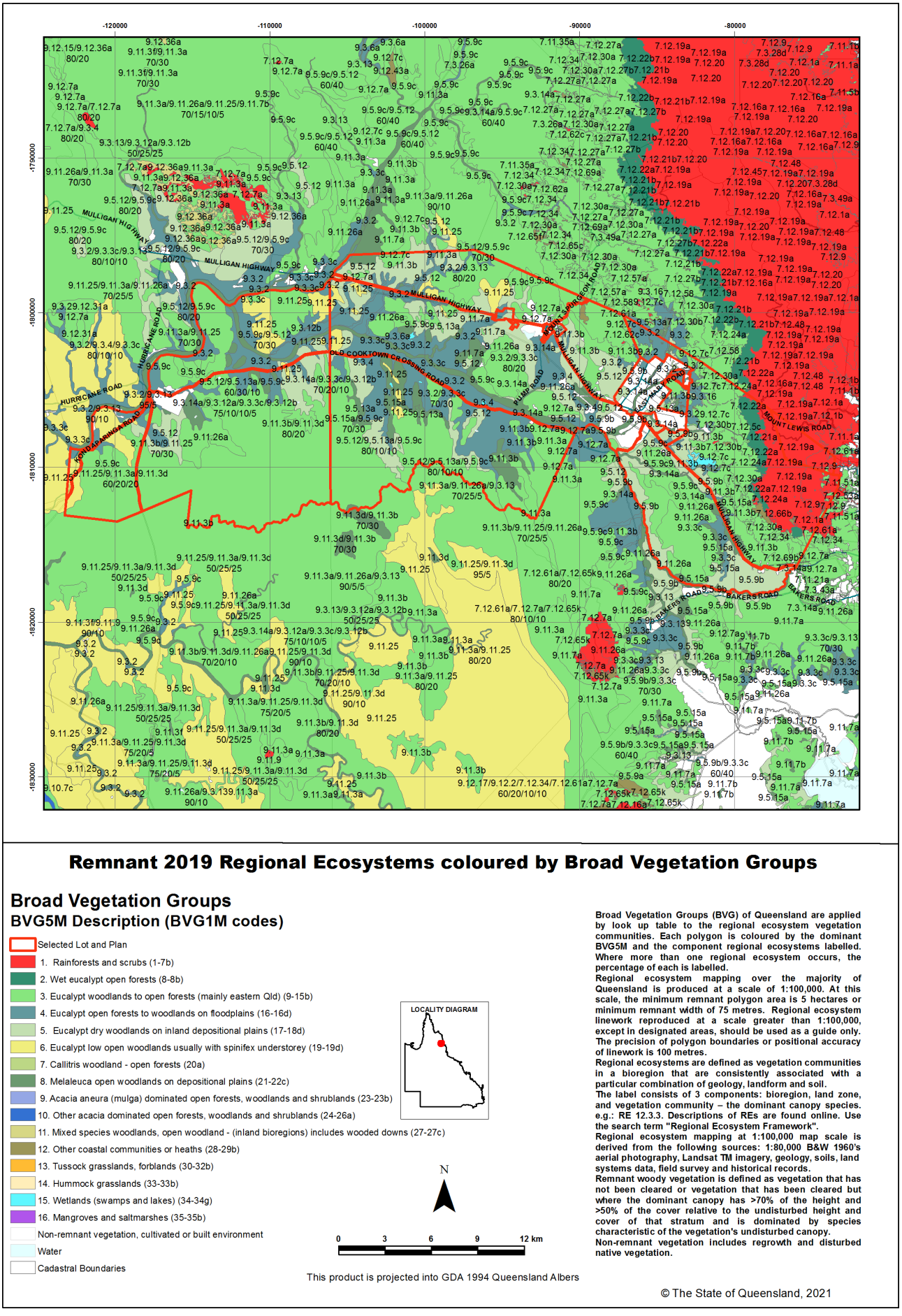
Map 2 - Remnant 2019 regional ecosystems



Map 3 - Pre-clearing regional ecosystems



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



Remnant 2019 Regional Ecosystems coloured by Broad Vegetation Groups

Broad Vegetation Groups
BVG5M Description (BVG1M codes)

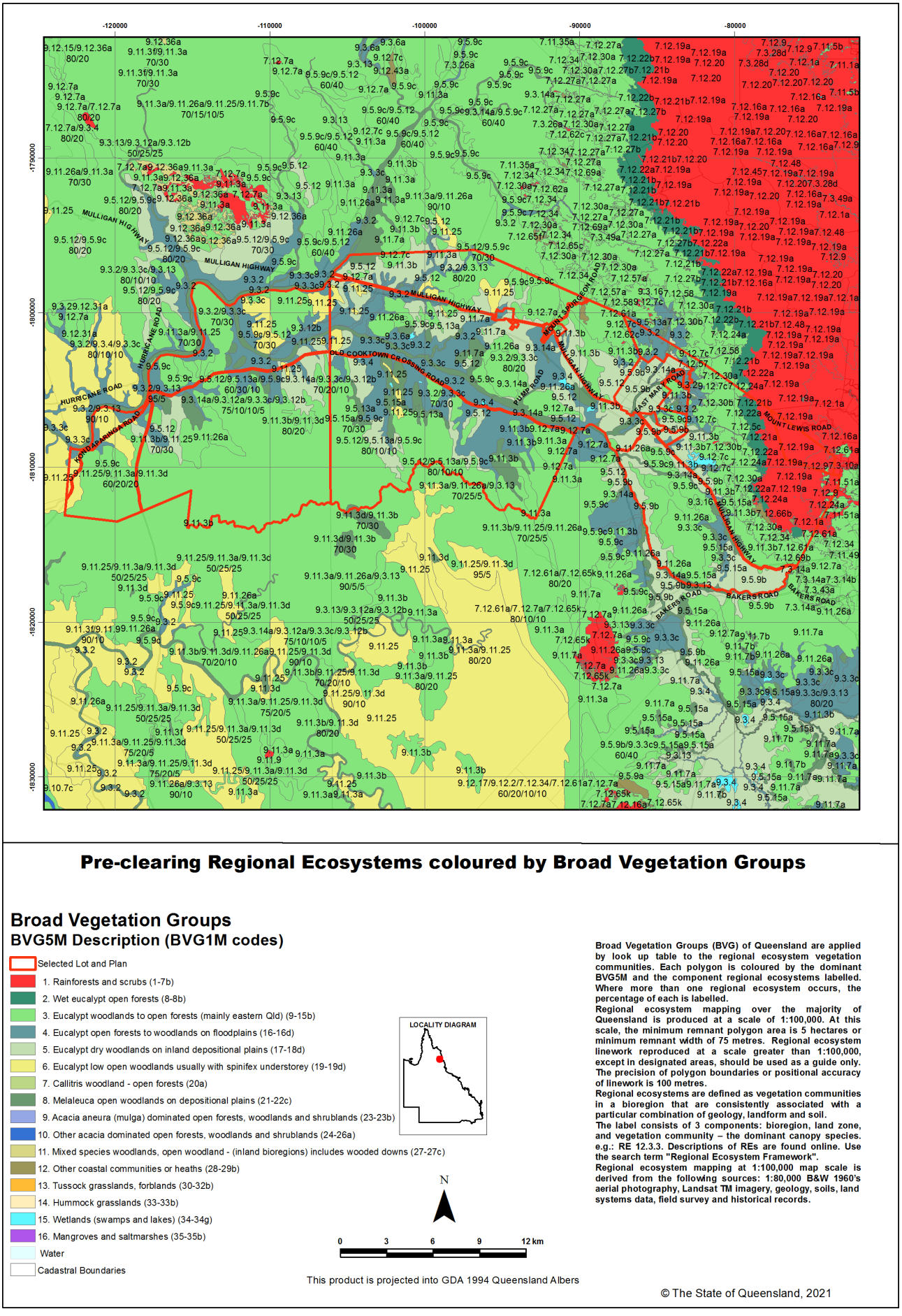
- Selected Lot and Plan
- 1. Rainforests and scrubs (1-7b)
- 2. Wet eucalypt open forests (8-8b)
- 3. Eucalypt woodlands to open forests (mainly eastern Qld) (9-15b)
- 4. Eucalypt open forests to woodlands on floodplains (16-16d)
- 5. Eucalypt dry woodlands on inland depositional plains (17-18d)
- 6. Eucalypt low open woodlands usually with spinifex understorey (19-19d)
- 7. Callitris woodland - open forests (20a)
- 8. Melaleuca open woodlands on depositional plains (21-22c)
- 9. Acacia aneura (mulga) dominated open forests, woodlands and shrublands (23-23b)
- 10. Other acacia dominated open forests, woodlands and shrublands (24-26a)
- 11. Mixed species woodlands, open woodland - (inland bioregions) includes wooded downs (27-27c)
- 12. Other coastal communities or heaths (28-29b)
- 13. Tussock grasslands, forblands (30-32b)
- 14. Hummock grasslands (33-33b)
- 15. Wetlands (swamps and lakes) (34-34g)
- 16. Mangroves and saltmarshes (35-35b)
- Non-remnant vegetation, cultivated or built environment
- Water
- Cadastral Boundaries

This product is projected into GDA 1994 Queensland Albers

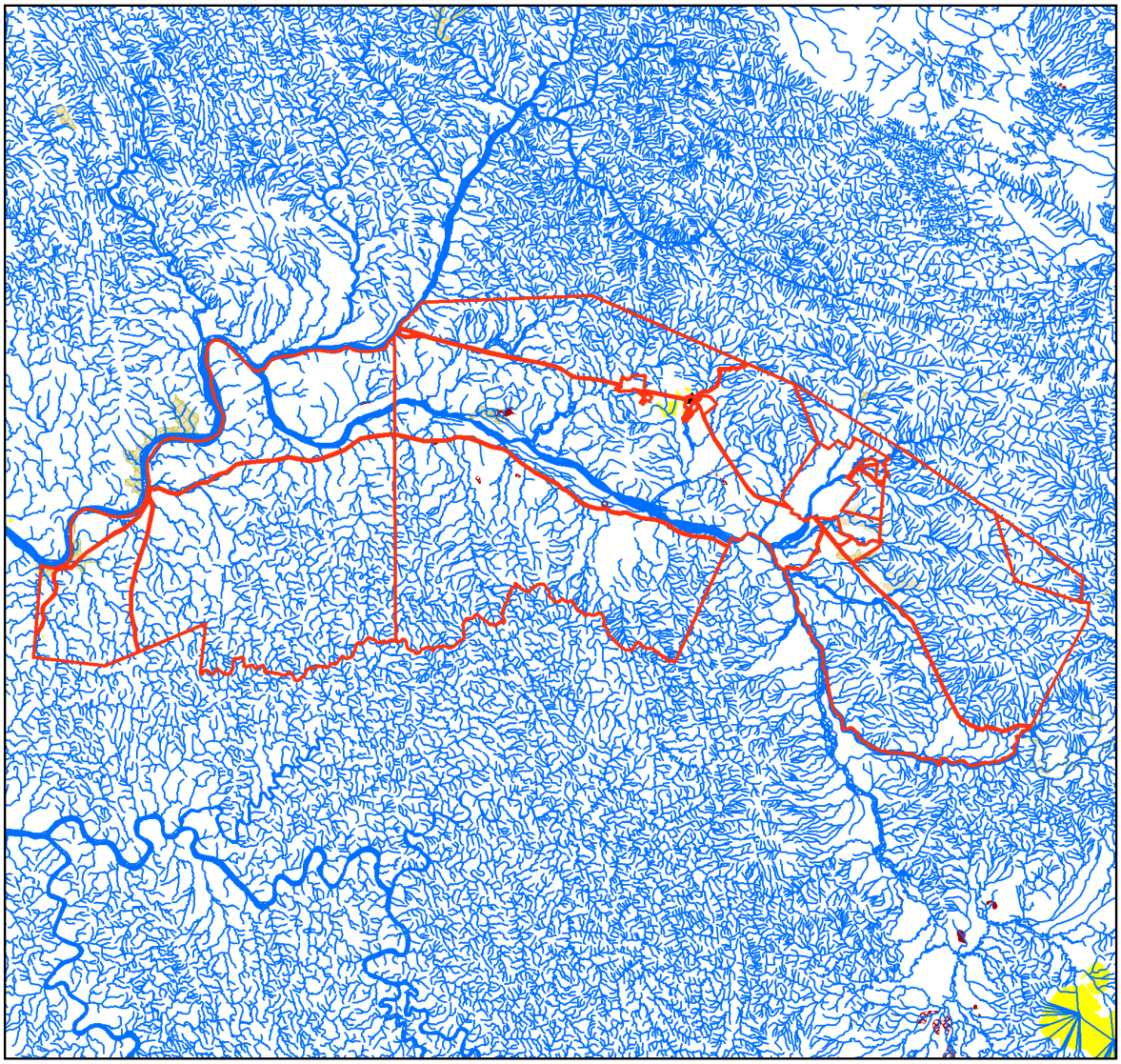
Broad Vegetation Groups (BVG) of Queensland are applied by look up table to the regional ecosystem vegetation communities. Each polygon is coloured by the dominant BVG5M and the component regional ecosystems labelled. Where more than one regional ecosystem occurs, the percentage of each is labelled.
Regional ecosystem mapping over the majority of Queensland is produced at a scale of 1:100,000. At this scale, the minimum remnant polygon area is 5 hectares or minimum remnant width of 75 metres. Regional ecosystem linework reproduced at a scale greater than 1:100,000, except in designated areas, should be used as a guide only. The precision of polygon boundaries or positional accuracy of linework is 100 metres.
Regional ecosystems are defined as vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform and soil.
The label consists of 3 components: bioregion, land zone, and vegetation community – the dominant canopy species. e.g.: RE 12.3.3. Descriptions of REs are found online. Use the search term "Regional Ecosystem Framework".
Regional ecosystem mapping at 1:100,000 map scale is derived from the following sources: 1:80,000 B&W 1960's aerial photography, Landsat TM imagery, geology, soils, land systems data, field survey and historical records.
Remnant woody vegetation is defined as vegetation that has not been cleared or vegetation that has been cleared but where the dominant canopy has >70% of the height and >50% of the cover relative to the undisturbed height and cover of that stratum and is dominated by species characteristic of the vegetation's undisturbed canopy.
Non-remnant vegetation includes regrowth and disturbed native vegetation.

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Map 5 - Pre-clearing regional ecosystems by BVG (5M)



Map 6 - Wetlands and waterways



Queensland Wetland Data

Legend

- Selected Lot and Plan
- Towns

Queensland Wetland Data

- Riverine Drainage Lines
- Springs

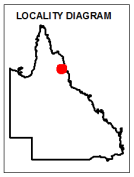
Wetland System - Water Bodies

- Marine Waterbodies
- Estuarine Waterbodies
- Riverine Waterbodies
- Lacustrine Waterbodies
- Palustrine Waterbodies

Wetland System - Regional Ecosystems

- Marine RE
- Estuarine RE
- Riverine RE
- Lacustrine RE
- Palustrine RE
- RE 51-80% wetland (mosaic units)
- RE 1-50% wetland (mosaic units)

LOCALITY DIAGRAM



N

0 2800 5600 8400 11200 14000 m

Accuracy information: The positional accuracy of wetland data mapped at a scale of 1:100,000 is +/-100m with a minimum polygon size of 5ha or 75m wide for linear features, except for areas along the east coa st which are mapped at the 1:50,000 scale with a positional accuracy of +/-50m, with a minimum polygon size of 1ha or 35m wide for linear features. Wetlands smaller than 1ha are not delineated on the wetland data. Consideration of the effects of mapped scale is necessary when interpret ing data at a larger scale, e.g. 1:25,000. For property assessment, digital linework should be used as a guide only. The extent of wetlands depicted on this map is based on rectified 2013 Landsat ETM+ imagery supplied by Statewide Landcover and Trees Study (SLATS), Department of Environment and Science. The extent of water bodies is based on the maximum extent of inundation derived from available Landsat imagery up to and including the 2013 imagery.

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This product is projected into GDA 1994 Queensland Albers

Links and Other Information Sources

The Department of Environment and Science's Website -

http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/

provides further information on the regional ecosystem framework, including access to links to the Regional Ecosystem Database, Broad Vegetation Group Definitions, Regional Ecosystem and Land zone descriptions.

Descriptions of the broad vegetation groups of Queensland can be downloaded from:

https://publications.qld.gov.au/dataset/redd/resource/

The methodology for mapping regional ecosystems can be downloaded from:

https://publications.qld.gov.au/dataset/redd/resource/

Technical descriptions for regional ecosystems can be obtained from:

http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/technical-descriptions/

Benchmarks can be obtained from:

http://www.qld.gov.au/environment/plants-animals/biodiversity/benchmarks/

For further information associated with the remnant regional ecosystem dataset used by this report, refer to the metadata associated with the Biodiversity status of pre-clearing and Remnant Regional Ecosystems of Queensland dataset (version listed in **Appendix 1**) which is available through the Queensland Government Information System portal,

http://dds.information.qld.gov.au/dds/

The Queensland Globe is a mapping and data application. As an interactive online tool, Queensland Globe allows you to view and explore Queensland maps, imagery (including up-to-date satellite images) and other spatial data, including regional ecosystem mapping. To further view and explore regional ecosystems over an area of interest, access the Biota Globe (a component of the Queensland Globe). The Queensland Globe can be accessed via the following link:

http://www.dnrm.qld.gov.au/mapping-data/queensland-globe

References

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Neldner, V.J., Wilson, B.A., Dillewaard, H.A., Ryan, T.S., Butler, D.W., McDonald, W.J.F, Addicott, E.P. and Appelman, C.N. (2020). Methodology for survey and mapping of regional ecosystems and vegetation communities in Queensland. Version 5.1. Updated March 2020. Queensland Herbarium, Queensland Department of Environment and Science, Brisbane.

(https://publications.qld.gov.au/dataset/redd/resource/6dee78ab-c12c-4692-9842-b7257c2511e4)

Sattler, P.S. and Williams, R.D. (eds) (1999). *The Conservation Status of Queensland's Bioregional Ecosystems*. Environmental Protection Agency, Brisbane.

Appendices

Appendix 1 - Source Data

The dataset listed below is available for download from:

http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/download/

- Regional Ecosystem Description Database

The datasets listed below are available for download from:

http://dds.information.qld.gov.au/dds/

- Biodiversity status of pre-clearing and 2019 remnant regional ecosystems of Queensland
- Pre-clearing Vegetation Communities and Regional Ecosystems of Queensland
- Queensland Wetland Data Version - Wetland lines
- Queensland Wetland Data Version - Wetland points
- Queensland Wetland Data Version - Wetland areas

Appendix 2 - Acronyms and Abbreviations

AOI	- Area of Interest
GDA94	- Geocentric Datum of Australia 1994
GIS	- Geographic Information System
RE	- Regional Ecosystem
REDD	- Regional Ecosystem Description Database
VMA	- *Vegetation Management Act 1999*

APPENDIX F – EPBC ACT PROTECTED MATTERS REPORT

TAILINGS.WATER.WASTE.

Australian Government

Department of Agriculture, Water and the Environment

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

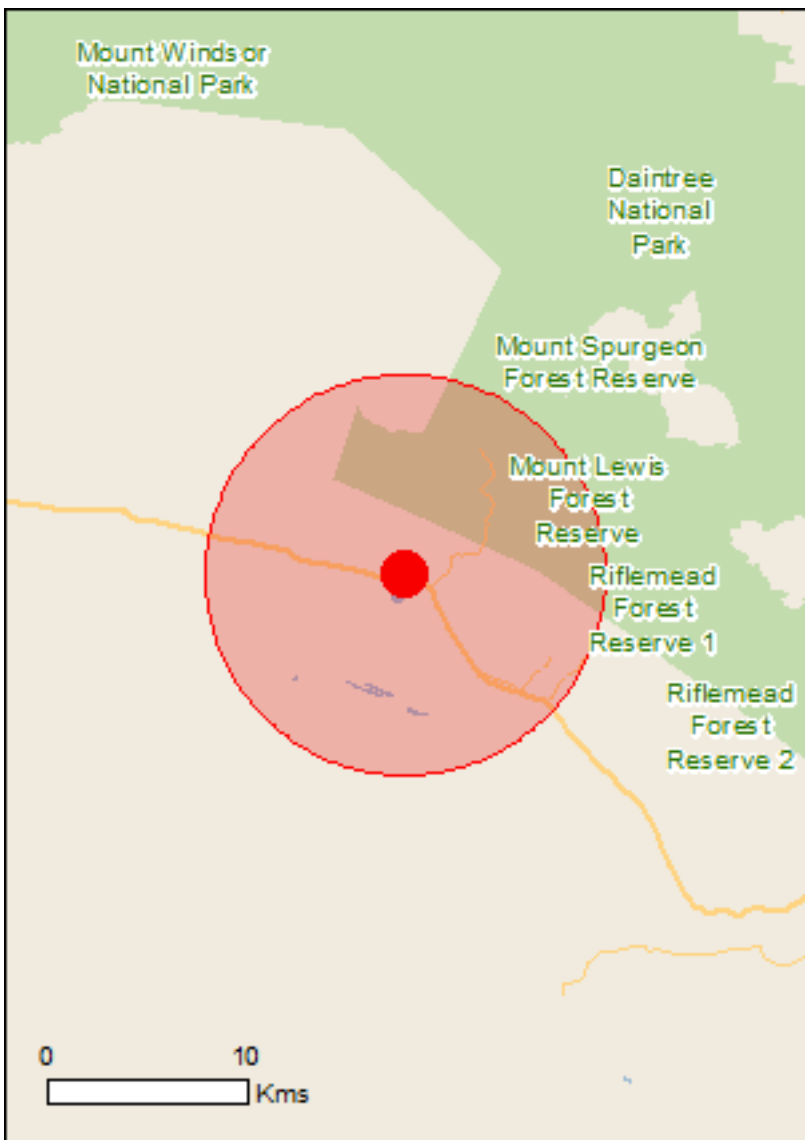
Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

Report created: 04/11/21 12:41:09

Summary
Details
- Matters of NES
- Other Matters Protected by the EPBC Act
- Extra Information

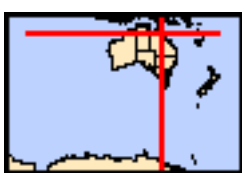
Caveat
Acknowledgements



This map may contain data which are ©Commonwealth of Australia (Geoscience Australia), ©PSMA 2015

Coordinates

Buffer: 10.0Km



Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	1
National Heritage Places:	2
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	None
Listed Threatened Ecological Communities:	1
Listed Threatened Species:	42
Listed Migratory Species:	20

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	None
Commonwealth Heritage Places:	None
Listed Marine Species:	26
Whales and Other Cetaceans:	None
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	3
Regional Forest Agreements:	None
Invasive Species:	26
Nationally Important Wetlands:	None
Key Ecological Features (Marine)	None

Details

Matters of National Environmental Significance

World Heritage Properties		[Resource Information]
Name	State	Status
Wet Tropics of Queensland	QLD	Declared property

National Heritage Properties		[Resource Information]
Name	State	Status
Natural		
Wet Tropics of Queensland	QLD	Listed place
Indigenous		
Wet Tropics World Heritage Area (Indigenous Values)	QLD	Within listed place

Listed Threatened Ecological Communities		[Resource Information]

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Name	Status	Type of Presence
Broad leaf tea-tree (Melaleuca viridiflora) woodlands in high rainfall coastal north Queensland	Endangered	Community may occur within area

Listed Threatened Species		[Resource Information]
Name	Status	Type of Presence
Birds		
Calidris ferruginea		
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat likely to occur within area
Casuarius casuarius johnsonii		
Southern Cassowary, Australian Cassowary, Double-wattled Cassowary [25986]	Endangered	Species or species habitat likely to occur within area
Erythrotriorchis radiatus		
Red Goshawk [942]	Vulnerable	Species or species habitat known to occur within area
Erythrura gouldiae		
Gouldian Finch [413]	Endangered	Species or species habitat likely to occur within area
Falco hypoleucos		
Grey Falcon [929]	Vulnerable	Species or species habitat known to occur within area
Hirundapus caudacutus		
White-throated Needletail [682]	Vulnerable	Species or species habitat known to occur within area
Numenius madagascariensis		
Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Rostratula australis		
Australian Painted Snipe [77037]	Endangered	Species or species habitat known to occur within area
Turnix olivii		
Buff-breasted Button-quail [59293]	Endangered	Species or species

Name	Status	Type of Presence
		habitat likely to occur within area
Tyto novaehollandiae kimberli Masked Owl (northern) [26048]	Vulnerable	Species or species habitat likely to occur within area
Frogs		
Cophixalus aenigma Tapping Nursery-frog [79086]	Endangered	Species or species habitat known to occur within area
Litoria dayi Australian Lace-lid, Lace-eyed Tree Frog, Day's Big-eyed Treefrog [86707]	Vulnerable	Species or species habitat likely to occur within area
Litoria lorica Armoured Mistfrog [1841]	Critically Endangered	Species or species habitat known to occur within area
Litoria nyakalensis Mountain Mistfrog, Nyakala Frog [1820]	Critically Endangered	Species or species habitat likely to occur within area
Mammals		
Bettongia tropica Northern Bettong [214]	Endangered	Species or species habitat likely to occur within area
Dasyurus hallucatus Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu] [331]	Endangered	Species or species habitat known to occur within area
Hipposideros semoni Semon's Leaf-nosed Bat, Greater Wart-nosed Horseshoe-bat [180]	Vulnerable	Species or species habitat may occur within area
Macroderma gigas Ghost Bat [174]	Vulnerable	Species or species habitat likely to occur within area
Mesembriomys gouldii rattoides Black-footed Tree-rat (north Queensland), Shaggy Rabbit-rat [87620]	Vulnerable	Species or species habitat likely to occur within area
Petauroides volans Greater Glider [254]	Vulnerable	Species or species habitat likely to occur within area
Petaurus australis Wet Tropics subspecies Yellow-bellied Glider (Wet Tropics), Fluffy Glider [88022]	Endangered	Foraging, feeding or related behaviour known to occur within area
Phascolarctos cinereus (combined populations of Qld, NSW and the ACT) Koala (combined populations of Queensland, New South Wales and the Australian Capital Territory) [85104]	Vulnerable	Species or species habitat likely to occur within area
Pteropus conspicillatus Spectacled Flying-fox [185]	Endangered	Species or species habitat known to occur within area
Rhinolophus robertsi Large-eared Horseshoe Bat, Greater Large-eared Horseshoe Bat [87639]	Vulnerable	Species or species habitat likely to occur within area
Saccolaimus saccolaimus nudicluniatus Bare-rumped Sheath-tailed Bat, Bare-rumped Sheathtail Bat [66889]	Vulnerable	Species or species habitat likely to occur within area
Plants		
Acriopsis emarginata Pale Chandelier Orchid [83928]	Vulnerable	Species or species habitat may occur within area

Name	Status	Type of Presence
Arthraxon hispidus Hairy-joint Grass [9338]	Vulnerable	Species or species habitat may occur within area
Cepobaculum carronii an orchid [78700]	Vulnerable	Species or species habitat likely to occur within area
Cycas platyphylla a cycad [55796]	Vulnerable	Species or species habitat may occur within area
Cyclophyllum costatum a shrub [82770]	Vulnerable	Species or species habitat may occur within area
Dichanthium setosum bluegrass [14159]	Vulnerable	Species or species habitat likely to occur within area
Macropteranthes montana [9003]	Vulnerable	Species or species habitat likely to occur within area
Oreogrammitis reinwardtii [83552]	Vulnerable	Species or species habitat may occur within area
Phaius australis Lesser Swamp-orchid [5872]	Endangered	Species or species habitat may occur within area
Phaleria biflora [82049]	Vulnerable	Species or species habitat likely to occur within area
Prostanthera albohirta [82052]	Critically Endangered	Species or species habitat may occur within area
Tomophyllum walleri [83507]	Vulnerable	Species or species habitat likely to occur within area
Tropilis callitrophilis Thin Feather Orchid [82771]	Vulnerable	Species or species habitat may occur within area
Vappodes lithocola Dwarf Butterfly Orchid, Cooktown Orchid [78893]	Endangered	Species or species habitat known to occur within area
Vappodes phalaenopsis Cooktown Orchid [78894]	Vulnerable	Species or species habitat may occur within area
Zeuxine polygonoides Velvet Jewel Orchid [46794]	Vulnerable	Species or species habitat may occur within area
Reptiles		
Egernia rugosa Yakka Skink [1420]	Vulnerable	Species or species habitat may occur within area

Listed Migratory Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur

Name	Threatened	Type of Presence within area
Migratory Terrestrial Species		
[Cecropis daurica](#) Red-rumped Swallow [80610]		Species or species habitat may occur within area
[Cuculus optatus](#) Oriental Cuckoo, Horsfield's Cuckoo [86651]		Species or species habitat known to occur within area
[Hirundapus caudacutus](#) White-throated Needletail [682]	Vulnerable	Species or species habitat known to occur within area
[Hirundo rustica](#) Barn Swallow [662]		Species or species habitat may occur within area
[Monarcha frater](#) Black-winged Monarch [607]		Species or species habitat may occur within area
[Monarcha melanopsis](#) Black-faced Monarch [609]		Species or species habitat known to occur within area
[Monarcha trivirgatus](#) Spectacled Monarch [610]		Species or species habitat likely to occur within area
[Motacilla cinerea](#) Grey Wagtail [642]		Species or species habitat known to occur within area
[Motacilla flava](#) Yellow Wagtail [644]		Species or species habitat likely to occur within area
[Myiagra cyanoleuca](#) Satin Flycatcher [612]		Species or species habitat likely to occur within area
[Rhipidura rufifrons](#) Rufous Fantail [592]		Species or species habitat known to occur within area
Migratory Wetlands Species		
[Actitis hypoleucos](#) Common Sandpiper [59309]		Species or species habitat known to occur within area
[Calidris acuminata](#) Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
[Calidris ferruginea](#) Curlew Sandpiper [856]	Critically Endangered	Species or species habitat likely to occur within area
[Calidris melanotos](#) Pectoral Sandpiper [858]		Species or species habitat may occur within area
[Gallinago hardwickii](#) Latham's Snipe, Japanese Snipe [863]		Species or species habitat known to occur within area
[Numenius madagascariensis](#) Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
[Pandion haliaetus](#) Osprey [952]		Species or species

Name	Threatened	Type of Presence
		habitat known to occur within area
Tringa nebularia		
Common Greenshank, Greenshank [832]		Species or species habitat likely to occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species		[Resource Information]
* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.		
Name	Threatened	Type of Presence
Birds		
Actitis hypoleucos		
Common Sandpiper [59309]		Species or species habitat known to occur within area
Anseranas semipalmata		
Magpie Goose [978]		Species or species habitat may occur within area
Apus pacificus		
Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea ibis		
Cattle Egret [59542]		Species or species habitat may occur within area
Calidris acuminata		
Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area
Calidris ferruginea		
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat likely to occur within area
Calidris melanotos		
Pectoral Sandpiper [858]		Species or species habitat may occur within area
Chrysococcyx osculans		
Black-eared Cuckoo [705]		Species or species habitat may occur within area
Gallinago hardwickii		
Latham's Snipe, Japanese Snipe [863]		Species or species habitat known to occur within area
Haliaeetus leucogaster		
White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area

Name	Threatened	Type of Presence
Hirundapus caudacutus White-throated Needletail [682]	Vulnerable	Species or species habitat known to occur within area
Hirundo daurica Red-rumped Swallow [59480]		Species or species habitat may occur within area
Hirundo rustica Barn Swallow [662]		Species or species habitat may occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area
Monarcha frater Black-winged Monarch [607]		Species or species habitat may occur within area
Monarcha melanopsis Black-faced Monarch [609]		Species or species habitat known to occur within area
Monarcha trivirgatus Spectacled Monarch [610]		Species or species habitat likely to occur within area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat known to occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat likely to occur within area
Myiagra cyanoleuca Satin Flycatcher [612]		Species or species habitat likely to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area
Pandion haliaetus Osprey [952]		Species or species habitat known to occur within area
Rhipidura rufifrons Rufous Fantail [592]		Species or species habitat known to occur within area
Rostratula benghalensis (sensu lato) Painted Snipe [889]	Endangered*	Species or species habitat known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat likely to occur within area
Reptiles		
Crocodylus johnstoni Freshwater Crocodile, Johnston's Crocodile, Johnstone's Crocodile [1773]		Species or species habitat may occur within area

Extra Information

State and Territory Reserves [Resource Information]

Name	State
Brooklyn	QLD
Brooklyn	QLD
Mount Lewis	QLD

Invasive Species [Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence
Birds		
Acridotheres tristis Common Myna, Indian Myna [387]		Species or species habitat likely to occur within area
Columba livia Rock Pigeon, Rock Dove, Domestic Pigeon [803]		Species or species habitat likely to occur within area
Lonchura punctulata Nutmeg Mannikin [399]		Species or species habitat likely to occur within area
Passer domesticus House Sparrow [405]		Species or species habitat likely to occur within area
Streptopelia chinensis Spotted Turtle-Dove [780]		Species or species habitat likely to occur within area
Sturnus vulgaris Common Starling [389]		Species or species habitat likely to occur within area
Frogs		
Rhinella marina Cane Toad [83218]		Species or species habitat known to occur within area
Mammals		
Canis lupus familiaris Domestic Dog [82654]		Species or species habitat likely to occur within area
Felis catus Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Mus musculus House Mouse [120]		Species or species habitat likely to occur within area
Oryctolagus cuniculus Rabbit, European Rabbit [128]		Species or species habitat likely to occur within area
Rattus rattus Black Rat, Ship Rat [84]		Species or species habitat likely to occur within area
Sus scrofa Pig [6]		Species or species habitat likely to occur within area

Name	Status	Type of Presence
Plants		
Acacia nilotica subsp. indica Prickly Acacia [6196]		Species or species habitat may occur within area
Andropogon gayanus Gamba Grass [66895]		Species or species habitat likely to occur within area
Annona glabra Pond Apple, Pond-apple Tree, Alligator Apple, Bullock's Heart, Cherimoya, Monkey Apple, Bobwood, Corkwood [6311]		Species or species habitat likely to occur within area
Asparagus plumosus Climbing Asparagus-fern [48993]		Species or species habitat likely to occur within area
Cenchrus ciliaris Buffel-grass, Black Buffel-grass [20213]		Species or species habitat may occur within area
Cryptostegia grandiflora Rubber Vine, Rubbervine, India Rubber Vine, India Rubbervine, Palay Rubbervine, Purple Allamanda [18913]		Species or species habitat likely to occur within area
Hymenachne amplexicaulis Hymenachne, Olive Hymenachne, Water Stargrass, West Indian Grass, West Indian Marsh Grass [31754]		Species or species habitat likely to occur within area
Lantana camara Lantana, Common Lantana, Kamara Lantana, Large-leaf Lantana, Pink Flowered Lantana, Red Flowered Lantana, Red-Flowered Sage, White Sage, Wild Sage [10892]		Species or species habitat likely to occur within area
Opuntia spp. Prickly Pears [82753]		Species or species habitat likely to occur within area
Parthenium hysterophorus Parthenium Weed, Bitter Weed, Carrot Grass, False Ragweed [19566]		Species or species habitat likely to occur within area
Salvinia molesta Salvinia, Giant Salvinia, Aquarium Watermoss, Kariba Weed [13665]		Species or species habitat likely to occur within area
Reptiles		
Hemidactylus frenatus Asian House Gecko [1708]		Species or species habitat likely to occur within area
Ramphotyphlops braminus Flowerpot Blind Snake, Brahminy Blind Snake, Cacing Besi [1258]		Species or species habitat may occur within area

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc). In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-16.52333 145.12559

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

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APPENDIX G – EROSION AND SEDIMENT CONTROL PLAN

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Environmental Approval & Compliance Solutions

Mt Carbine Project Erosion and Sediment Control Plan Update

Mt Carbine Quarries Pty Ltd

Document Control Summary

NRA Environmental Consultants

NRA Filepath:	F:\AAA\380_EQ Resources\380008_ESCP\380008.02 EQR ESCP update 2021\Rpt\EQR ESCP_R02.docx		
Status:	R02	**Date of Issue:**	27 April 2022
Project Manager:	Darcy Simpson		
Title:	Mt Carbine Project Erosion and Sediment Control Plan Update		
Client:	Mt Carbine Quarries Pty Ltd		
Client Contact:	Natasha Troughton, Administration Manager		
Copies Dispatched:	1 PDF via email		
Other Info or Requirements:	This R02 supersedes and replaces all previous documentation prepared.		

Report Summary	
Key Words	Mount Carbine, Mt Carbine Quarries Pty Ltd, MCQ, EQ Resources, EQR, Erosion and Sediment Control Plan, ESCP.
Abstract	This ESCP details the erosion and sediment control measures applicable to current operations at the Mt Carbine Project. It has been prepared based on Best Practice Erosion and Sediment Control guidelines (IECA 2008). The ESCP should be considered a live document and will require periodic review and update.

Citation
This report should be cited as: NRA 2022, *Mt Carbine Project Erosion and Sediment Control Plan Update*, R02, prepared by NRA Environmental Consultants for Mt Carbine Quarries Pty Ltd, 27 April 2022.

Quality Assurance					
Author	**Technical Review**	**Editor**	**Document Version**	**Approved for Issue by QA Manager**	
				Date	**Signature**
Darcy Simpson BSc-BEng(Env), RPEQ (#27080) CPESC-IT (#9664)	Tim Anderson MAgrSc, BAgrSc(Hons), CEnvP (#002), CPESC (#2723)	Nadine Hunt BA	R01	8/4/2022	NHunt
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1. Introduction

NRA Environmental Consultants (NRA) was commissioned by Mt Carbine Quarries Pty Ltd (MCQ) to update the Erosion and Sediment Control Plan (ESCP) for the Mt Carbine Project (the site). The ESCP is a requirement of Environmental Authority (EA) EPML00956913, dated 14 April 2022. EA Condition D13 states:

> *An Erosion and Sediment Control Plan must be developed by an appropriately qualified person and implemented before 1 November 2013, to minimise erosion, contamination of stormwater and the release of sediment to receiving waters.*

This ESCP has been prepared cognisant of the Department of Environment and Science guidance[1] and updates the previous Erosion and Sediment Control Plan (NRA 2013a), which is included in **Appendix A**.

1.1 Qualifications

The International Erosion Control Association (IECA) Best Practice Guidelines (IECA 2008) have been referred to for technical guidance on the erosion and sediment control (ESC) measures adopted.

This ESCP has been prepared by appropriately qualified persons who are Certified Professionals in Erosion and Sediment Control (CPESC):

- Darcy Simpson - CPESC-IT (#9664)
- Tim Anderson - CPESC (#2723).

1.2 Site description

The site is on mining leases 4867 and 4919 at Mount Carbine, approximately 80 km north-west of Cairns, in north Queensland (**Figure 1**). The site is within the existing disturbance area of an open cut and underground tungsten mine which operated in the 1970s and 1980s. In addition to mining activities, quarrying occurs on-site under EA EPPR00438313 (dated 16 March 2021), with the surrounding land use a mixture of residential (the township of Mount Carbine), conservation (Brooklyn Wildlife Sanctuary) and low intensity cattle grazing (NRA 2013b).

The site has a history of land degradation (QT 1993, NRA 2013a, 2013b,).

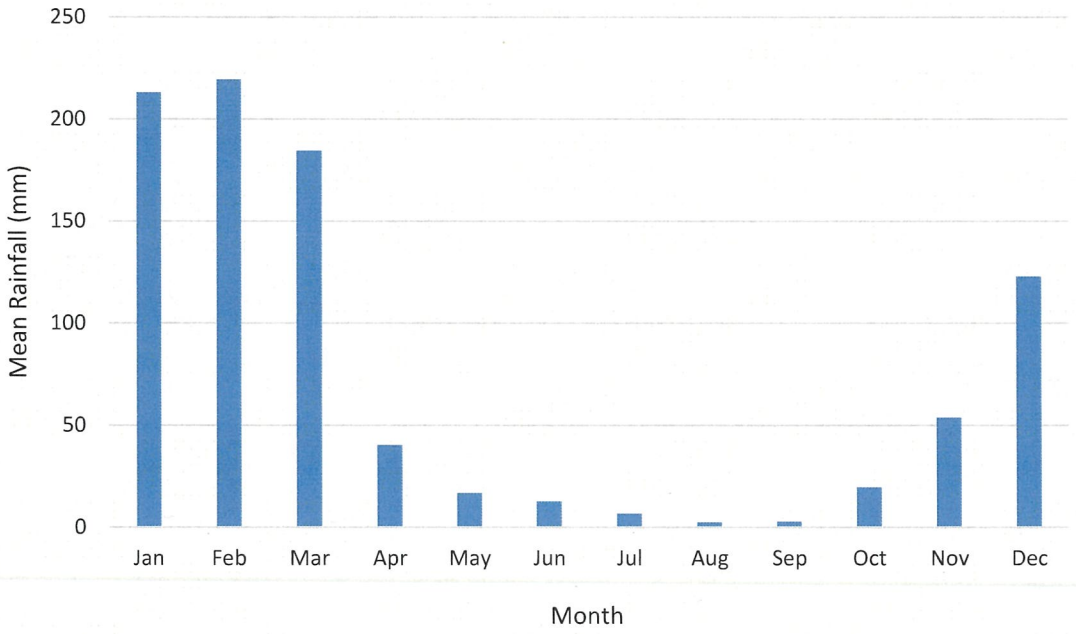
Current mining activities consist of reprocessing existing stockpiles from historical mining operations. Parts of the site have been, and are currently being, used for extractive industry purposes (quarrying/crushing of existing stockpiles) that are administered under separate statutory approvals by MCQ.

[1] DES 2021, *Stormwater Guideline: Environmentally Relevant Activities*, Queensland Department of Environment and Science, Brisbane, ESR/2015/1653 Version 1.04.

1.3 Climate

Mt Carbine is located in an area dominated by low rainfall 'dry' seasons and tropical monsoon 'wet' seasons. The meteorological station at the Mount Carbine Township (Bureau of Meteorology (BoM) Station 31180) was used to provide the information in **Graph 1**.

The majority of rain falls from December to March (*ie* the wet season), while the lowest rainfall typically occurs from April to November (*ie* the dry season). Mean annual rainfall is 952.1 mm (BoM 2022).



Source: BoM (2022).

Graph 1: Mean monthly rainfall for Mount Carbine Township weather station

1.4 Topography

The topography of the site is described as varying between level alluvial plains, rising to short, gently sloping pediments and foot-slopes, to high hilly, to mountainous lands with very steep slopes (Northcote *et al.* 1960–1968). All waterways in the site drain to the Mitchell River, approximately 5 km south of the leases, via the catchments of Manganese and Holmes creeks (**Figure 1**). The topography south of the Mulligan Highway is generally flat in comparison to north of the highway (**Figure 2**).

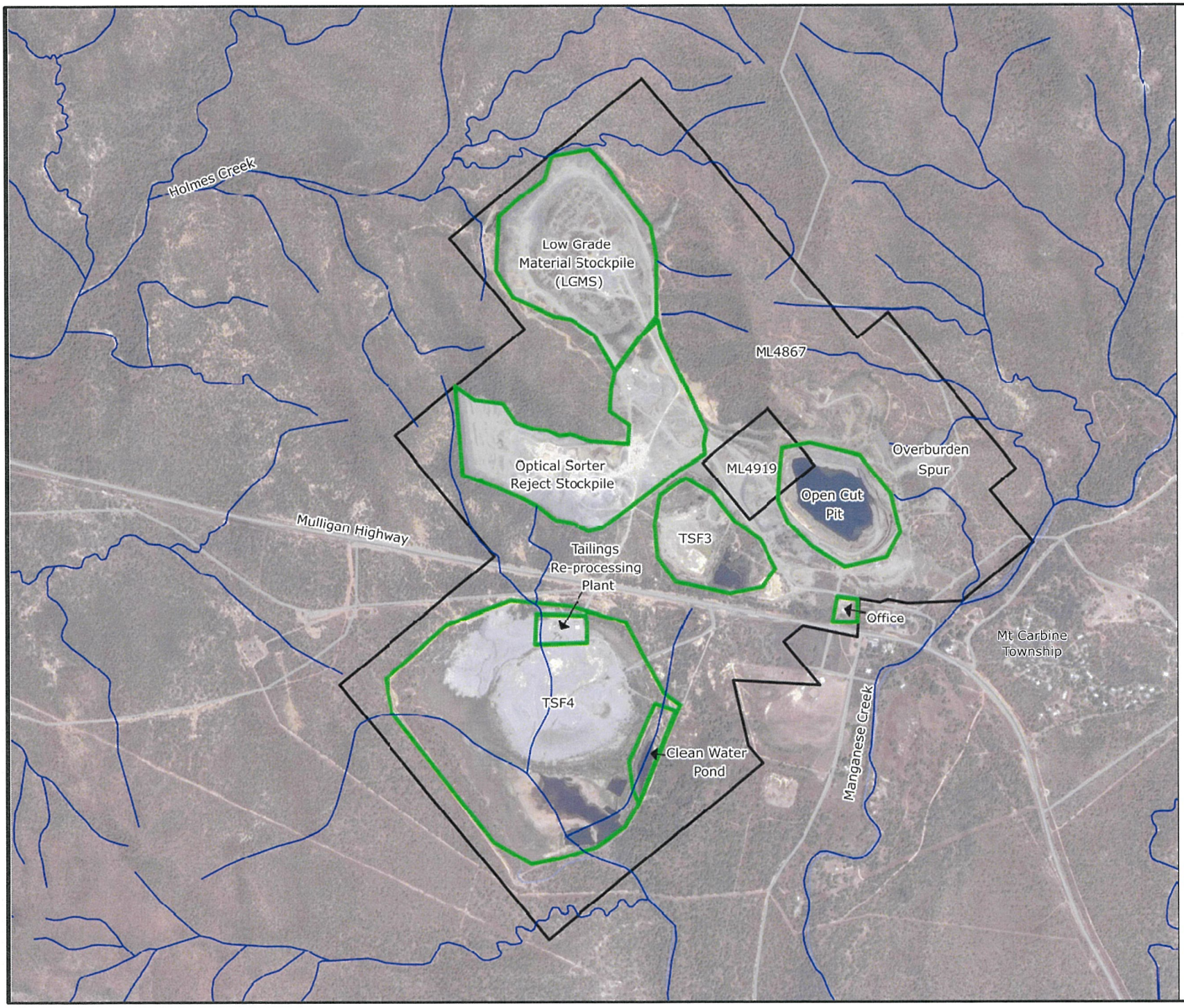


Figure 1: Site features and layout

Project: Mount Carbine Project
Erosion and Sediment Control Plan Update

Mining lease boundaries
Site features
Roads
Drainage

N

0 750

Metres

Source:
Queensland Department of Resources 2022, Queensland Department of Resources 2021, Google Earth

NRA Ref: 380008.02
Date: April 2022

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Recommended print size: A4



Figure 2: Site topography

Project: Mount Carbine Project
Erosion and Sediment Control Plan Update

Mining lease boundaries

Site features

5 m interval contours

N

0 750

Metres

Source:
Queensland Department of Resources 2022

NRA Ref: 380008.02
Date: April 2022

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Recommended print size: A4

1.5 Soils

The ESCP prepared in 2013 (**Appendix A**) presents information on soil. There is limited site-specific information available on pre-disturbance soil condition (land disturbances occurred circa 1970 and soil material was not salvaged for reuse). Results of previous soil testing indicate that surface materials are generally infertile having chemical and physical limitations (inherently low levels of soil nutrients and low organic matter).

Recent investigations (NRA 2021) have further confirmed that soils are shallow on-site (*eg* rock outcrops at surface and soil limited to 0.3 m depth). Additionally, areas previously disturbed (*eg* drains excavated at the time of NRA (2013a)), now exhibit signs of active erosion demonstrative of inherent dispersive characteristics in the exposed subsoils (**Plates 1** and **2**). Soils on-site are considered vulnerable and should be managed with care *ie:*

1. existing vegetated areas should not be disturbed wherever practicable
2. disturbance of subsoils should be avoided
3. stabilisation of areas where vegetation has been removed is essential, and will require resource inputs, given the characteristic infertility of the growing media (*in situ* surface soil and old mine wastes) and the limitations likely in subsoil materials.



Plate 1: **TSF4 diversion drain invert erosion with vegetated banks**



Plate 2: **Erosion along TSF4 diversion drain banks, sediment deposition in drain invert**

2. Erosion and Sediment Control Plan

By a combination of historical land uses (*eg* waste rock stockpiling) and ongoing land uses (*eg* rock quarrying) much of the disturbances at the site are covered by crushed rock (particularly north of the Mulligan Highway). For the purposes of ESC, this may be considered a form of large-scale rock mulching. Operations south of the Mulligan Highway (*ie* tailings re-processing) are undertaken within the TSF4 catchment, a closed catchment not intended to discharge. As such, many of the remaining ESC measures to be implemented or maintained are focused on clean water diversion away from site operations, and minimising erosion where practicable. Relevant standard drawings from IECA guidance material are provided in Appendix B.

2.1 Drainage controls (clean water diversions)

Diversion of clean water away from site activities is a key element of ESC. By minimising the amount of water on-site, the erosive potential of water that moves through the site is reduced and, accordingly, the amount of material (sediment) transported. Clean water diversions around major site infrastructure consist of the following and are indicated in **Figures 3** and **4**:

- TSF4 East
- TSF4 West
- LGMS East
- LGMS West.

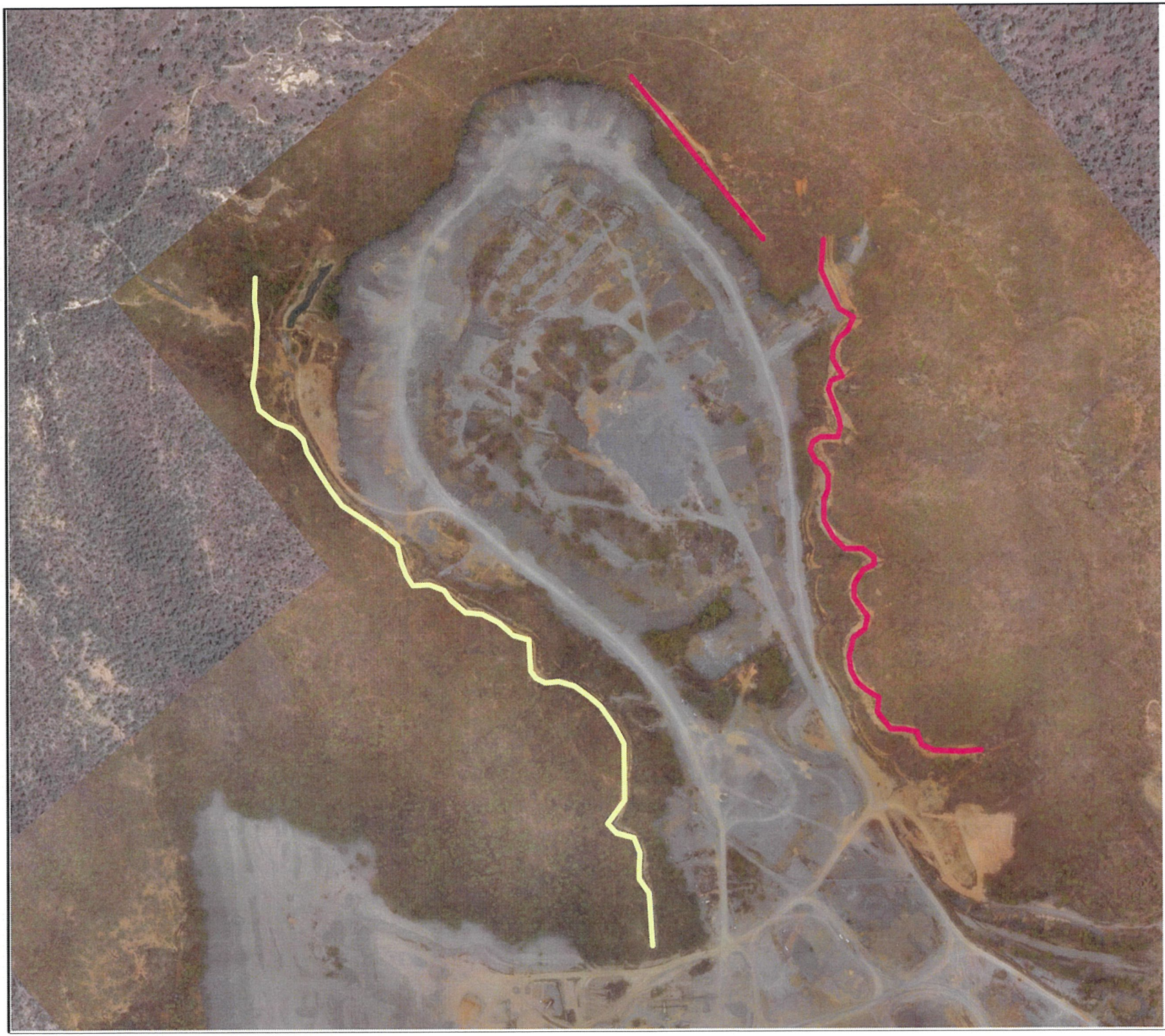


Figure 3: LGMS diversion drainage

Project: Mount Carbine Project Erosion and Sediment Control Plan Update

LGMS diversion drainage east
LGMS diversion drainage west

N

0 0.3
Kilometres

Source: Google Earth 2022

NRA Ref: 380008.02
Date: April 2022

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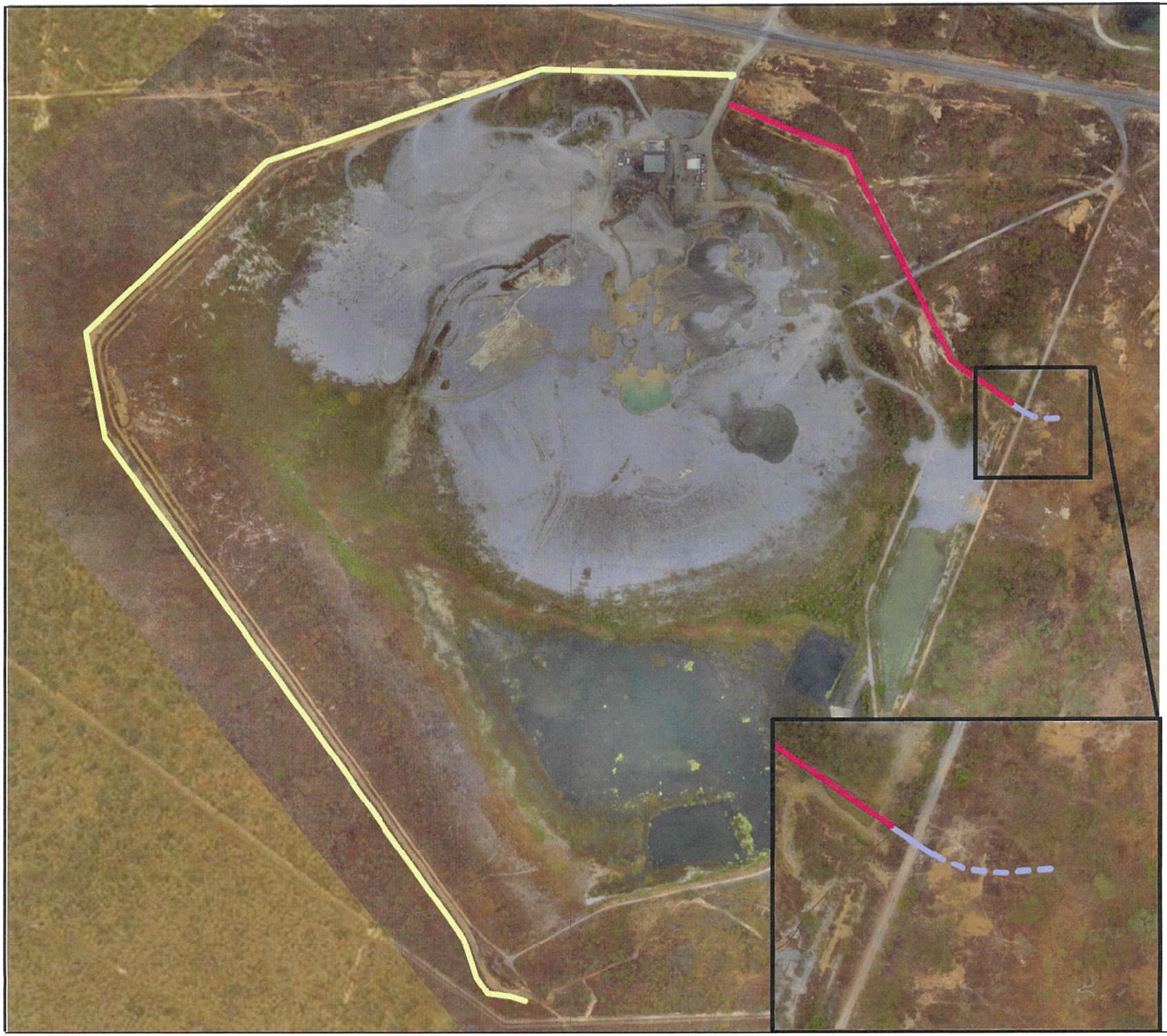


Figure 4: TSF4 diversion drainage

Project: Mount Carbine Project Erosion and Sediment Control Plan Update

TSF4 diversion drainage east
TSF4 diversion drainage west
Extended drain[1]
Level spreader[2]

[1]Under perimeter road.

[2]Outlet side must be level. End of level spreader must be higher than outlet side.

N

0 0.3
Kilometres

Source:EQ Resources, Bing Aerial

NRA Ref: 380008.02
Date: April 2022

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2.1.1 Capacity assessment

These diversions were assessed for suitability, with all diversions deemed capable of discharging a 10% annual exceedance probability (AEP) storm for their relevant catchment, and all except the LGMS East diversion able to discharge a 1% AEP storm (ATCW 2021).

2.1.2 TSF4 East outfall

There is no apparent outfall for diversion TSF4 East (the channel appears to end in a topographical low north of the clean water pond). This diversion should be extended east to drain via a level spreader (**Figure 4** and **Appendix B**) towards the Manganese Creek tributary system south of TSF4 (as per TSF4 West). IECA (2008) recommends stabilised earth be used for the level spreader; however, IECA (2018) recommends wood and/or V-notch plate (aluminium or steel) set in concrete. Preliminary works should use stabilised earth, and be reviewed for suitability. The level spreader must be constructed and maintained level (*ie* 0% grade) across its length to avoid concentrating water flow.

2.2 Erosion controls

Following drainage controls, controlling erosion should be the next priority. Associated controls are detailed below.

2.2.1 Rock mulching

The majority of the site is covered by crushed rock. This is considered a form of rock mulching and good ESC practice. Following recent site visits by NRA (*eg* 23 November 2021) minor improvements are suggested, as follows.

- Consider laying rock over all access tracks, including infrequently used tracks.
- Avoid the use of fine (*ie* <5 mm) gravels where practicable.

2.2.2 Diversion lining

Channelised flow in diversion drains may require erosion controls, depending on the material from which the drain is formed.

LGMS

Diversions around LGMS are generally formed by cutting into the weathered rock outcropping of Mt Carbine. This provides a stable (non-eroding) channel base for the diversion. No lining of this drain is required at this time.

TSF4

Diversions around TSF4 are generally formed in the alluvial floodplains of the Mitchell River valley and are less stable (**Plates 1** and **2**). Placement of suitable rock fill in the base of this channel to reduce flow velocity and provide a less erosive surface for water to flow over may reduce the observed erosion occurring. Previous rock lining (*eg* as recommended in NRA (2013a)) covered only the most high-risk areas and has degraded over time.

Rock lining must be recessed into the diversion channel with Geofabric underlay where rock lining is deployed, with specific attention to the stabilisation of the interfaces between natural surface and formed channel. Soils affected should be further assessed for sodicity and

ameliorated as required[2]. Inadequate or incorrect lining of the drain may increase erosion and reduce drain capacity (**Appendix B**).

Preliminary design work (**Appendix C**)[3] has identified a minimum material size (d_{50}=0.2 m) for rock lining all TSF4 drains.

Potential alternatives to rock lining include grass lining, erosion control mats and cellular confinement systems. These are not considered as practicable as rock lining, given the cost of materials and the proximity of the Mt Carbine Quarry.

2.2.3 Clearing and rehabilitation

Clearing should be progressive and only as required. Clearing is expected to be limited to access tracks, which will be surfaced with rock where practicable. Rehabilitation trials, a requirement of the EA, were undertaken at Mt Carbine (NRA 1994) and are due to continue (*pers. comm.* Natasha Troughton, Administration Manager, EQ Resources, to NRA, email dated 1 December 2021).

2.3 Sediment controls

Large scale sediment control structures (*eg* sediment basins) are problematic in monsoonal climates (given the volume of water). Modified approaches that incorporate the use of chemicals to promote settlement of suspended solids (and reduce the size of basins) can be applied, though present challenges as well (*eg* chemical suitability and operational challenges). Further, the basin(s) need to be constructed, and for this site, it is advisable to avoid additional disturbance and to avoid exposing subsoil materials. The area's natural watercourses, which may have naturally elevated turbidity during rainfall events, should also be considered (**Plate 3**).

[2] Typical gypsum application rates are 10–25 t/ha. The actual application rate should be determined by soil testing (IECA 2008).

[3] This design has conservatively used enlarged catchments (*cf* ATCW 2021), which are applicable only to sizing rock lining and should not be used for any other purpose.



Plate 3: Manganese Creek upstream of site impacts (February 2022); water is visibly turbid following rainfall

Sediment controls should be implemented where practicable, for example:

- long-term stockpiles of fine material (*eg* <2 mm or 'crusher dust') should have a sediment fence or other bunding to capture mobilised sediments down gradient
- releases from site-affected water storages (*eg* TSF4) should be avoided.

2.4 Dust controls

Dust suppression should be undertaken where required, based on visual inspection. This may be performed via sprinklers and/or a water cart. Water used in dust suppression may briefly pond, but should not run off-site.

3. Monitoring and Maintenance

Review of ESC measures should be undertaken prior to the onset of the wet season, and monitoring and maintenance should continue throughout the wet season. Careful attention should be given to the TSF4 diversion drainage as this feature requires maintenance now and into the future to prevent further degradation.

3.1 Responsible Person

The nominated Responsible Person for the monitoring and maintenance of the ESCP is the Site Senior Executive (or their delegate). Maintaining records of review and the maintenance of ESCP measures is their responsibility.

3.2 Performance standards

3.2.1 Water quality

Water quality performance criteria exist for the site and should be maintained for this ESCP (*ie* Receiving Environment Monitoring Program and EA water quality criteria). No additional water quality criteria are required.

3.2.2 Rehabilitation

Rehabilitation success criteria should be informed by rehabilitation trials. IECA (2008) recommends 70% cover outside of the wet season[4].

3.3 ESCP review

The ESCP should be reviewed and updated as required, or every 3 years as a minimum (in line with site-based management planning and third-party compliance reporting).

[4] Based on average monthly dry season rainfall and Tables 4.4.2 and 4.4.7 of IECA (2008).

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NRA 2013b, *Mount Carbine Tungsten Project Stage 1 Environmental Management Plan June 2013,* R03 (Final), prepared by NRA Environmental Consultants for Carbine Tungsten Limited, 28 June 2013.

NRA 2021, *Surficial bore logs from 6-9 December 2021*, letter prepared by NRA Environmental Consultants for EQ Resources Limited, 21 December 2021.

QT 1993, *Mount Carbine Mine Decommissioning and Rehabilitation Programme*, prepared by Queensland Tungsten, a subsidiary of Normandy Poseidon Ltd, 17 September 1993.

Appendix A:
2013 Erosion and Sediment Control Plan

Environmental Approval & Compliance Solutions

Mount Carbine Tungsten Project (Stage 1) Erosion and Sediment Control Plan

Carbine Tungsten Limited

Environmental Approval & Compliance Solutions

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1 November 2013

Carbine Tungsten Ltd
PO Box 1040
BUNGALOW QLD 4870

Attention: Jim Morgan, CEO and Managing Director, Carbine Tungsten Limited

Dear Jim

RE: Mount Carbine Tungsten Project (Stage 1) – Erosion and Sediment Control Plan

Please find enclosed the Mount Carbine Tungsten Project (Stage 1) – Erosion and Sediment Control Plan.

If you have any questions about the enclosed document please do not hesitate to contact me on 4034 5300 or tim@natres.com.au.

Yours sincerely

NRA Environmental Consultants

Tim Anderson
Principal Environmental Scientist

Our Ref: CT ESCP Coverletter L01.docx

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Status:	R01
Project Manager:	Shannon Wetherall
Title:	Mount Carbine Tungsten Project (Stage 1) Erosion and Sediment Control Plan
Author/s:	Tim Anderson
Client:	Carbine Tungsten Limited
Client Contact:	Jim Morgan, CEO & Managing Director, Carbine Tungsten Limited
Date of Issue:	1 November 2013
No. of Copies:	1 PDF
Dispatched Via:	Email
Other Info or Requirements:	-

Report Summary	
Key Words	Mount Carbine, Carbine Tungsten, Mount Carbine Tungsten Project Stage 1, ESCP, Erosion.
Abstract	This ESCP details the measures applicable to current operations at the Mount Carbine Tungsten Project. The current Environmental Authority requires that an ESCP be prepared. The ESCP will require review and update in response to field conditions and routine monitoring observations as well as to modifications to the nature and scale of activities.

Quality Assurance					
Author	**Technical Review**	**Editor**	**Document Version**	**Approved for Issue by QA Manager**	
				Date	**Signature**
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Appendix D: Inspection Test Plans (ITPs)

Appendix E: ESC Monitoring Checklist

1. Introduction

NRA Environmental Consultants (NRA) was commissioned by Carbine Tungsten Limited to prepare an Erosion and Sediment Control Plan (ESCP) for the Mount Carbine Tungsten Project, North Queensland.

The ESCP is a requirement of Environmental Authority (EA) EPML00956913, dated 15 August 2013, and is limited to the mining activities of Carbine Tungsten Limited.

EA Condition D13 states:

An Erosion and Sediment Control Plan must be developed by an appropriately qualified person and implemented before 1 November 2013, to minimise erosion, contamination of stormwater and the release of sediment to receiving waters.

The International Erosion Control Association (IECA) Best Practice Guidelines (IECA 2008) have been referred to for technical guidance on the erosion and sediment control (ESC) measures adopted.

No site surveys specific to the preparation of this ESCP have been conducted; rather existing data (including that gathered during recent site visits by NRA scientists) and personal knowledge of the site gained by the author from the late 1980s has been used.

The ESCP will be subject to periodic revisions and updates. Triggers for revisions include:

- results of performance monitoring of the ESC measures during and following wet seasons
- changes to activities that warrant amendments to either the Plan of Operations (PoO) and/or the EA
- annual review.

The process for managing these future alterations is detailed in **Section 3.4**.

1.1 Site description

The Mount Carbine Tungsten Project is on granted mining leases 4867 and 4919 at Mount Carbine, approximately 80 km north-west of Cairns, in north Queensland (**Figure 1**). The project is within the existing disturbance area of an open cut and underground tungsten mine which operated in the 1970s and 1980s. In addition to mining activities, land use on the site is quarrying, with the surrounding land use a mixture of residential (the township of Mount Carbine), conservation (Brooklyn Wildlife Sanctuary) and low intensity beef cattle grazing (NRA 2013a).

The land capability of the area in 1992 was described as '*not of high quality and supports a variety of Braham at a density of about one head per 20 hectares outside of small area of improved pastures.*' (QT 1992); with EMOS (1995) reporting that the "*agricultural capability of the general area in and around the project is assessed as CVII and VIII*" – noting that this assessment was based on the pre-mining land use including areas of 'decommissioned waste rock dump and decommissioned tailings dam'. Following a visit to the project area QDPI (1993) reported "*Whatever pasture exists is subject to heavy overgrazing because of the proximity of water. This applies to everywhere around Mt Carbine, not just the mine site. It has probably been the normal condition for a hundred*

years. As a consequence, the whole area is degraded, and the vegetation is of little value from aesthetic, botanical or pastoral points of view. It has, however, a useful function to perform in the stabilisation of some of the disturbed surfaces of the mine area. --- The disturbed areas as a whole cannot be restored and revegetated in the modern manner, since the operation was begun before such demands were made and top soil was not stockpiled. They are too extensive to contemplate retrospective action. They are, moreover, in an area where evidence of mining activity has long been accepted as part of the scenery. They are not unduly obtrusive, and the surfaces are not notably mobile. The process of revegetation of the deposits of fine material could be hastened by deliberate action if this were required, but there seems to be little point, and ground cover is likely to return naturally, if slowly. ". NRA concluded that based on field observations, pre-disturbance land suitability for beef cattle grazing is assumed to be Class 4 on flatter areas, and Class 5 on steeper areas (NRA 2013a).

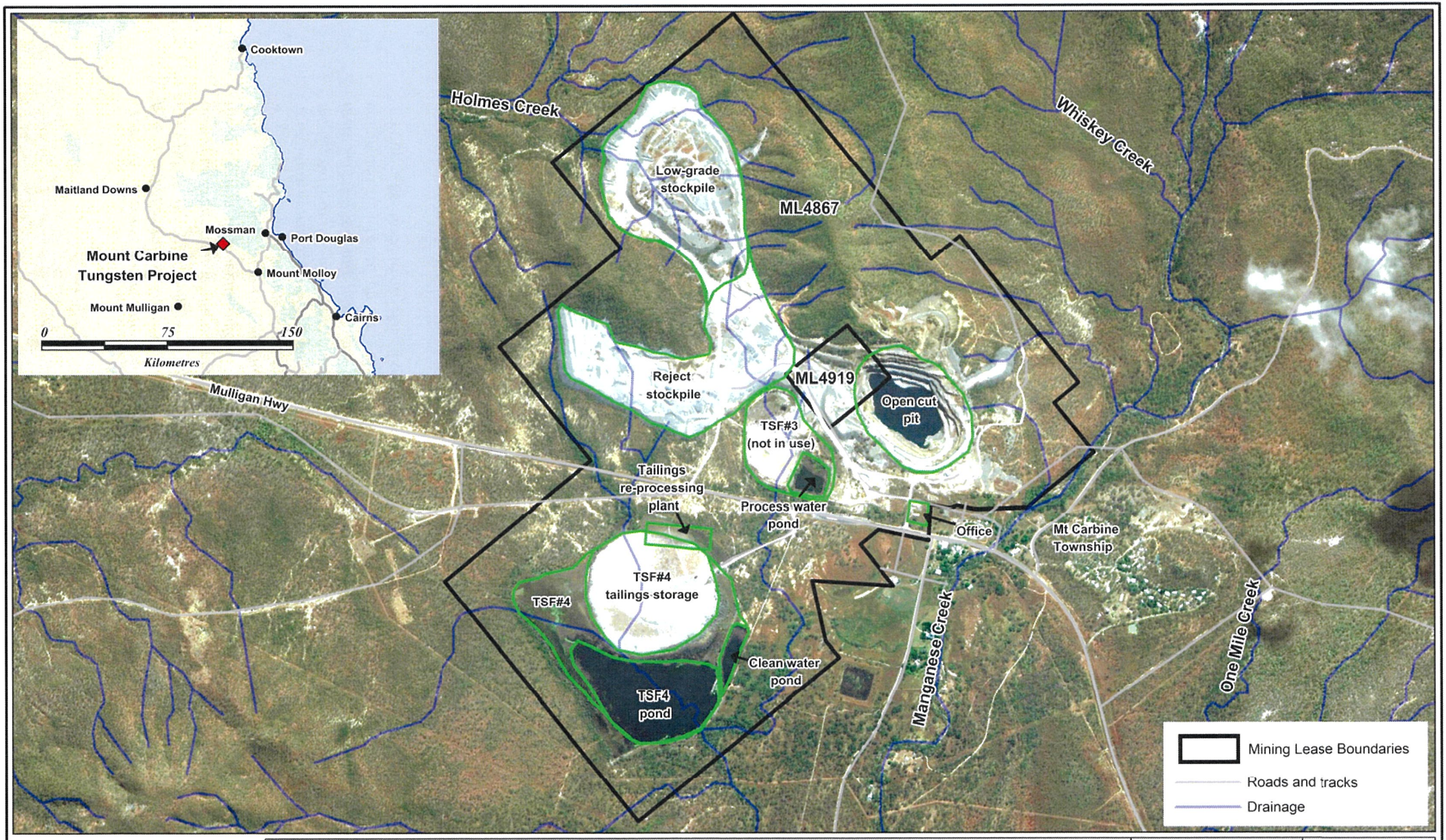
The mine site is within the Mitchell River Catchment. The site drains to two creeks. Manganese Creek collects water from the south and east, and Holmes Creek from the north-west. The environmental values for waterways in the Mount Carbine Project Area that are to be protected and enhanced are:

- aquatic ecosystems (slightly to moderately disturbed)
- livestock drinking water
- industrial use
- cultural heritage (NRA 2013a).

The current mining activities consist of reprocessing tailings and low-grade stockpiles from previous mining operations. Further detail is provided in the Plan of Operations (PoO) (NRA 2013b). Parts of the project area have been, and are currently being, used for extractive industry purposes (quarrying/crushing of waste rock and tailings) that are administered under separate statutory approvals by Mount Carbine Quarries Proprietary Limited.

1.2 Climate

The following information is from the Mount Carbine Tungsten Project Stage 1 Environmental Management Plan (EM Plan) (NRA 2013a). The nearest meteorological station likely to be representative of site conditions is at the Mareeba Airport (Bureau of Meteorology (BoM) Station 031210), 80 km from the site. **Graph 1** shows the average minimum and maximum temperature at Mareeba. Temperatures in the area range from 13.6°C in winter to 32.0°C during summer (BoM 2012). **Graph 1** shows that the majority of rain falls during February (mean 259.4 mm) in Mareeba, while the lowest rainfall typically occurs in September (mean 4.4 mm) (*ie* the highest risk of high intensity storms occurs in the distinct wet season between November and April inclusive). Average total rainfall is 829 mm (BoM 2012).



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PROJECT: Mount Carbine Tungsten Project (Stage 1) Erosion and Sediment Control Plan
TITLE: Locality and general arrangements

JOB NO: 380008.01
DATE: November 2013

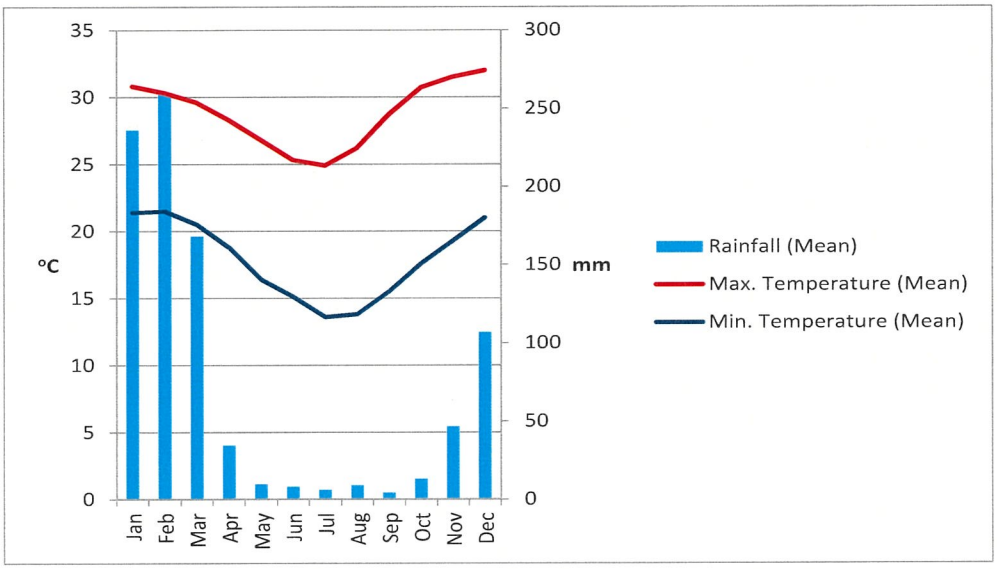
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SOURCE:
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Carbine Tungsten Ltd
Google Earth
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0 250 500 750 1000
Metres

Figure 1

Recommended print size: A4



Source: BoM 2012.

Graph 1: Average monthly minimum and maximum temperatures and rainfall (Mareeba Airport)

1.3 Topography

The area is relatively rugged[1] with the topography described as varying between level alluvial plains rising to short gently sloping pediments and foot-slopes to high hilly to mountainous lands with very steep slopes (Northcote *et al.* 1960–1968). All waterways in the project area drain to the Mitchell River, approximately 5 km downstream of the leases, via the catchments of Manganese and Holmes creeks (**Figure 2a** and **2b**). Manganese Creek, which collects run-off from the majority of the leases, is an intermittent creek. The low-grade stockpile areas of the lease drain northwards to Holmes Creek, which is also an intermittent waterway.

1.4 Soils

Geology of the mine site is dominated by the Hodgkinson Formation, recent alluvium, and old mine workings (Bultitude *et al.* 1999). Soils are either shallow bleached loams or hard pedal mottled-yellow duplex soils (Northcote *et al.* 1960–1968). There is limited information available on soil (land disturbances occurred in a different era and soil material was not salvaged for reuse). The decommissioning plan for the project (QT 1993) presents limited data that was used to inform rehabilitation trials that NRA undertook in 1993/94 (NRA 1993a, b; NRA 1994)[2]. The soil data supports the assertion that the soils are generally low in chemical fertility though do not present significant challenges in regard to physical stability (such as highly dispersive)[3]. In 2013 NRA collected four surface soil samples, associated with planned water diversion works, for slaking and dispersion assessment using a

[1] A description of physiography presented in the Plan of Operations (QT 1992) was extracted from *The Wolfram Mines of Mt Carbine-North Queensland* by Lionel C. Ball. Geological Survey of Queensland, 1915.

[2] The soil analysis data (QT 1993) and the tailings analysis data for the NRA trial work is presented in **Appendix A** for future reference.

[3] From NRA (1993a) – "*The soil analysis of tailings material (Table 1) indicates the general absence of toxic quantities of metals or excessive salts and deficiencies in nitrogen, phosphorus and potassium. The pH of the material was slightly-moderately alkaline, but not considered to directly inhibit plant growth. A virtual absence of organic matter was noted.*".

screening test based on the Modified Emerson Dispersion Test (MEDT) described by Loveday and Pyle (1973). The samples were collected by NRA Environmental Scientist John Broughton on 1 October 2013 from the southern end of the TSF4 diversion drain (in the vicinity of the spillway). The drain was under construction at the time of sampling. Sample descriptions are given in **Table 1**. Results of the MEDT are given in **Table 2**.

Table 1: Details of Samples Screened by the Modified Emerson Dispersion Test

Sample ID	Description	Type
TSF4 Drain #1	Dark yellowish brown (2.5Y 7/4), no roots, no mottles, weak consistency. Collected from pile of disturbed surface material excavated to form drain.	Topsoil
TSF4 Drain #2	Dark yellowish brown (10YR 4/4), fine roots, no mottles, very weak consistency. Collected from disturbed surface material excavated to form drain.	Topsoil
TSF4 Drain #3	Pale yellow (2.5Y 7/4), no roots, faint orange mottles, very firm consistency. Collected from material excavated to form drain.	Subsoil
TSF4 Drain #4	Light yellowish brown (10YR 6/4), no roots, no mottles, firm consistency. Collected from material excavated to form drain.	Subsoil

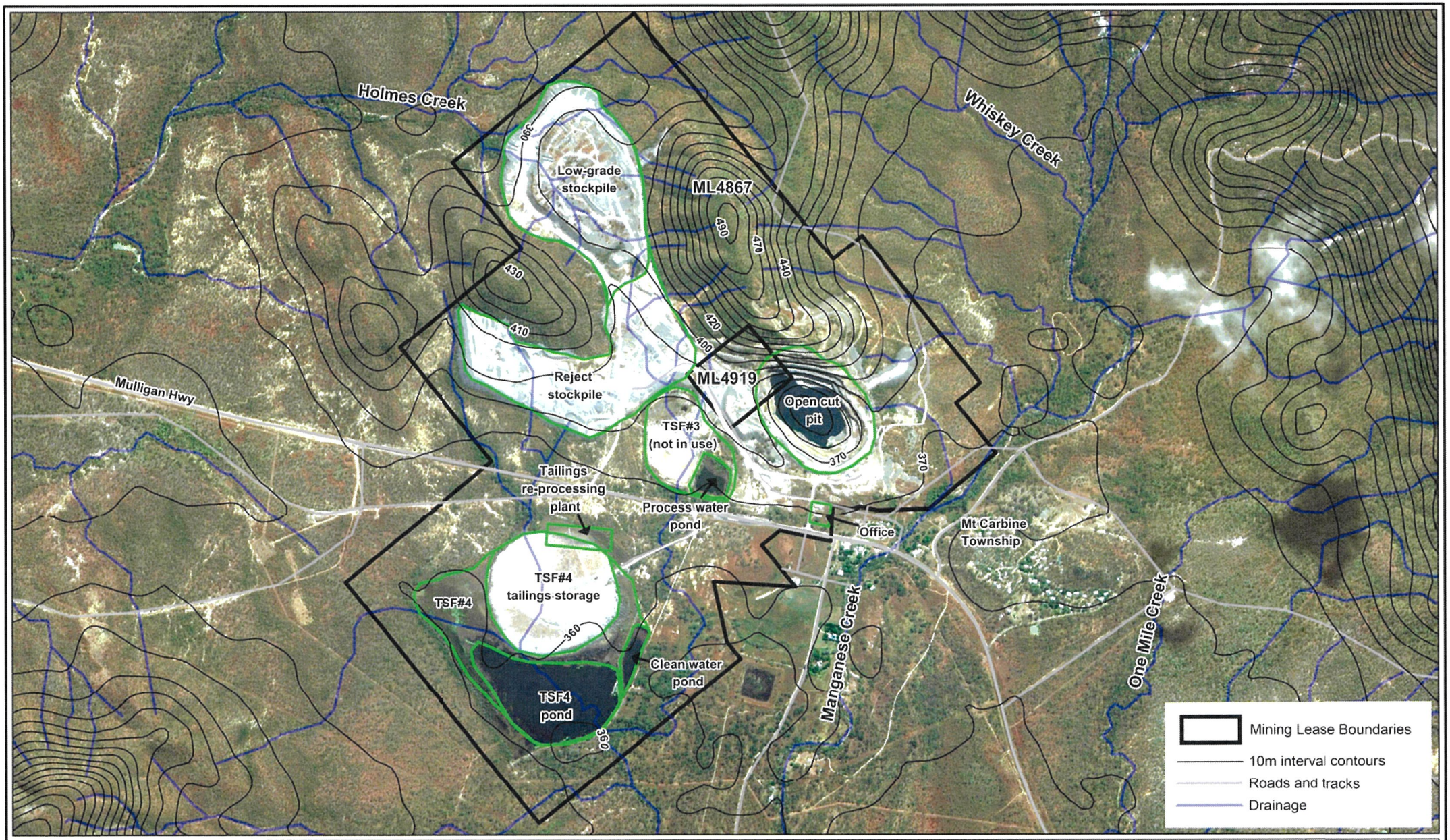
Table 2: Results of the Modified Emerson Dispersion Test

		Dispersion	
Sample	Slaking	After 2 hours	After 20 hours
TSF4 Drain #1	Immediate complete slumping	No dispersion	No dispersion
TSF4 Drain #2	No significant slumping	No dispersion	No dispersion
TSF4 Drain #3	Immediate minor slumping	No dispersion	Slight dispersion
TSF4 Drain #4	Immediate complete slumping	No dispersion	No dispersion

Based on the observations and results, the soils of the project area appear to be not of high quality and typical of arid regions of northern Queensland. Nevertheless most soils, especially those near the surface, are worthy of salvage ahead of being disturbed on account of their improved agronomic value relative to waste rock/tailings material. Given the previous practice of not salvaging soil material, it is very important that the salvage of soil material happens for any future land disturbances. Wherever possible, soil should be placed directly onto areas to be rehabilitated. Where storage is unavoidable, stockpiles should be placed away from drainage lines, steep slopes where they may be exposed to erosive sheet or concentrated flows, and areas of future disturbance. They should be built no more than 2 m in height, and sown with a species mix proposed for use in the rehabilitation program or in the absence of specification sown with a 20–40 kg/ha of cover crop (commercially available sterile hybrid pasture species). In addition to the benefits of maintaining some degree of biological activity, combating weed invasion and generating a useful seed bank, the rapid establishment of a vegetative cover (at least 60% cover) will negate the need for construction of silt fences around the toe of soil stockpiles.

It is concluded that surface soil materials are unlikely to present unusually difficult erosion and sediment control issues (though fertiliser addition will be required for the establishment of cover crops in any revegetation program where this material is used). While soils are likely to be generally stable in their undisturbed state (noting that a significant area of land disturbance has occurred in the past and soil salvage was not enacted), the lack of cohesion is likely to result in an increased erosion risk in the following cases:

- loose windrowed or stockpiled material from local excavations
- on slopes
- in areas of concentrated flow.



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PROJECT: Mount Carbine Tungsten Project (Stage 1) Erosion and Sediment Control Plan
TITLE: General arrangement and site topography

JOB NO: 380008.01
DATE: November 2013

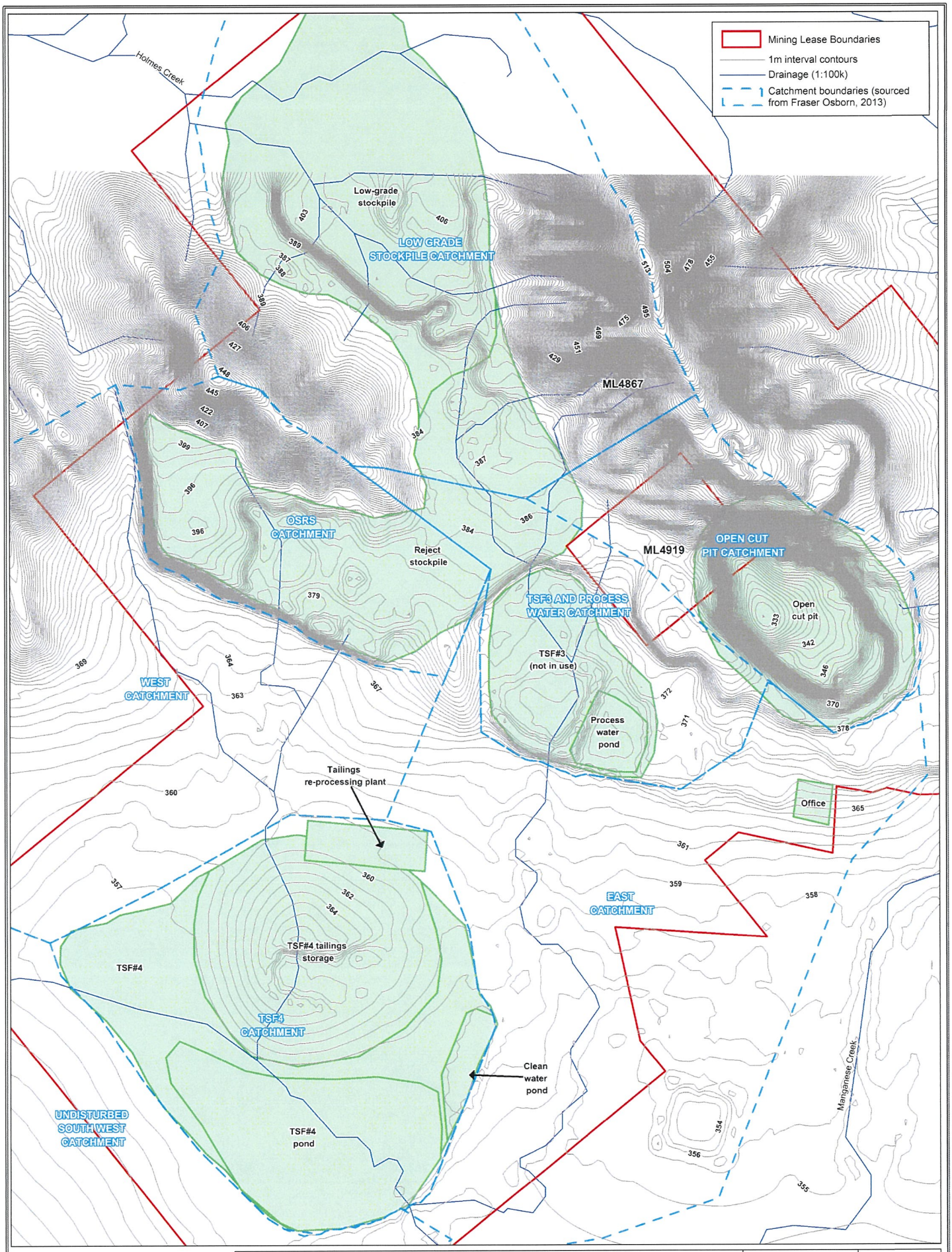
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Carbine Tungsten Ltd
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0 250 500 750 1000
Metres

Figure 2a

Recommended print size: A4



PROJECT: Mount Carbine Tungsten Project (Stage 1) Erosion and Sediment Control Plan
TITLE: General arrangement, site topography and catchments

JOB NO: 380008.01
DATE: November 2013

N

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SOURCE
© State of Queensland (Department of Natural Resources and Mines) 2013
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Fraser Osborn 2013
Carbine Tungsten Ltd
Google Earth
File Path: T:_AAAJ380\WOR\380008_01\380008.01_CTMGA topo b_13110f.wor

0 100 300 500
metres

Figure 2b

Recommended print size: A3

2. Erosion and Sediment Control Plan

Water management and erosion and sediment control are interlinked and are controlled under a Water Management Plan (NRA 2013c *in prep.*) which addresses clean water and mine water management. The objectives of the Water Management Plan are to divert run-off from undisturbed catchments, where possible, and manage run-off from disturbed areas[4]. ESC measures that are applicable to activities proposed in the PoO (NRA 2013b) are relatively straight forward on account of:

1. the limited nature and scale of proposed activities
2. the proposed activities are restricted to areas of past disturbance
3. the relatively stable condition of existing disturbed areas over an extended period of time (>25 years) and the apparent sustained containment of sedimentation in the area of the project.

The ESCP will require revision and updating if there are changes to the nature and scale of activities.

Deviation from the recommendations provided herein may be necessary due to site-specific conditions encountered. Any alternative practices should be documented to facilitate future monitoring. A change management mechanism is detailed in **Section 3.4**.

It will be necessary to monitor performance of structures (refer to **Section 3.2**). Routine monitoring should be in the form of site inspections following rainfall events that cause run-off to determine if repair/replacement is necessary. Detailed monitoring should be carried out prior to and following the wet season and necessary reparation and/or corrective actions taken.

Structures defined as high or significant hazard dams according to the *Manual for Assessing Hazard Categories and Hydraulic Performance of Dams* (DERM 2012) are to be managed and operated according to conditions outlined in Schedule E of the EA and as such the EA conditions take precedence over any requirements of this ESCP. These storage facilities are not considered further in this ESCP.

2.1 Clean water diversions

A clean water diversion has been constructed to reduce the catchment of TSF4. Permanent ESC measures were not considered necessary due to the low fall of the diversion drain 0.5%) (*pers comm*. Matthew Boschen, Senior Civil Engineer, Fraser Osborn, email dated 3 October 2013). A post construction inspection was undertaken by Fraser Osborn civil engineer on 28 October 2013. Rock armouring is required on the diversion drain where two gullies intercept the drain on the south-western side, and rock armouring is required at the outlets of the diversion drain on the western and eastern sides (*pers. comm.* Matthew Boschen, Senior Civil Engineer, Fraser Osborn). The base and sides of the diversion drain would benefit from cover (*eg* established vegetative cover (*eg* sterile grass)). No further diversions are anticipated given the activities proposed; however, the following information is relevant to

[4] A clean water diversion has been installed to reduce the catchment reporting to the TSF4 and these ESC measures have been reported separately (included as **Appendix B**).

the construction and operation of clean water diversions around infrastructure sites (refer also to **Appendix C**).

- Prior to commencement of any clearing, the extent of proposed work areas should be delineated in the field.
- Diversion banks should be installed at the limits of the disturbance area to divert clean flows around the earthworks area.
- Run-off from disturbed areas area should be controlled by temporary structures to limit the velocity and concentration of flows (*eg* diversion banks and sediment fencing).
- Run-off from disturbed areas should be treated prior to leaving site (*eg* rock filter dams).
- Any discharge of run-off should be via controlled discharge points with energy dissipaters as required (*eg* placed rock).
- The area of disturbance should be minimised and temporary/permanent surface stabilisation provided as soon as practicable following completion of earthworks.
- Batter slopes should be between 1:4 and 1:6 on fill slopes and a maximum of 1:3 on cut slopes to allow surface stabilisation and maintenance (DMR 2000).

2.1.1 Performance standards

Performance standards applying to erosion and sediment control works associated with clean water diversions are described in **Table 3**.

Table 3: Performance Standards

Key Measure	Development Phase	Performance Standard	Method	Timing
Water Quality	Operational	Investigation threshold - turbidity in receiving water greater than 10% above background (up stream of development site) or total suspended solids in receiving water greater than 50 mg/L[1] whichever is higher.	Samples taken upstream and downstream of the site	During run-off event.
Stabilisation	Post-construction (or maintenance)	60% groundcover (vegetation and/or rock mulch) in areas identified for surface stabilisation.	Groundcover estimate	Removal of temporary ESC measures.
Erosion control structures functional	Operational	Structures correctly placed and serviceable. Weeds and sediment removed from drains.	Inspection	November (prior to the wet season[2]). During the wet season after run-off events. Following the wet season (April).

[1] DERM 2009. Queensland Water Quality Guidelines. Version 3. September 2009 (Table 8.2.1).
[2] Wet season: 1 November – 30 April.

2.2 Access corridors

The following approach will apply to erosion and sediment control on access corridors.

- Maintain a single access point to the work area (*ie* avoid multiple entry and exit tracks).
- If excavation is not required (*eg* exploration tracks) limit clearing to removal of above ground woody material.
- Run-off from disturbed areas should be controlled by temporary structures to limit the velocity and concentration of flows (for example diversion banks and sediment fencing).

- The area of disturbance should be minimised and temporary/permanent surface stabilisation provided as soon as practicable following completion of earthworks.
- Batter slopes should be between 1:4 and 1:6 on fill slopes and a maximum of 1:3 on cut slopes to allow surface stabilisation and maintenance (DMR 2000).
- Road/access track drainage should be:
  - crowned to ensure cross-fall and run-off is to the road side and not along the road.
  - length of slope minimised by cross-fall, cross-drains or whoa boys. Maximum spacings between structures should be as follows:

Slope	Max spacing of drainage control (m)
<8%	30
8-25%	20
>25%	10

- Road maintenance should avoid windrowing along road edges which prevent discharge of surface drainage.

Suitable ESC structures for use in access corridors and exploration areas are described in **Table 4.**

Table 4: Access Corridors and Exploration ESC Structures

Type of Structure	Purpose	Design Criteria	Design/Construction Notes	As Built Confirmation
Roll Over Bank	To direct run-off from sloping tracks (not suitable for haul roads).	Minimum Specification: - 500 mm high - 1:6 approaches - Cross fall of <2% Relevant Guideline: NA.	- Compact material to prolong serviceability.	Inspection Test Procedure (ITP) documentation. Field inspection records.
Roadside Table Drains	To collect and control road and track run-off.	Design Criteria: - 1 in 2 year critical event. Minimum Specification: Trapezoidal profile - Base width – 0.8 m - Depth – 0.5 m Relevant Guideline: NA.	- Compact side slopes - Ensure all loose material removed from shoulder and surrounds following construction. - Where slopes exceed 5% use Check Dams to control velocity. - Turnout provided at regular intervals (if scour or gullying occurs - install additional turnouts). - Turnouts discharge to placed rock (1m x 1 m) and grass (if necessary seed the area downslope).	Inspection Test Procedure (ITP) documentation. Field inspection records.
Check Dams	To control velocity of concentrated flows in roadside drains.	Minimum Specification: - Height to 0.3 m - Provide central invert Relevant Guideline[1]: **Appendix C**.	- On slopes install at spacing so that crest of lower check dam is level with toe of upstream check dam. - Construct of rock min 200 mm diameter.	Inspection Test Procedure (ITP) documentation. Field inspection records.

[1] Note these are guidelines not specifications

Performance standards applying to erosion and sediment control works associated with access corridors and exploration are described in **Table 5.**

Table 5: Performance Standards

Key Measure	Development Phase	Performance Standard	Method	Timing
Installation of ESC measures.	Establishment or maintenance of access track or exploration facility (*eg* drill pad).	ESC structures in place and serviceable.	Inspection by Senior Environmental Advisor.	Completion and duration of construction.
Stability	Operations	Turnout drain outlets discharge to stable grassed or rock-lined areas.	Inspection	Completion of construction and maintenance.
Stability	Operations	No scour or gullying of road surface.	Inspection	Completion of construction and maintenance.
Stability	Operations	No scour or gullying of table drains.	Inspection	Completion of construction and maintenance.
Erosion control structures functional	Operations	Structures correctly placed and serviceable.	Inspection	November (prior to the wet season[1]). During the wet season after run-off events. Following the wet season (April).

[1] Wet season: 1 November – 30 April.

3. Implementation

This section describes the process to be followed in implementing erosion and sediment control on-site.

3.1 Inspection Test Plan

Installation is controlled by use of an Inspection Test Plan (ITP) as described below.

- Each structure is given a unique number (or other identifier).
- Structures are numbered/identified in the field.
- ITPs are completed as structures are installed.

An example of an ITP is provided in **Appendix D**.

3.2 Monitoring and reporting

Routine monitoring should be undertaken in the form of site inspections. These inspections should follow rainfall events that cause run-off to determine if repair/replacement is necessary.

Detailed monitoring should be carried out prior to and following the wet season and necessary reparation and/or corrective actions taken.

The ESC Monitoring Checklist (**Appendix E**) should be used as a record of monitoring.

Reporting will be via the ITP (signifying status of structure installation) and the ESC Monitoring Checklist (running record of any maintenance requirements).

3.3 Responsible Person

The nominated Responsible Person for the implementation of the ESCP is the Site Senior Executive. Final sign-off on ITPs and ESC Monitoring Checklist will be provided by the Site Senior Executive.

3.4 Modifications

ESCP reviews

Changes to the ESCP will be necessary as the result of monitoring of performance of erosion and sediment control measures and site developments that warrant amendment to either the PoO and/or the EA. Irrespective of this, the ESCP should be reviewed annually.

Change management

It is expected that modifications to the measures described in the ESCP will be needed in response to site circumstances. The modifications may be considered minor, moderate or significant. It is expected that significant modifications will be the exception, whereas moderate and certainly minor changes will occur.

To accommodate these circumstances a change management decision matrix is presented in **Table 6**.

Table 6: Change Management Decision Matrix

Authority Required/Item	Minor	Moderate		Significant
	Maintenance of all structures	Removal or relocation of minor structures	Permanent measure relocation	Permanent measure removal revisions to ESCP
Site ESC Representative	✓	✗	✗	✗
Responsible Person Site Senior Executive	✓	✓	✓	✗
Qualified Erosion Control Professional or Senior Environmental Advisor	✓	✓	✓	✓

✓ Authorised to undertake.
✗ Not authorised to undertake.

3.5 Training

Should project expansion occur, as anticipated, it is recommended that at least one member of the site team have formal training in erosion and sediment control.

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Appendix A:
Soils and Tailings Characterisation Data

Soil Sample Analysis Summary

	SITE 3	SITE 6	SITE 5	SITE 4
Soil Colour (Munsell)	Brown	Brown	Brown	Brown
Soil Texture	Gravelly Sandy Clay Loam	Gravelly Sandy Clay Loam	Gravelly Sandy Clay Loam	Gravelly Sandy Clay Loam
pH (1:5 Water)	5.2	5.3	5.7	5.7
Buffer pH	6.1	5.9	6.1	6.2
Organic Carbon %C	1.0	1.3	1.2	0.6
Nitrate Nitrogen mg/kg	3.4	2.3	0.5	0.4
Sulfur mg/kg	65	194	16	4
Phosphorus (BSES) mg/kg	41	9	7	7
Phosphorus (Colwell) mg/kg	7	3	3	4
Potassium meq/100g	0.25	0.15	0.21	0.25
Calcium meq/100g	1.55	2.83	3.92	1.78
Magnesium meq/100g	1.31	2.91	2.40	0.53
Aluminium meq/100g	0.17	0.03	-	-
Sodium meq/100g	0.36	0.70	0.23	0.07
Chloride mg/kg	60	85	40	20
Copper mg/kg	2.9	0.9	1.0	0.5
Zinc mg/kg	3.4	0.3	0.7	0.4
Manganese mg/kg	19	8	6	28
Iron mg/kg	82	137	44	9
Boron mg/kg	0.07	0.10	0.04	0.06
Liming Requirement 5.5	0.1	0.3	-	-
Liming Requirement 6.5	0.7	1.3	0.7	0.5
Cation Exch. Capacity meq/100g	3.64	6.62	6.77	2.64
Calcium/Magnesium Ratio	1.18	0.97	1.63	3.36
Aluminium Saturation %	4.7	0.5	-	-
Sodium% of cations (ESP)	9.89	10.57	3.40	2.65
Elec. Conductivity (s.e.) ds/m	1.2	2.3	0.5	0.3

SITE 3 - ***Adjacent highway***

SITE 4 - ***Pipeline easement***

SITE 5 - ***Adjacent creeks behind large size rock pile***

SITE 6 - ***Adjacent highway***

A copy of Analysis Systems test reports is included as appendix 1.

SOIL ANALYSIS REPORT

Incitec Ltd
Australian Company Number 010 767 263
Paringa Road, Gibson Island, Murarrie
P.O. Box 140, Morningside, Qld 4170
Tel: (07) 867 9300

Analysis Systems
From Incitec People with answers.

QLD Tungsten
Mt Carbine
Mt Carbine
QLD 4871

Phone 070 943157 Fax
Nearest Town Postcode
Distance to Town Direction to Town
Australian Map Grid Ref - - Average Annual Rainfall mm

SOIL SAMPLE AND SITE INFORMATION:

Sampling depth(cm)	0-15 Surface	Months of Fallow	
Sampling depth(cm)	- Deep	Age of cultivation	yrs
		Drainege	
Paddock area	ha	Stubble/Trash	
Soil type		Tillage	
Slope		Irrigation	
Soil profile depth	m		

Reasons for sampling 1. Determine fertilizer needs
2. Concern with major nutrients

PRODUCTION INFORMATION:

			yrs mths
Main species to be fertilized	Aluvium	Age established	-
Variety		Root stock(Hort)	
Previous best yield		Plant population	ha
Yield last year		Canopy radius(Hort)	m
Vigour of growth		Grain protein	
Row/tree spacing(Hort)	m X m	Legume content	
Row spacing(Grain/Cotton)		Stock type	
Interrow treatment		Stock number	

Stage in Crop Cycle(Sugar Cane)
Method of fertilizer placement:
1. 2. 3.

FERTILIZER HISTORY:

	Fertilizers	Application Rate	Units	Date Applied Year Month
Most Recent Crop	==========	==========	=====	==========
Previous Crop				
Previous Crop				

Other Relevant Comments

Form No. 804 (Rev.1)

Results of Analysis

PADDOCK NAME	No5
ORDER NUMBER	129648
PRODUCT	Hort and Full Range Soil
SAMPLE BAG NUMBER SURFACE	03126
CORRESPONDING DEEP SOIL BAG No	
DATE OF SAMPLING	24/05/93
DATE RECEIVED	26/05/93
DATE OF REPORT	02/06/93

Soil colour (Munsell)	Brown
Soil texture	Gravelly Sandy Clay Loam
pH(1:5 Water)	5.2
Buffer pH	6.1
Organic Carbon %C	1.0
Nitrate Nitrogen mg/kg	3.4
Sulfur mg/kg	65
Phosphorus(BSES) mg/kg	41
Phosphorus(Colwell) mg/kg	7
Potassium meq/100g	0.25
Calcium meq/100g	1.55
Magnesium meq/100g	1.31
Aluminium meq./100g	0.17
Sodium meq/100g	0.36
Chloride mg/kg	60
Copper mg/kg	2.9
Zinc mg/kg	3.4
Manganese mg/kg	19
Iron mg/kg	82
Boron mg/kg	0.07

Calculations

Liming Requirement 5.5	0.1
Liming Requirement 6.5	0.7
Cation Exch. Capacity meq/100g	3.64
Calcium/Magnesium Ratio	1.18
Aluminium Saturation %	4.7
Sodium% of cations(ESP)	9.89
Elec. Conductivity (s.e.) dS/m	1.2

Methods, Calculations outlined overpage.

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PLEASE CONTACT YOUR DEALER: 070 922444
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MAREEBA QLD 4880

OR YOUR INCITEC AREA MANAGER
J STEPHENSON PH: 070 922524/018 774452

Registered Signatory

Samples are analysed as received

Report # 23788

SOIL ANALYSIS REPORT

Incitec Ltd
Australian Company Number 010 767 263
Paringa Road, Gibson Island, Murarrie
P.O. Box 140, Morningside, Qld 4170
Tel: (07) 867 9300

Analysis Systems
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SOIL SAMPLE AND SITE INFORMATION:

Sampling depth(cm)	0-15 Surface	Months of Fallow	
Sampling depth(cm)	- Deep	Age of cultivation	yrs
		Drainage	
Paddock area	ha	Stubble/Trash	
Soil type		Tillage	
Slope		Irrigation	
Soil profile depth	m		

Reasons for sampling 1. Determine fertilizer needs
2. Concern with major nutrients

PRODUCTION INFORMATION:

			yrs mths
Main species to be fertilized	Wooded Stockpile	Age established	-
Variety		Root stock(Hort)	
Previous best yield		Plant population	ha
Yield last year		Canopy radius(Hort)	m
Vigour of growth		Grain protein	
Row/tree spacing(Hort)	m X m	Legume content	
Row spacing(Grain/Cotton)		Stock type	
Interrow treatment		Stock number	
Stage in Crop Cycle(Sugar Cane)			

Method of fertilizer placement:
1. 2. 3.

FERTILIZER HISTORY:	Fertilizers	Application Rate	Units	Date Applied Year Month
Most Recent Crop				
Previous Crop				
Previous Crop				

Other Relevant Comments

Results of Analysis

PADDOCK NAME	No 8
ORDER NUMBER	131051
PRODUCT	Hort and Full Range Soil
SAMPLE BAG NUMBER SURFACE	04592
CORRESPONDING DEEP SOIL BAG No	
DATE OF SAMPLING	24/05/93
DATE RECEIVED	26/05/93
DATE OF REPORT	02/06/93
Soil colour (Munsell)	Brown
Soil texture	Gravelly Sandy Clay Loam
pH(1:5 Water)	5.3
Buffer pH	5.9
Organic Carbon %C	1.3
Nitrate Nitrogen mg/kg	2.3
Sulfur mg/kg	194
Phosphorus(BSES) mg/kg	9
Phosphorus(Colwell) mg/kg	3
Potassium meq/100g	0.15
Calcium meq/100g	2.83
Magnesium meq/100g	2.91
Aluminium meq./100g	0.03
Sodium meq/100g	0.70
Chloride mg/kg	85
Copper mg/kg	0.9
Zinc mg/kg	0.3
Manganese mg/kg	8
Iron mg/kg	137
Boron mg/kg	0.10

Calculations

Liming Requirement 5.5	0.3
Liming Requirement 6.5	1.3
Cation Exch. Capacity meq/100g	6.62
Calcium/Magnesium Ratio	0.97
Aluminium Saturation %	0.5
Sodium% of cations(ESP)	10.57
Elec. Conductivity (s.e.) dS/m	2.3

Methods, Calculations outlined overpage.

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Report # 23791

SOIL ANALYSIS REPORT

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SOIL SAMPLE AND SITE INFORMATION:

Sampling depth(cm)	- Surface	Months of Fallow	
Sampling depth(cm)	- Deep	Age of cultivation	yrs
		Drainage	
Paddock area	ha	Stubble/Trash	
Soil type		Tillage	
Slope		Irrigation	
Soil profile depth	m		
Reasons for sampling	1. Determine fertilizer needs		
	2. Concern with major nutrients		

PRODUCTION INFORMATION:

			yrs mths
Main species to be fertilized	Wooded near dam	Age established	-
Variety		Root stock(Hort)	
Previous best yield		Plant population	ha
Yield last year		Canopy radius(Hort)	m
Vigour of growth		Grain protein	
Row/tree spacing(Hort)	m X m	Legume content	
Row spacing(Grain/Cotton)		Stock type	
Interrow treatment		Stock number	

Stage in Crop Cycle(Sugar Cane)
Method of fertilizer placement:
1. 2. 3.

FERTILIZER HISTORY:

	Fertilizers	Application Rate	Units	Date Applied Year Month
Most Recent Crop	==========	==========	=====	==========
Previous Crop				
Previous Crop				

Other Relevant Comments

Form No. 804 (Rev.1)

Results of Analysis

PADDOCK NAME	No6
ORDER NUMBER	129649
PRODUCT	Hort and Full Range Soil
SAMPLE BAG NUMBER SURFACE	06922
CORRESPONDING DEEP SOIL BAG No	
DATE OF SAMPLING	24/05/93
DATE RECEIVED	26/05/93
DATE OF REPORT	02/06/93

Soil colour (Munsell)	Brown
Soil texture	Gravelly Sandy Clay Loam
pH(1:5 Water)	5.7
Buffer pH	6.2
Organic Carbon %C	0.6
Nitrate Nitrogen mg/kg	0.4
Sulfur mg/kg	4
Phosphorus(BSES) mg/kg	7
Phosphorus(Colwell) mg/kg	4
Potassium meq/100g	0.25
Calcium meq/100g	1.78
Magnesium meq/100g	0.53
Sodium meq/100g	0.07
Chloride mg/kg	20
Copper mg/kg	0.5
Zinc mg/kg	0.4
Manganese mg/kg	28
Iron mg/kg	9
Boron mg/kg	0.06

Calculations

Liming Requirement 6.5	0.5
Cation Exch. Capacity meq/100g	2.64
Calcium/Magnesium Ratio	3.36
Sodium% of cations(ESP)	2.65
Elec. Conductivity (s.e.) dS/m	0.3

Methods, Calculations outlined overpage.

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METHODS OF SOIL ANALYSIS

Soil Colour	-	visual assessment of moist soil against Munsell colour chart.
Soil Texture	-	field texture techniques of Northcote.
pH (1:5 water)	-	1 to 5, soil to water dilution, stirred, stand 1 hour and read while stirring, using combination electrode.
Buffer pH	-	Mehlich buffer - 1:1 soil water for 1/2 hour, add buffer to 1:2 soil solution, stand 1 hour, read while stirring.
Organic Carbon	-	Walkley and Black, using H_2SO_4 and $K_2Cr_2O_7$ in 1:100 dilution, colourimetric, finished with Brinkman Probe colourimeter.
Nitrate Nitrogen	-	1:5 soil:water, intermittent stirring over 1 hour, centrifuged and nitrate measured colourimetrically in segmented flow analyser.
Sulfur	-	1:5 soil: solution of 0.01 M Ca $(H_2PO_4)_2$, end-over-end shake for 16 hours, centrifuge, measured on ICP AES as phosphate extractable sulfur (sulfate).
Phosphorus (Colwell)	-	1:100 soil:solution of 0.5 M $NaHCO_3$, end-over-end 16 hour shake, centrifuge, measured colourimetrically in segmented flow analyser.
Phosphorus (BSES)	-	1:200 soil:solution of 0.01 N H_2SO_4, end-over-end, 16 hour shake, centrifuge, measured colourimetrically in segmented flow analyser.
Potassium, calcium magnesium, sodium	-	1:10 neutral, normal ammonium acetate, 1/2 hour vigorous shake, centrifuged, measured on ICP AES.
Aluminium	-	1:10 soil:solution of IM KCl, 1 hour vigorous shake, centrifuged, measured on Atomic Absorption spectrophotometer.
Chloride	-	1:5 soil:water, intermittent stirring over 1 hour, centrifuged and chloride measured colourimetrically in segmented flow analyser.
Electrical conductivity	-	1:5 soil:water, stirred, stand 1 hour and read by conductivity meter.
Copper, zinc, manganese, iron	-	1:10 soil:solution of DTPA, triethanolamine and Ca Cl_2 1/2 hour vigorous shake, centrifuged, measured on ICP AES.
Boron	-	1:2 soil:solution of hot 0.01M Ca Cl_2, end-over-end, 1 hour shake, centrifuged, measured on ICP AES.

CALCULATIONS

Cation exchange capacity = sum of K, Ca, Mg, Na and Al (if present).
Calcium/Magnesium ratio = Ca ÷ Mg

$$\text{Aluminium saturation} = \frac{\text{Al} \times 100}{\text{Cation exchange capacity}}$$

$$\text{Sodium \% (ESP)} = \frac{\text{Na} \times 100}{\text{Cation exchange capacity}}$$

Elec. conductivity of saturated extract (equiv) is based on conversions of EC (1:5) and soil texture class, to give more accurate assessment of soil salinity hazard (R.J. Shaw et al. QDPI)

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SOIL SAMPLE AND SITE INFORMATION:

Sampling depth(cm)	0-15 Surface	Months of Fallow	
Sampling depth(cm)	- Deep	Age of cultivation	yrs
		Drainage	
Paddock area	ha	Stubble/Trash	
Soil type		Tillage	
Slope		Irrigation	
Soil profile depth	m		
Reasons for sampling	1. Concern with major nutrients		
	2. Concern with micronutrients		

PRODUCTION INFORMATION:

			yrs mths
Main species to be fertilized	Lower 4 Dam	Age established	-
Variety		Root stock(Hort)	
Previous best yield		Plant population	- ha
Yield last year		Canopy radius(Hort)	m
Vigour of growth		Grain protein	
Row/tree spacing(Hort)	m X m	Legume content	
Row spacing(Grain/Cotton)		Stock type	
Interrow treatment		Stock number	

Stage in Crop Cycle(Sugar Cane)
Method of fertilizer placement:
1. 2. 3.

FERTILIZER HISTORY:	Fertilizers	Application Rate	Units	Date Applied Year Month
Most Recent Crop	==========	==========	=====	==========
Previous Crop				
Previous Crop				

Other Relevant Comments

rm No. 804 (Rev.1)

Results of Analysis

PADDOCK NAME	No2
ORDER NUMBER	129645
PRODUCT	Hort and Full Range Soil
SAMPLE BAG NUMBER SURFACE	06948
CORRESPONDING DEEP SOIL BAG No	
DATE OF SAMPLING	19/05/93
DATE RECEIVED	20/05/93
DATE OF REPORT	26/05/93

Soil colour (Munsell)	Grey Brown
Soil texture	Gritty Sandy Loam
pH(1:5 Water)	8.6
Organic Carbon %C	0.1
Nitrate Nitrogen mg/kg	0.2
Sulfur mg/kg	293
Phosphorus(BSES) mg/kg	200+
Phosphorus(Colwell) mg/kg	5
Potassium meq/100g	0.09
Calcium meq/100g	5.80
Magnesium meq/100g	0.26
Sodium meq/100g	0.19
Chloride mg/kg	55
Copper mg/kg	1.7
Zinc mg/kg	2.3
Manganese mg/kg	8
Iron mg/kg	10
Boron mg/kg	0.13

Calculations

Cation Exch. Capacity meq/100g	6.35
Calcium/Magnesium Ratio	22.31
Sodium% of cations(ESP)	2.99
Elec. Conductivity (s.e.) dS/m	3.4

Methods, Calculations outlined overpage.

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Report # 23465

SOIL ANALYSIS REPORT

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SOIL SAMPLE AND SITE INFORMATION:

Sampling depth(cm)	0-15 Surface	Months of Fallow	
Sampling depth(cm)	- Deep	Age of cultivation	yrs
		Drainage	
Paddock area	ha	Stubble/Trash	
Soil type		Tillage	
Slope		Irrigation	
Soil profile depth	m		
Reasons for sampling	1. Concern with major nutrients		
	2. Concern with micronutrients		

PRODUCTION INFORMATION: yrs mths

Main species to be fertilized 4 Tailings Dam Mid		Age established	-
Variety		Root stock(Hort)	
Previous best yield		Plant population	ha
Yield last year		Canopy radius(Hort)	m
Vigour of growth		Grain protein	
Row/tree spacing(Hort)	m X m	Legume content	
Row spacing(Grain/Cotton)		Stock type	
Interrow treatment		Stock number	
Stage in Crop Cycle(Sugar Cane)			

Method of fertilizer placement:
1. 2. 3.

FERTILIZER HISTORY:	Fertilizers	Application Rate	Units	Date Applied Year Month
Most Recent Crop				
Previous Crop				
Previous Crop				

Other Relevant Comments

Results of Analysis

PADDOCK NAME	No3
ORDER NUMBER	129646
PRODUCT	Hort and Full Range Soil
SAMPLE BAG NUMBER SURFACE	04589
CORRESPONDING DEEP SOIL BAG No	
DATE OF SAMPLING	19/05/93
DATE RECEIVED	20/05/93
DATE OF REPORT	26/05/93

Soil colour (Munsell)	Grey Brown
Soil texture	Gritty Sandy Loam
pH(1:5 Water)	8.9
Organic Carbon %C	0.1
Nitrate Nitrogen mg/kg	0.2
Sulfur mg/kg	87
Phosphorus(BSES) mg/kg	200 +
Phosphorus(Colwell) mg/kg	5
Potassium meq/100g	0.06
Calcium meq/100g	5.70
Magnesium meq/100g	0.15
Sodium meq/100g	0.09
Chloride mg/kg	30
Copper mg/kg	1.7
Zinc mg/kg	2.1
Manganese mg/kg	4
Iron mg/kg	10
Boron mg/kg	0.14

Calculations

Cation Exch. Capacity meq/100g	6.01
Calcium/Magnesium Ratio	38.00
Sodium% of cations(ESP)	1.50
Elec. Conductivity (s.e.) dS/m	1.3

Methods, Calculations outlined overpage.

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Report # 23466

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SOIL SAMPLE AND SITE INFORMATION:

Sampling depth(cm)	0- Surface	Months of Fallow	
Sampling depth(cm)	- Deep	Age of cultivation	yrs
		Drainage	
Paddock area	ha	Stubble/Trash	
Soil type		Tillage	
Slope		Irrigation	
Soil profile depth	m		

Reasons for sampling
1. Concern with major nutrients
2. Concern with micronutrients

PRODUCTION INFORMATION:

Main species to be fertilized Top 4 Dam		Age established	yrs mths -
Variety		Root stock(Hort)	
Previous best yield		Plant population	ha
Yield. last year		Canopy radius(Hort)	m
Vigour of growth		Grain protein	
Row/tree spacing(Hort)	m X m	Legume content	
Row spacing(Grain/Cotton)		Stock type	
Interrow treatment		Stock number	
Stage in Crop Cycle(Sugar Cane)			

Method of fertilizer placement:
1. 2. 3.

FERTILIZER HISTORY:	Fertilizers	Application Rate	Units	Date Applied Year Month
Most Recent Crop				
Previous Crop				
Previous Crop				

Other Relevant Comments

Results of Analysis

PADDOCK NAME	No4
ORDER NUMBER	129647
PRODUCT	Hort and Full Range Soil
SAMPLE BAG NUMBER SURFACE	06949
CORRESPONDING DEEP SOIL BAG No	
DATE OF SAMPLING	19/05/93
DATE RECEIVED	20/05/93
DATE OF REPORT	26/05/93

Soil colour (Munsell)	Grey Brown
Soil texture	Gritty Sandy Loam
pH(1:5 Water)	9.2
Organic Carbon %C	0.1
Nitrate Nitrogen mg/kg	0.2
Sulfur mg/kg	8
Phosphorus(BSES) mg/kg	200 +
Phosphorus(Colwell) mg/kg	4
Potassium meq/100g	0.04
Calcium meq/100g	6.67
Magnesium meq/100g	0.10
Sodium meq/100g	0.11
Chloride mg/kg	25
Copper mg/kg	1.0
Zinc mg/kg	1.9
Manganese mg/kg	2
Iron mg/kg	6
Boron mg/kg	0.07

Calculations

Cation Exch. Capacity meq/100g	6.93
Calcium/Magnesium Ratio	66.70
Sodium% of cations(ESP)	1.59
Elec. Conductivity (s.e.) dS/m	0.7

Methods, Calculations outlined overpage.

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Report # 23480

Table 1

Soil Analysis – No. 4 Tailings Dam

Parameters	Site 1	Site 2	Site 3	Guideline Levels **
Soil colour (Munsell)	Grey Brown	Grey Brown	Grey Brown	–
Soil texture	Gritty Sandy Loam	Gritty Sandy Loam	Gritty Sandy Loam	–
pH (1:5 water)	8.6	8.9	9.2	5.5 – 8.5
Organic carbon %C	0.1	0.1	0.1	–
Nitrate Nitrogen mg/kg	0.2	0.2	0.2	–
Sulphur mg/kg	293	87	8	15
Phosphorus (BSES) mg/kg	200+	200+	200+	–
Phosphorus (Colwell) mg/kg	5	5	4	30
Potassium meq/100g	0.09	0.06	0.04	0.3
Calcium meq/100g	5.80	5.70	6.67	1.2
Magnesium meq/100g	0.26	0.15	0.10	0.8
Sodium meq/100g	0.19	0.09	0.11	–
Chloride mg/kg	55	30	25	<200–600
Copper mg/kg	1.7	1.7	1.0	0.2
Zinc mg/kg	2.3	2.1	1.9	0.5–1
Manganese mg/kg	8	4	2	2.0
Iron mg/kg	10	10	6	4.5
Boron mg/kg	0.13	0.14	0.07	–
Cation Exch. Capacity meq/100g	6.35	6.01	6.93	–
Calcium/Magnesium ratio	22.31	38.00	66.70	–
Sodium % of cations (ESP)	2.99	1.50	1.59	<6++
Elec. Conductivity (s.e.) dS/m	3.4	1.3	0.7	<2+

** Cited in Bell, L.C. and Bell, M.A. (1988) AMIC 1988 Papers; and ASSSI Refresher Course in Soil Science (1985). For nutrients, this is the level below which a plant response to application of the nutrient is expected (Aitken et al, 1984); for Cl, E.C. and ESP, the critical level is the value above which growth retardation may occur.

\+ An $E.C._{SE}$ <2 dS/m is considered to have negligible affects on plant growth with many plants affected in soils having an EC in the range of 4–8 dS/m. Beyond 16 dS/m only a few very salt tolerant plants grow.

++ An ESP >15% is classed strongly sodic.

Table 3
'Soil' Analysis – No 4 Tailings Dam

Parameters	Block 1A	Block 1B	Block 2A	Block 2B	Block 3A	Block 3B	Guideline Levels *
Soil colour (Munsell)	Grey	Grey	Grey	Grey	Grey	Grey	–
Soil texture	Sandy Tails	Sandy Tails	Sandy Tails	Sandy Tails	Sandy Tails	Sandy Tails	–
pH (1:5 Water)	8.7	7.2	8.4	8.8	8.8	9.2	5.5–8.5
Organic Carbon %C	0.1	0.1	0.1	0.1	0.1	0.1	–
Nitrate Nitrogen mg/kg	1.5	0.5	1.2	1	0.8	0.9	–
Sulfur mg/kg	8	5	8	6	10	12	15
Phosphorus (BSES) mg/kg	200+	200+	200+	200+	200+	200+	–
Phosphorus (Colwell) mg/kg	3	2	2	2	5	2	30
Potassium meq/100g	0.03	0.02	0.02	0.01	0.02	0.01	0.3
Calcium meq/100g	1.76	1.01	1.24	1.76	1.55	3.72	1.2
Magnesium meq/100g	0.06	0.06	0.06	0.06	0.06	0.1	0.8
Sodium meq/100g	0.01	0.01	0.01	0.01	0.01	0.01	–
Chloride mg/kg	10	5	10	10	10	5	<200–600
Copper mg/kg	0.7	0.6	0.8	0.6	0.5	0.6	0.2
Zinc mg/kg	1.3	1.2	1.2	1.2	1.3	1.4	0.5–1
Manganese mg/kg	1	1	1	1	1	1	2
Iron mg/kg	7	8	5	5	5	6	4.5
Boron mg/kg	0.04	0.03	0.04	0.02	0.05	0.06	–
ESP (%)	0.53	0.9	0.75	0.54	0.61	0.26	<6**
$EC_{(se)}$d S/m	0.4	0.2	0.4	0.3	0.3	0.4	<2***
CEC meq/100g	1.87	1.11	1.34	1.85	1.65	3.85	–
Ca/Mg ratio	29.33	16.83	20.67	29.33	25.83	37.2	–

* Cited in Bell, L C and Bell M A (1988) and ASSSI Refresher course in Soil Science (1985). For nutrients, this is the level below which a plant response to application of the nutrient is expected (Aitken et al, 1984); for Cl, EC and ESP, the critical level is the value above which growth retardation may occur.

** An ESP >15% is classed strongly sodic.

*** An EC_{se2} dS/m is considered to have negligible effects on plant growth with many plants affected in soils having an EC in the range of 4–8 dS/m. Beyond 16 dS/m only a few very salt tolerant plants grow.

Appendix B:
Erosion and Sediment Control Plan for TSF4 Catchments Diversion Works

Erosion and Sediment Control Plan for TSF4 Catchment Diversion Works

The following erosion and sediment control plan (ESCP) has been developed for the isolation/diversion drain works required (in part) to make TSF4 on the Mount Carbine mine site conform to hazardous dam guidelines (DERM 2012[1]).

Erosion and sedimentation risk – construction

Earthworks associated with installing the isolation/diversion drains for TSF4 pose the primary risk for erosion issues during the construction activities. These works are planned to occur during September and October 2013, during the nominal dry season for the area. It is not likely that significant rainfall will occur at site during the construction. Should heavy rainfall occur, erosion may occur when soils are disturbed.

Due to the timing of the construction works (*ie* north Queensland dry season) there is a low risk of sediment-laden water leaving the construction site during or following rainfall events. Windblown dirt in the dry season may be an issue if excavations or stockpiles are exposed for extended periods and dry out.

Erosion and sediment control measures – construction

The following controls should be implemented during the proposed construction works.

- Works shall be staged so that disturbance of one drain will not occur until the previous drain has been stabilised.
- Use existing tracks where possible.
- Mark limits of disturbance.
- Minimise handling of material.
- Spread seed on disturbed areas to establish ground cover on drains at the onset of the wet season.
- Cover soil stockpiles, if they are to remain on-site for more than 4 weeks or if dust is mobilised during dry conditions. Note that it is expected that there will be minimal stockpiles as material excavated will be used to create banks on the diversion drains.
- Install sediment fences around stockpiles if rainfall is expected to occur.
- Install sediment traps at drainage outlet (*eg* sandbags) if rainfall is expected to occur prior to drains having an established ground cover.
- Remove all temporary erosion and sediment controls after disturbed areas are stabilised.

Site-specific plans for construction are not provided here due to the low risk and simple erosion and sediment control measures. Information on the correct installation and maintenance of relevant erosion and sediment control measures are provided in **Attachment 1**.

Erosion and sediment control – operation

Water captured in the proposed diversion drains will be diverted to stable areas prior to release to the receiving environment. The V-Drain to the north of the TSF4 will drain to a stable area to the east of the TSF4. The Table Drain along the north-west part of the TSF4 will flow into the Catchbank, which will enter the receiving environment via a stabilised (rock armoured) drainage line adjacent to the existing TSF4 spillway.

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[1] DERM 2012. *Manual for assessing hazard categories and hydraulic performance of dams.* EM635, Version 1. February 2012

Construction plans will consider permanent erosion and sediment control requirements.

Monitoring – construction phase

Prior to rainfall events, sediment traps (*eg* using sand bags) should be installed at drainage outlets, and sediment fences should be installed around stockpile areas (if present). The check dams and sediment fences should be inspected following any heavy rainfall events. Clean out or repair as required. Re-position if required.

Monitoring – operation phase

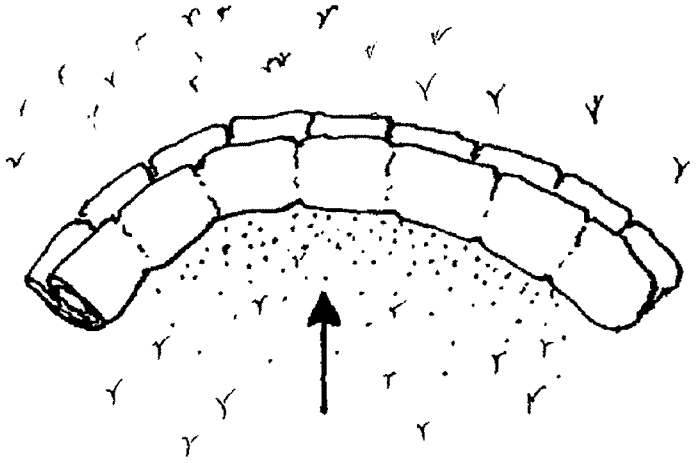
The integrity of the diversion drains and outlets will be inspected after major rainfall events during the wet season for evidence of erosion. Any occurrences of erosion will be remediated and stabilised (*eg* grass cover or rock mulch) as soon as possible. The receiving environment will be inspected during the wet season for evidence of sedimentation. If sedimentation is found, the source of the erosion will be investigated and remediated.

Attachment 1

Sediment Trap

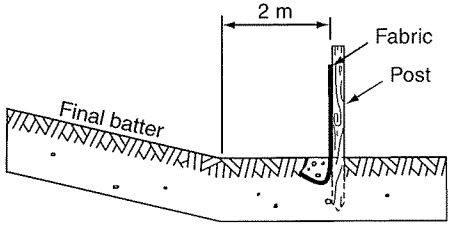
Rationale: Capture eroded sediment by slowing the velocity of water so that the soil particles settle out.

Installation: Wall of sandbags covered with a filter fabric to create a structure that will form a pond.

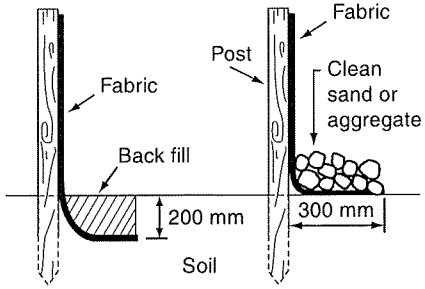




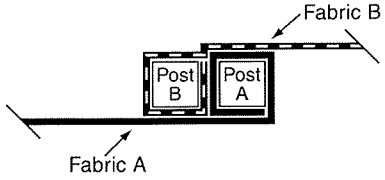
Monitoring and Maintenance: Sediment traps should be inspected after each runoff event (after rainfall). Sediment collected behind the sandbag wall should be removed if the sediment is within 200 mm of the top of the structure. Spread the collected sediment over areas being worked (provided no contamination is present) or on stable grassed areas. Any damaged sections of the sediment traps (*eg* undercutting, flows around trap) are to be repaired or replaced. The source of any excessive sedimentation should be identified and treated.



(a) Location of fence relative to base of slope

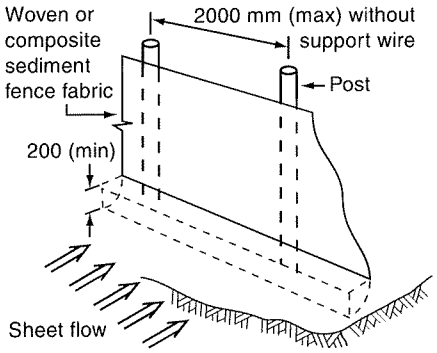


(b) Anchoring base of fabric

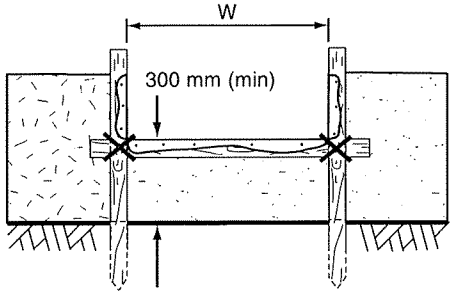


Fabric to fold around each stake one full turn.
Stake B to be drive tightly against Stake A.
The tops of both stakes to be secured with wire.

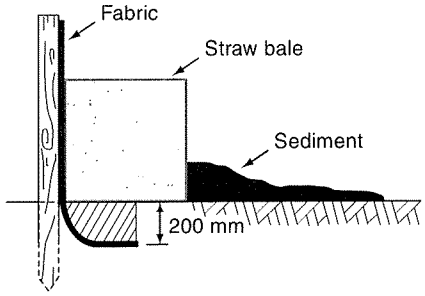
(c) Joining fabric - Method 1



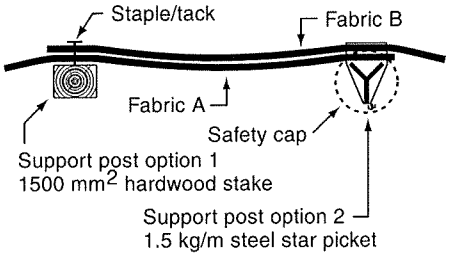
(d) Installation without backing support



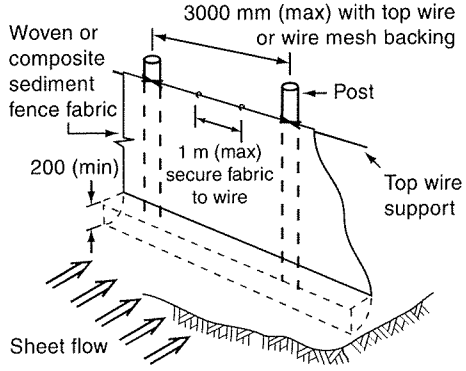
(e) Spill-through weir



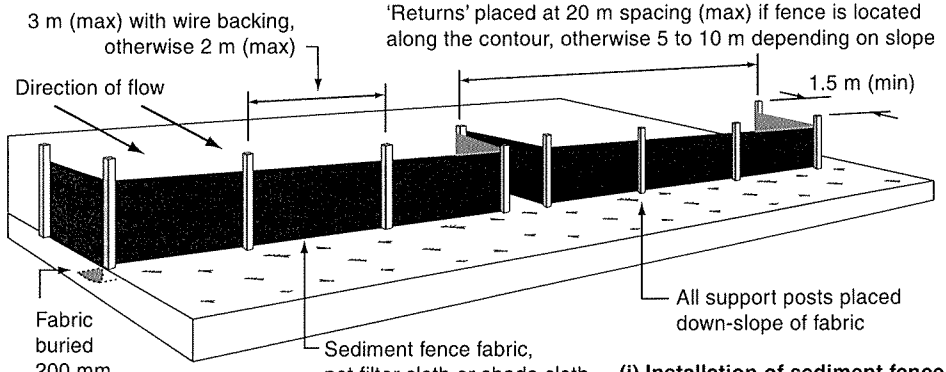
(f) Placement of up-slope straw bale



(g) Joining fabric - Method 2



(h) Installation with top wire support



(i) Installation of sediment fence

Notes:

1. Sediment fence to be installed along a line of constant ground elevation wherever practical.
2. Both end of the sediment fence to extend up the slope at least 1m.
3. Support post to be spaced a maximum 2m unless the fence is supported by a top wire or wire mesh backing, in which case 3m maximum spacing.
4. Fence 'returns' shall be installed at maximum 20m spacing if fence is installed along the contour, otherwise 5 to 10m maximum spacing.
5. Minimum 4 staples or tie wires per stake.

Drawn:	Date:		
GMW	Dec-09	Sediment Fence	SF-01

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MATERIALS

FABRIC: POLYPROPYLENE, POLYAMIDE, NYLON, POLYESTER, OR POLYETHYLENE WOVEN OR NON-WOVEN FABRIC, AT LEAST 700mm IN WIDTH AND A MINIMUM UNIT WEIGHT OF 140GSM. ALL FABRICS TO CONTAIN ULTRAVIOLET INHIBITORS AND STABILISERS TO PROVIDE A MINIMUM OF 6 MONTHS OF USEABLE CONSTRUCTION LIFE (ULTRAVIOLET STABILITY EXCEEDING 70%).

FABRIC REINFORCEMENT: WIRE OR STEEL MESH MINIMUM 14-GAUGE WITH A MAXIMUM MESH SPACING OF 200mm.

SUPPORT POSTS/STAKES: 1500mm^2 (MIN) HARDWOOD, 2500mm^2 (MIN) SOFTWOOD, OR 1.5kg/m (MIN) STEEL STAR PICKETS SUITABLE FOR ATTACHING FABRIC.

INSTALLATION

1. REFER TO APPROVED PLANS FOR LOCATION, EXTENT, AND REQUIRED TYPE OF FABRIC (IF SPECIFIED). IF THERE ARE QUESTIONS OR PROBLEMS WITH THE LOCATION, EXTENT, FABRIC TYPE, OR METHOD OF INSTALLATION CONTACT THE ENGINEER OR RESPONSIBLE ON-SITE OFFICER FOR ASSISTANCE.

2. TO THE MAXIMUM DEGREE PRACTICAL, AND WHERE THE PLANS ALLOW, ENSURE THE FENCE IS LOCATED:
(i) TOTALLY WITHIN THE PROPERTY BOUNDARIES;
(ii) ALONG A LINE OF CONSTANT ELEVATION WHEREVER PRACTICAL;
(iii) AT LEAST 2m FROM THE TOE OF ANY FILLING OPERATIONS THAT MAY RESULT IN SHIFTING SOIL/FILL DAMAGING THE FENCE.

3. INSTALL RETURNS WITHIN THE FENCE AT MAXIMUM 20m INTERVALS IF THE FENCE IS INSTALLED ALONG THE CONTOUR, OR 5 TO 10m MAXIMUM SPACING (DEPENDING ON SLOPE) IF THE FENCE IS INSTALLED AT AN ANGLE TO THE CONTOUR. THE 'RETURNS' SHALL CONSIST OF EITHER:
(i) V-SHAPED SECTION EXTENDING AT LEAST 1.5m UP THE SLOPE; OR
(ii) SANDBAG OR ROCK/AGGREGATE CHECK DAM A MINIMUM 1/3 AND MAXIMUM 1/2 FENCE HEIGHT, AND EXTENDING AT LEAST 1.5m UP THE SLOPE.

4. ENSURE THE EXTREME ENDS OF THE FENCE ARE TURNED UP THE SLOPE AT LEAST 1.5m, OR AS NECESSARY, TO MINIMISE WATER BYPASSING AROUND THE FENCE.

5. ENSURE THE SEDIMENT FENCE IS INSTALLED IN A MANNER THAT AVOIDS THE CONCENTRATION OF FLOW ALONG THE FENCE, AND THE UNDESIRABLE DISCHARGE OF WATER AROUND THE ENDS OF THE FENCE.

6. IF THE SEDIMENT FENCE IS TO BE INSTALLED ALONG THE EDGE OF EXISTING TREES, ENSURE CARE IS TAKEN TO PROTECT THE TREES AND THEIR ROOT SYSTEMS DURING INSTALLATION OF THE FENCE. DO NOT ATTACH THE FABRIC TO THE TREES.

7. UNLESS DIRECTED BY THE SITE SUPERVISOR OR THE APPROVED PLANS, EXCAVATE A 200mm WIDE BY 200mm DEEP TRENCH ALONG THE PROPOSED FENCE LINE, PLACING THE EXCAVATED MATERIAL ON THE UP-SLOPE SIDE OF THE TRENCH.

8. ALONG THE LOWER SIDE OF THE TRENCH, APPROPRIATELY SECURE THE STAKES INTO THE GROUND SPACED NO GREATER THAN 3m IF SUPPORTED BY A TOP SUPPORT WIRE OR WEIR MESH BACKING, OTHERWISE NO GREATER THAN 2m.

9. IF SPECIFIED, SECURELY ATTACH THE SUPPORT WIRE OR MESH TO THE UP-SLOPE SIDE OF THE STAKES WITH THE MESH EXTENDING AT LEAST 200mm INTO THE EXCAVATED TRENCH. ENSURE THE MESH AND FABRIC IS ATTACHED TO THE UP-SLOPE SIDE OF THE STAKES EVEN WHEN DIRECTING A FENCE AROUND A CORNER OR SHARP CHANGE OF DIRECTION.

10. WHEREVER POSSIBLE, CONSTRUCT THE SEDIMENT FENCE FROM A CONTINUOUS ROLL OF FABRIC. TO JOIN FABRIC EITHER:
(i) ATTACH EACH END TO TWO OVERLAPPING STAKES WITH THE FABRIC FOLDING AROUND THE ASSOCIATED STAKE ONE TURN, AND WITH THE TWO STAKES TIED TOGETHER WITH WIRE; OR
(ii) OVERLAP THE FABRIC TO THE NEXT ADJACENT SUPPORT POST.

11. SECURELY ATTACH THE FABRIC TO THE SUPPORT POSTS USING 25 X 12.5mm STAPLES, OR TIE WIRE AT MAXIMUM 150mm SPACING.

12. SECURELY ATTACH THE FABRIC TO THE SUPPORT WIRE/MESH (IF ANY) AT A MAXIMUM SPACING OF 1m.

13. ENSURE THE COMPLETED SEDIMENT FENCE IS AT LEAST 450mm, BUT NOT MORE THAN 700mm HIGH. IF A SPILL-THOUGH WEIR IS INSTALLED, ENSURE THE CREST OF THE WEIR IS AT LEAST 300mm ABOVE GROUND LEVEL.

14. BACKFILL THE TRENCH AND TAMP THE FILL TO FIRMLY ANCHOR THE BOTTOM OF THE FABRIC AND MESH TO PREVENT WATER FROM FLOWING UNDER THE FENCE.

ADDITIONAL REQUIREMENTS FOR THE INSTALLATION OF A SPILL-THROUGH WEIR

1. LOCATE THE SPILL-THROUGH WEIR SUCH THAT THE WEIR CREST WILL BE LOWER THAN THE GROUND LEVEL AT EACH END OF THE FENCE.

2. ENSURE THE CREST OF THE SPILL-THROUGH WEIR IS AT LEAST 300mm THE GROUND ELEVATION.

3. SECURELY TIE A HORIZONTAL CROSS MEMBER (WEIR) TO THE SUPPORT POSTS/ STAKES EACH SIDE OF THE WEIR. CUT THE FABRIC DOWN THE SIDE OF EACH POST AND FOLD THE FABRIC OVER THE CROSS MEMBER AND APPROPRIATELY SECURE THE FABRIC.

4. INSTALL A SUITABLE SPLASH PAD AND/OR CHUTE IMMEDIATELY DOWN-SLOPE OF THE SPILL-THROUGH WEIR TO CONTROL SOIL EROSION AND APPROPRIATELY DISCHARGE THE CONCENTRATED FLOW PASSING OVER THE WEIR.

MAINTENANCE

1. INSPECT THE SEDIMENT FENCE AT LEAST WEEKLY AND AFTER ANY SIGNIFICANT RAIN. MAKE NECESSARY REPAIRS IMMEDIATELY.

2. REPAIR ANY TORN SECTIONS WITH A CONTINUOUS PIECE OF FABRIC FROM POST TO POST.

3. WHEN MAKING REPAIRS, ALWAYS RESTORE THE SYSTEM TO ITS ORIGINAL CONFIGURATION UNLESS AN AMENDED LAYOUT IS REQUIRED OR SPECIFIED.

4. IF THE FENCE IS SAGGING BETWEEN STAKES, INSTALL ADDITIONAL SUPPORT POSTS.

5. REMOVE ACCUMULATED SEDIMENT IF THE SEDIMENT DEPOSIT EXCEEDS A DEPTH OF 1/3 THE HEIGHT OF THE FENCE.

6. DISPOSE OF SEDIMENT IN A SUITABLE MANNER THAT WILL NOT CAUSE AN EROSION OR POLLUTION HAZARD.

7. REPLACE THE FABRIC IF THE SERVICE LIFE OF THE EXISTING FABRIC EXCEEDS 6-MONTHS.

REMOVAL

1. WHEN DISTURBED AREAS UP-SLOPE OF THE SEDIMENT FENCE ARE SUFFICIENTLY STABILISED TO RESTRAIN EROSION, THE FENCE MUST BE REMOVED.

2. REMOVE MATERIALS AND COLLECTED SEDIMENT AND DISPOSE OF IN A SUITABLE MANNER THAT WILL NOT CAUSE AN EROSION OR POLLUTION HAZARD.

3. REHABILITATE/REVEGETATE THE DISTURBED GROUND AS NECESSARY TO MINIMISE THE EROSION HAZARD.

Drawn:	Date:		
GMW	Apr-10	Sediment Fence	SF-02

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Appendix C:
Technical Notes
(IECA 2008)

INSTALLATION

1. REFER TO APPROVED PLANS FOR LOCATION, DIMENSIONS AND CONSTRUCTION DETAILS. IF THERE ARE QUESTIONS OR PROBLEMS WITH THE LOCATION, DIMENSIONS, OR METHOD OF INSTALLATION CONTACT THE ENGINEER OR RESPONSIBLE ON-SITE OFFICER FOR ASSISTANCE.

2. WHEREVER PRACTICAL, LOCATE THE LEVEL SPREADER ON UNDISTURBED, STABLE SOIL.

3. ENSURE FLOW DISCHARGING FROM THE LEVEL SPREADER WILL DISPERSE ACROSS A PROPERLY STABILISED SLOPE NOT EXCEEDING 10:1 (H:V) AND SUFFICIENTLY EVEN IN GRADE ACROSS THE SLOPE TO AVOID CONCENTRATING THE OUTFLOW.

4. THE OUTLET SILL OF THE SPREADER SHOULD BE PROTECTED WITH EROSION CONTROL MATTING TO PREVENT EROSION DURING THE ESTABLISHMENT OF VEGETATION. THE MATTING SHOULD BE A MINIMUM OF 1200mm WIDE EXTENDING AT LEAST 300mm UPSTREAM OF THE EDGE OF THE OUTLET CREST AND BURIED AT LEAST 150mm IN A VERTICAL TRENCH. THE DOWNSTREAM EDGE SHOULD BE SECURELY HELD IN PLACE WITH CLOSELY SPACED HEAVY-DUTY WIRE STAPLES AT LEAST 150mm LONG.

5. ENSURE THAT THE OUTLET SILL (CREST) IS LEVEL FOR THE SPECIFIED LENGTH.

6. IMMEDIATELY AFTER CONSTRUCTION, TURF, OR SEED AND MULCH WHERE APPROPRIATE, THE LEVEL SPREADER.

MAINTENANCE

1. INSPECT THE LEVEL SPREADER AFTER EVERY RAINFALL EVENT UNTIL VEGETATION IS ESTABLISHED.

2. AFTER ESTABLISHMENT OF VEGETATION OVER THE LEVEL SPREADER, INSPECTIONS SHOULD BE MADE ON A REGULAR BASIS AND AFTER RUNOFF-PRODUCING RAINFALL.

3. ENSURE THAT THERE IS NO SOIL EROSION AND THAT SEDIMENT DEPOSITION IS NOT CAUSING THE CONCENTRATION OF FLOW.

4. ENSURE THAT THERE IS NO SOIL EROSION OR CHANNEL DAMAGE UPSTREAM OF THE LEVEL SPREADER, OR SOIL EROSION OR VEGETATION DAMAGE DOWNSTREAM OF THE LEVEL SPREADER.

5. INVESTIGATE THE SOURCE OF ANY EXCESSIVE SEDIMENTATION.

6. MAINTAIN GRASS IN A HEALTH CONDITION WITH NO LESS THAN 90% COVER UNLESS CURRENT WEATHER CONDITIONS REQUIRE OTHERWISE.

7. GRASS HEIGHT SHOULD BE MAINTAINED AT A MINIMUM 50mm BLADE LENGTH WITHIN THE LEVEL SPREADER AND DOWNSTREAM DISCHARGE AREA, AND A MAXIMUM BLADE LENGTH NO GREATER THAN ADJACENT GRASSES.

REMOVAL

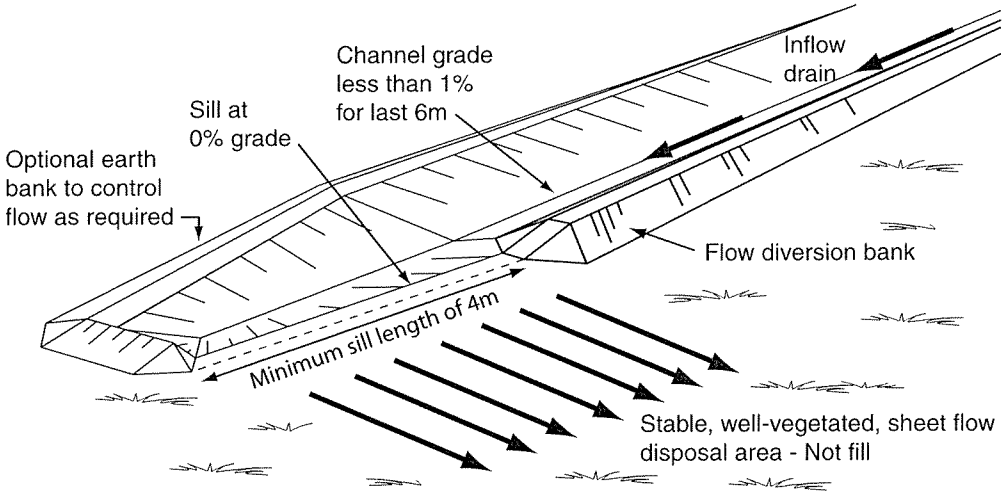
1. TEMPORARY LEVEL SPREADERS SHOULD BE DECOMMISSIONED ONLY AFTER AN ALTERNATIVE STABLE OUTLET IS OPERATIONAL, OR WHEN THE INFLOW CHANNEL IS DECOMMISSIONED.

2. REMOVE COLLECTED SEDIMENT AND DISPOSE OF IN A SUITABLE MANNER THAT WILL NOT CAUSE AN EROSION OR POLLUTION HAZARD.

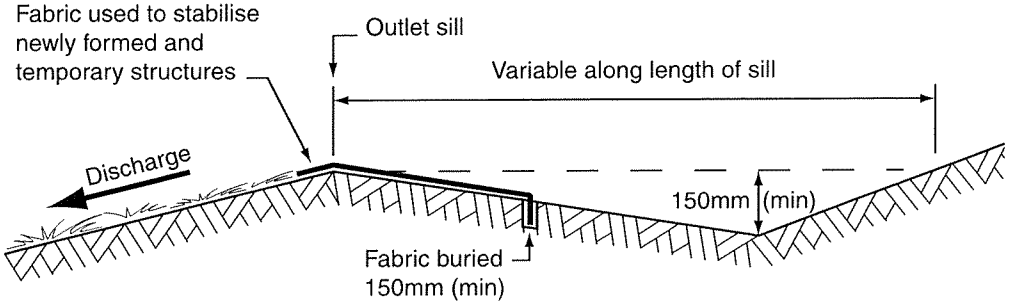
3. REMOVE AND APPROPRIATELY DISPOSE OF ANY EXPOSED GEOTEXTILE.

4. GRADE THE AREA AND SMOOTH IT OUT IN PREPARATION FOR STABILISATION.

5. STABILISE THE AREA AS SPECIFIED ON THE APPROVED PLAN.



(a) Typical layout of level spreader



(b) Typical profile of the the outlet weir

Drawn:	Date:		
GMW	Dec-09	Level Spreaders	LS-01

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Appendix B:
IECA Standard Drawings

Monitoring Checklist– Erosion/Sediment Control Measures

Area: .....

Date: .....

Inspection Participants: .....

Page: ***of***

ESC Structure	Identification Code	Complies (✓/ x)	Corrective Action / Notes

Authorisation/Acceptance of Corrective Actions

Relevant Department Manager: ....
name signature date

Senior Environmental Advisor: ....
name signature date

Appendix E:
ESC Monitoring Checklist

Inspection Test Plan – Erosion/Sediment Control Measures

Note: Structures are to be identified and individually numbered (or otherwise identified) in the field as part of the implementation of the ESCP. The ITP will then be updated.

ESC Structure	Identification Code	Location	Installation Date	Validation			
				Contractor Verification	Date	ESC Professional's/ SEA signature	Date

Authorisation/Acceptance of Corrective Actions

Relevant Department Manager: ....
name signature date

Senior Environmental Advisor: ....
name signature date

Appendix D:
Inspection Test Plans (ITPs)

MATERIALS

ROCK: 150 TO 300mm EQUIVALENT DIAMETER, HARD, EROSION RESISTANT ROCK.

SANDBAGS: GEOTEXTILE BAGS (WOVEN SYNTHETIC, OR NON-WOVEN BIODEGRADABLE) FILLED WITH CLEAN COARSE SAND, CLEAN AGGREGATE, OR COMPOST.

INSTALLATION (ROCK CHECK DAM)

1. REFER TO APPROVED PLANS FOR LOCATION AND INSTALLATION DETAILS. IF THERE ARE QUESTIONS OR PROBLEMS WITH THE LOCATION OR METHOD OF INSTALLATION CONTACT THE ENGINEER OR RESPONSIBLE ON-SITE OFFICER FOR ASSISTANCE.

2. PRIOR TO PLACEMENT OF THE SEDIMENT TRAP, ENSURE THE DRAINAGE CHANNEL IS DEEP ENOUGH TO PREVENT WATER BEING UNSAFELY DIVERTED OUT OF THE DRAIN ONCE THE CHECK DAMS ARE INSTALLED.

3. LOCATE EACH CHECK DAM SEDIMENT TRAP AS DIRECTED WITHIN THE APPROVED PLANS, OR OTHERWISE AT SUCH A SPACING TO ACHIEVE THE REQUIRED SEDIMENT TRAPPING OUTCOMES.

4. IF THE CHECK DAMS ARE ALSO BEING USED TO CONTROL EROSION WITHIN THE DRAINAGE CHANNEL, THEN LOCATE EACH SUCCESSIVE CHECK DAM SUCH THAT THE CREST OF THE IMMEDIATE DOWNSTREAM DAM IS LEVEL WITH THE CHANNEL INVERT AT THE IMMEDIATE UPSTREAM CHECK DAM.

5. CONSTRUCT EACH CHECK DAM TO THE DIMENSIONS AND PROFILE SHOWN WITHIN THE APPROVED PLAN.

6. WHERE SPECIFIED, THE CHECK DAMS MUST BE CONSTRUCTED ON A SHEET OF GEOTEXTILE FABRIC USED AS A DOWNSTREAM SPLASH PAD.

7. EACH CHECK DAM MUST BE EXTENDED UP THE CHANNEL BANK (WHERE PRACTICABLE) TO AN ELEVATION AT LEAST 150mm ABOVE THE CREST LEVEL OF THE DAM.

INSTALLATION (COMPOST-FILLED SOCKS)

1. REFER TO APPROVED PLANS FOR LOCATION AND INSTALLATION DETAILS. IF THERE ARE QUESTIONS OR PROBLEMS WITH THE LOCATION OR METHOD OF INSTALLATION CONTACT THE ENGINEER OR RESPONSIBLE ON-SITE OFFICER FOR ASSISTANCE.

2. PRIOR TO PLACEMENT OF THE SEDIMENT TRAP, ENSURE THE DRAINAGE CHANNEL IS DEEP ENOUGH TO PREVENT WATER BEING UNSAFELY DIVERTED OUT OF THE DRAIN ONCE THE CHECK DAMS ARE INSTALLED.

3. LOCATE EACH SOCK AS DIRECTED WITHIN THE APPROVED PLANS, OR OTHERWISE AT SUCH A SPACING TO ACHIEVE THE REQUIRED SEDIMENT TRAPPING OUTCOMES.

4. PLACE EACH SOCK TO THE LINES AND PROFILE SHOWN IN THE APPROVED PLAN OR AS DIRECTED BY THE SITE SUPERVISOR.

5. ENSURE EACH SOCK EXTENDS UP THE CHANNEL BANKS (WHERE PRACTICAL) TO A LEVEL AT LEAST 100mm ABOVE THE CREST LEVEL OF THE CHECK DAM.

MAINTENANCE

1. INSPECT EACH CHECK DAM AND THE DRAINAGE CHANNEL AT LEAST WEEKLY AND AFTER RUNOFF-PRODUCING RAINFALL.

2. CORRECT ALL DAMAGE IMMEDIATELY. IF SIGNIFICANT EROSION OCCURS BETWEEN ANY OF THE CHECK DAMS, THEN CHECK THE SPACING OF THE DAMS AND WHERE NECESSARY INSTALL INTERMEDIATE CHECK DAMS OR A SUITABLE CHANNEL LINER.

3. CHECK FOR DISPLACEMENT OF THE CHECK DAMS.

4. CHECK FOR SOIL SCOUR AROUND THE ENDS OF EACH CHECK DAM. IF SUCH EROSION IS OCCURRING, CONSIDER EXTENDING THE WIDTH OF THE CHECK DAM TO AVOID SUCH PROBLEMS.

5. IF SEVERE SOIL EROSION OCCURS EITHER UNDER OR AROUND THE CHECK DAMS, THEN SEEK EXPERT ADVICE ON AN ALTERNATIVE TREATMENT MEASURE.

6. DE-SILT SEDIMENT TRAP IF THE SEDIMENT LEVEL EXCEEDS 1/3 THE CREST HEIGHT.

7. DISPOSE OF COLLECTED SEDIMENT IN A SUITABLE MANNER THAT WILL NOT CAUSE AN EROSION OR POLLUTION HAZARD.

REMOVAL

1. WHEN CONSTRUCTION WORK WITHIN THE DRAINAGE AREA ABOVE THE CHECK DAMS HAS BEEN COMPLETED AND DISTURBED AREAS SUFFICIENTLY STABILISED TO RESTRAIN EROSION, THE DAMS MUST BE REMOVED, UNLESS THE SEDIMENT TRAPS ARE TO REMAIN AS A PERMANENT FEATURE.

2. REMOVE COLLECTED SEDIMENT AND DISPOSE OF IN A SUITABLE MANNER THAT WILL NOT CAUSE AN EROSION OR POLLUTION HAZARD.

3. REMOVE AND APPROPRIATELY DISPOSE OF ALL MATERIALS INCLUDING ANY GEOTEXTILE FABRIC.

4. STABILISE THE DISTURBED CHANNEL WITH A LINING OF FABRIC AND ROCK, OR ESTABLISH VEGETATION AS APPROPRIATE.

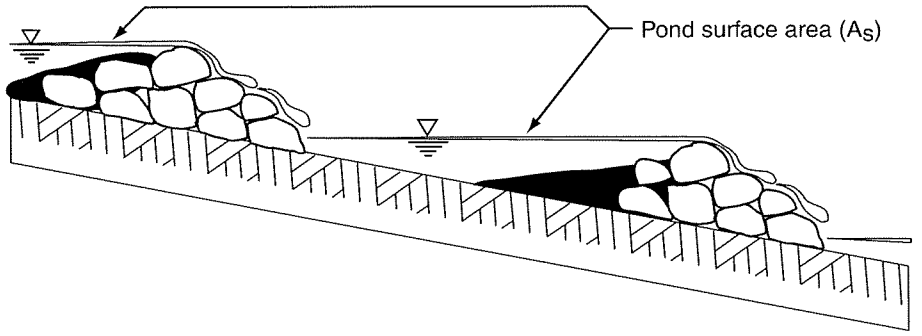


Figure 1 - Placement of check dam sediment traps

Drawn:	Date:		
GMW	Apr-10	Check Dam Sediment Trap	CDT-01

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INSTALLATION

1. REFER TO APPROVED PLANS FOR LOCATION, EXTENT, AND CONSTRUCTION DETAILS. IF THERE ARE QUESTIONS OR PROBLEMS WITH THE LOCATION, EXTENT, OR METHOD OF INSTALLATION, CONTACT THE ENGINEER OR RESPONSIBLE ON-SITE OFFICER FOR ASSISTANCE.

2. ENSURE ALL NECESSARY SOIL TESTING (e.g. SOIL pH, NUTRIENT LEVELS) AND ANALYSIS HAS BEEN COMPLETED, AND REQUIRED SOIL ADJUSTMENTS PERFORMED PRIOR TO PLANTING.

3. CLEAR THE LOCATION FOR THE CHANNEL, CLEARING ONLY WHAT IS NEEDED TO PROVIDE ACCESS FOR PERSONNEL AND CONSTRUCTION EQUIPMENT.

4. REMOVE ROOTS, STUMPS, AND OTHER DEBRIS AND DISPOSE OF THEM PROPERLY. DO NOT USE DEBRIS TO BUILD ANY ASSOCIATED EMBANKMENTS.

5. EXCAVATE THE DIVERSION CHANNEL TO THE SPECIFIED SHAPE, ELEVATION AND GRADIENT. THE SIDES OF THE CHANNEL SHOULD BE NO STEEPER THAN A 2:1 (H:V) IF CONSTRUCTED IN EARTH, UNLESS SPECIFICALLY DIRECTED WITHIN THE APPROVED PLANS.

6. STABILISE THE CHANNEL AND BANKS IMMEDIATELY UNLESS IT WILL OPERATE FOR LESS THAN 30 DAYS. IN EITHER CASE, TEMPORARY EROSION PROTECTION (MATTING, ROCK, ETC.) WILL BE REQUIRED AS SPECIFIED WITHIN THE APPROVED PLANS OR AS DIRECTED.

7. ENSURE THE CHANNEL DISCHARGES TO A STABLE AREA.

ADDITIONAL REQUIREMENTS FOR TURF PLACEMENT:

1. TURF SHOULD BE USED WITHIN 12 HOURS OF DELIVERY, OTHERWISE ENSURE THE TURF IS STORED IN CONDITIONS APPROPRIATE FOR THE WEATHER CONDITIONS (e.g. A SHADED AREA).

2. MOISTENING THE TURF AFTER IT IS UNROLLED WILL HELP MAINTAIN ITS VIABILITY.

3. TURF SHOULD BE LAID ON A MINIMUM 75mm BED OF ADEQUATELY FERTILISED TOPSOIL. RAKE THE SOIL SURFACE TO BREAK THE CRUST JUST BEFORE LAYING THE TURF.

4. DURING THE WARMER MONTHS, LIGHTLY IRRIGATE THE SOIL IMMEDIATELY BEFORE LAYING THE TURF.

5. ENSURE THE TURF IS NOT LAID ON GRAVEL, HEAVILY COMPACTED SOILS, OR SOILS THAT HAVE BEEN RECENTLY TREATED WITH HERBICIDES.

6. ENSURE THE TURF EXTENDS UP THE SIDES OF THE DRAIN AT LEAST 100mm ABOVE THE ELEVATION OF THE CHANNEL INVERT, OR AT LEAST TO A SUFFICIENT ELEVATION TO FULLY CONTAIN EXPECTED CHANNEL FLOW.

7. ON CHANNEL GRADIENTS OF 3:1(H:V) OR STEEPER, OR IN SITUATIONS WHERE HIGH FLOW VELOCITIES (i.e. VELOCITY >1.5m/s) ARE LIKELY WITHIN THE FIRST TWO WEEK FOLLOWING PLACEMENT, SECURE THE INDIVIDUAL TURF STRIPS WITH WOODEN OR PLASTIC PEGS.

8. ENSURE THAT INTIMATE CONTACT IS ACHIEVED AND MAINTAINED BETWEEN THE TURF AND THE SOIL SUCH THAT SEEPAGE FLOW BENEATH THE TURF IS AVOIDED.

9. WATER UNTIL THE SOIL IS WET 100mm BELOW THE TURF. THEREAFTER, WATERING SHOULD BE SUFFICIENT TO MAINTAIN AND PROMOTE HEALTHY GROWTH

MAINTENANCE

1. DURING THE SITE'S CONSTRUCTION PERIOD, INSPECT THE DIVERSION CHANNEL WEEKLY AND AFTER ANY INCREASE IN FLOWS WITHIN THE CHANNEL. REPAIR ANY SLUMPS, WHEEL TRACK DAMAGE OR LOSS OF FREEBOARD.

2. ENSURE FILL MATERIAL OR SEDIMENT IS NOT PARTIALLY BLOCKING THE CHANNEL. WHERE NECESSARY, REMOVE ANY DEPOSITED MATERIAL TO ALLOW FREE DRAINAGE.

3. DISPOSE OF ANY COLLECTED SEDIMENT OR FILL IN A MANNER THAT WILL NOT CREATE AN EROSION OR POLLUTION HAZARD.

REMOVAL

1. WHEN THE CONSTRUCTION WORK ABOVE A TEMPORARY DIVERSION CHANNEL IS FINISHED AND THE AREA IS STABILISED, THE AREA SHOULD BE APPROPRIATELY REHABILITATED.

2. DISPOSE OF ANY COLLECTED SEDIMENT OR FILL IN A MANNER THAT WILL NOT CREATE AN EROSION OR POLLUTION HAZARD.

3. GRADE THE AREA AND SMOOTH IT OUT IN PREPARATION FOR STABILISATION.

4. STABILISE THE AREA AS SPECIFIED IN THE APPROVED PLAN.

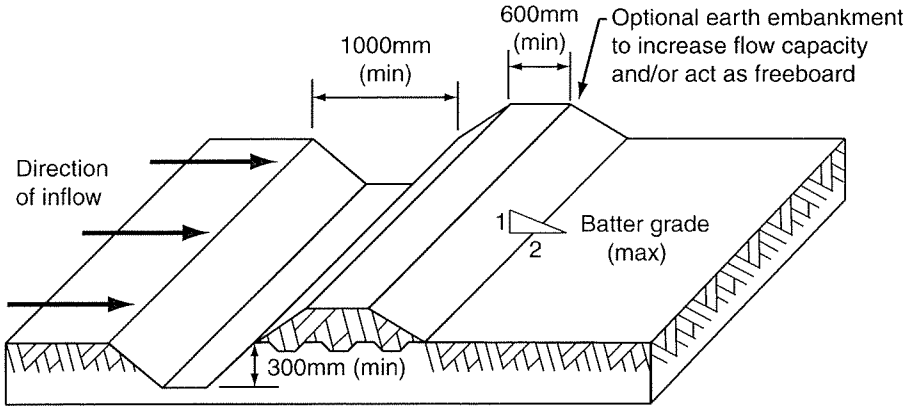


Figure 1 - Typical profile of diversion channel with bank

Drawn:	Date:		
GMW	Dec-09	Diversion Channels	DC-01

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MATERIAL

ROCK MULCH: 25–75mm DURABLE, WEATHER RESISTANT AND EVENLY GRADED WITH 50% BY WEIGHT LARGER THAN THE SPECIFIED NOMINAL ROCK SIZE (IF SPECIFIED).

INSTALLATION

1. REFER TO APPROVED PLANS FOR LOCATION, EXTENT, AND APPLICATION DETAILS. IF THERE ARE QUESTIONS OR PROBLEMS WITH THE LOCATION, EXTENT, OR METHOD OF APPLICATION CONTACT THE ENGINEER OR RESPONSIBLE ON-SITE OFFICER FOR ASSISTANCE.

2. SPREAD ENOUGH ROCK TO COMPLETELY COVER THE SURFACE OF THE SOIL AT THE DENSITY OR THICKNESS SPECIFIED IN THE APPROVED PLANS. IF THE APPLICATION DENSITY IS NOT SUPPLIED, THEN APPLY AT A THICKNESS OF AT LEAST 50mm OR TWICE THE NOMINAL ROCK SIZE (WHICHEVER IS GREATER).

3. IF THE EXPOSED SOILS ARE DISPERSIVE, THEN ENSURE THESE SOILS ARE COVERED WITH A LAYER OF NON-DISPERSIVE SOIL (MINIMUM 200mm) BEFORE PLACEMENT OF ROCK.

4. MAKE ALL NECESSARY ADJUSTMENTS TO ENSURE ANY SURFACE FLOW IS ALLOWED TO PASS FREELY ACROSS THE TREATED AREA FOLLOWING ITS NATURAL DRAINAGE PATH.

MAINTENANCE

1. INSPECT ALL TREATED SURFACES FORTNIGHTLY AND AFTER RUNOFF-PRODUCING RAINFALL.

2. CHECK FOR RILL EROSION, OR DISLODGMENT OF THE ROCKS.

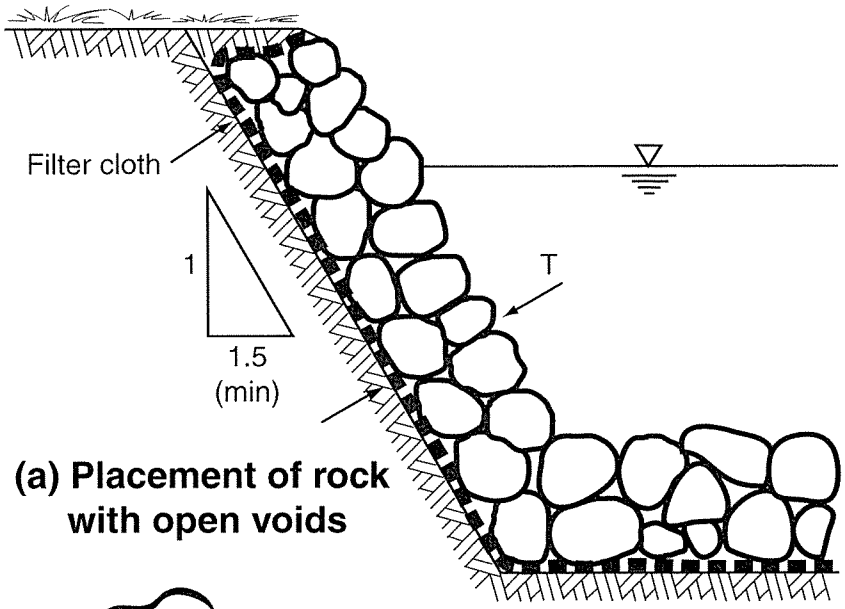
3. REPLACE ANY DISPLACED ROCKS TO MAINTAIN THE REQUIRED COVERAGE.

4. IF WASH-OUTS OCCUR, REPAIR THE SLOPE AND REINSTALL ROCK COVER.

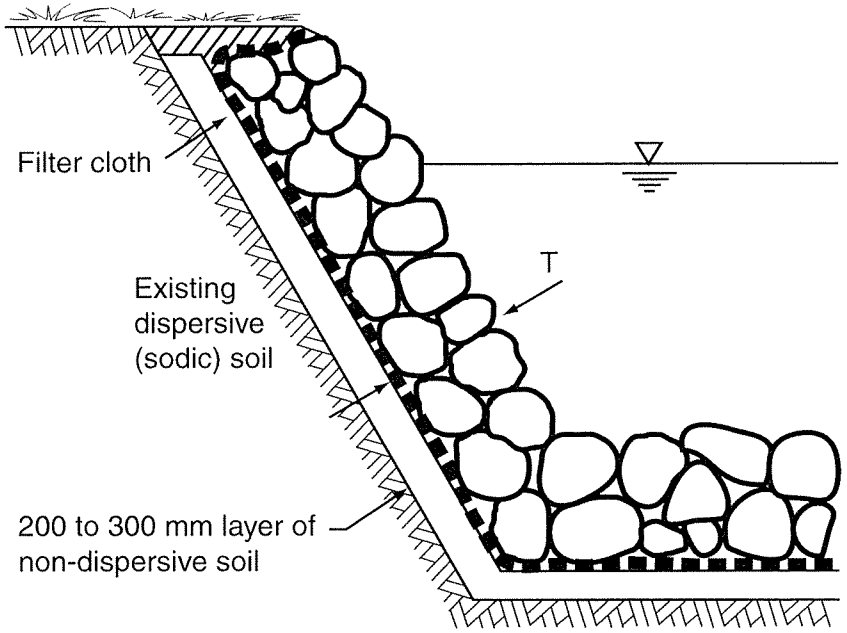
5. IF THE ROCK MULCHING IS NOT EFFECTIVE IN CONTAINING THE SOIL EROSION IT SHOULD BE REPLACED, OR AN ALTERNATIVE EROSION CONTROL PROCEDURE ADOPTED.

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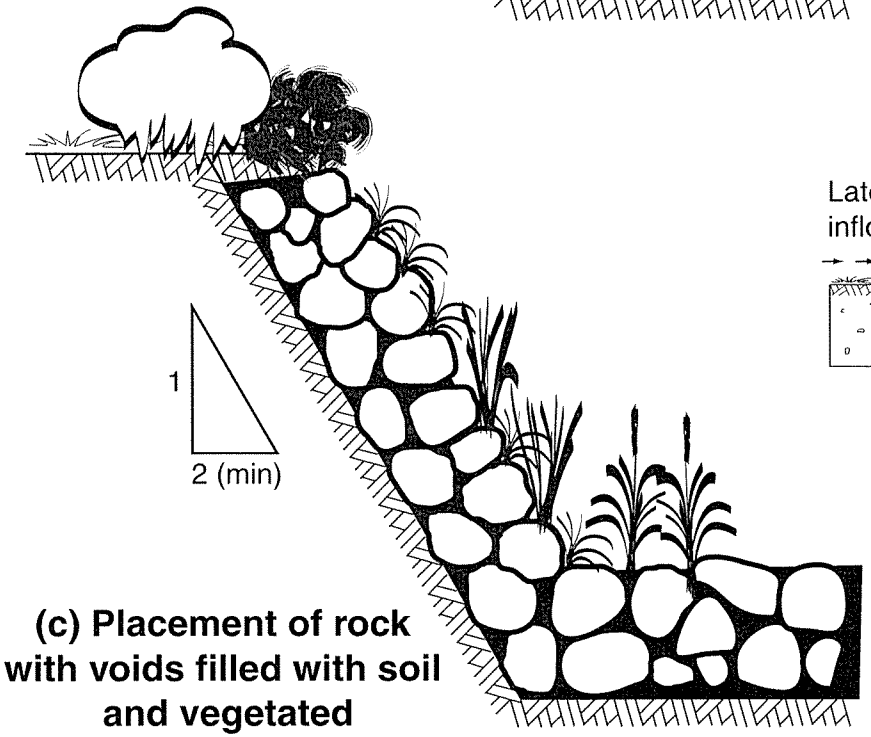
Drawn:	Date:		
GMW	Dec-09	Rock Mulching	MR-01



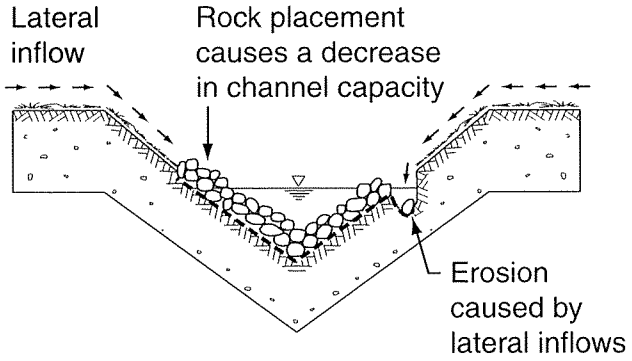
(a) Placement of rock with open voids



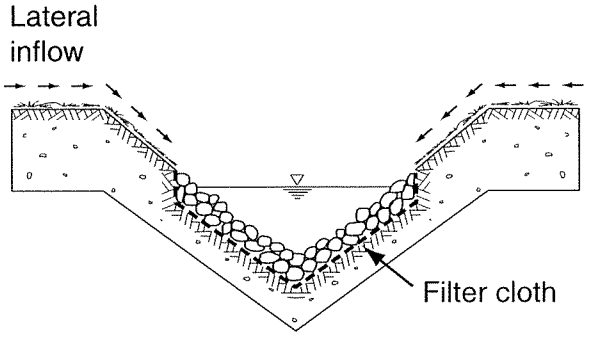
(b) Placement of rock within a channel cut into dispersive soils



(c) Placement of rock with voids filled with soil and vegetated



(d) Poor placement of rock along channel invert



(e) Good placement of rock along channel invert

Drawn:	Date:		
GMW	Dec-09	Rock Linings	RR-01

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MATERIALS

ROCK: HARD, ANGULAR, DURABLE, WEATHER RESISTANT AND EVENLY GRADED WITH 50% BY WEIGHT LARGER THAN THE SPECIFIED NOMINAL ROCK SIZE AND SUFFICIENT SMALL ROCK TO FILL THE VOIDS BETWEEN THE LARGER ROCK. THE DIAMETER OF THE LARGEST ROCK SIZE SHOULD BE NO LARGER THAN 1.5 TIMES THE NOMINAL ROCK SIZE. SPECIFIC GRAVITY TO BE AT LEAST 2.5.

GEOTEXTILE FABRIC: HEAVY-DUTY, NEEDLE-PUNCHED, NON-WOVEN FILTER CLOTH, MINIMUM BIDIM A24 OR EQUIVALENT.

INSTALLATION

1. REFER TO APPROVED PLANS FOR LOCATION, EXTENT AND INSTALLATION DETAILS. IF THERE ARE QUESTIONS OR PROBLEMS WITH THE LOCATION, EXTENT, OR METHOD OF INSTALLATION CONTACT THE ENGINEER OR RESPONSIBLE ON-SITE OFFICER FOR ASSISTANCE.

2. CLEAR THE PROPOSED CHANNEL AREA OF TREES, STUMPS, ROOTS, LOOSE ROCK, AND OTHER OBJECTIONABLE MATERIALS.

3. EXCAVATE THE CHANNEL TO THE LINES AND GRADES AS SHOWN ON THE PLANS. OVER-CUT THE CHANNEL TO A DEPTH EQUAL TO THE SPECIFIED DEPTH OF ROCK PLACEMENT SUCH THAT THE FINISHED ROCK SURFACE WILL BE AT THE ELEVATION OF THE SURROUNDING LAND.

4. ROCK MUST BE PLACED WITHIN THE CHANNEL AS SPECIFIED WITHIN THE APPROVED PLANS, INCLUDING THE PLACEMENT OF ANY SPECIFIED FILTER LAYER.

5. IF DETAILS ARE NOT PROVIDED ON THE ROCK PLACEMENT, THEN THE PRIMARY ARMOUR ROCK MUST BE EITHER PLACED ON:

(i) A FILTER BED FORMED FROM A LAYER OF SPECIFIED SMALLER ROCK (ROCK FILTER LAYER);

(ii) AN EARTH BED LINED WITH FILTER CLOTH;

(iii) AN EARTH BED NOT LINED IN FILTER CLOTH, BUT ONLY IF ALL VOIDS BETWEEN THE ARMOUR ROCK ARE TO BE FILLED WITH SOIL AND POCKET PLANTED IMMEDIATELY AFTER PLACEMENT OF THE ROCK.

6. IF A ROCK/AGGREGATE FILTER LAYER IS SPECIFIED, THEN PLACE THE FILTER LAYER IMMEDIATELY AFTER THE FOUNDATIONS ARE PREPARED. SPREAD THE FILTER ROCK IN A UNIFORM LAYER TO THE SPECIFIED DEPTH BUT A MINIMUM OF 150mm. WHERE MORE THAN ONE LAYER OF FILTER MATERIAL HAS BEEN SPECIFIED, SPREAD EACH LAYER SUCH THAT MINIMAL MIXING OCCURS BETWEEN EACH LAYER OF ROCK.

7. IF A GEOTEXTILE (FILTER CLOTH) UNDERLAY IS SPECIFIED, PLACE THE FABRIC DIRECTLY ON THE PREPARED FOUNDATION. IF MORE THAN ONE SHEET OF FABRIC IS REQUIRED TO OVER THE AREA, OVERLAP THE EDGE OF EACH SHEET AT LEAST 300mm AND PLACE ANCHOR PINS AT MINIMUM 1m SPACING ALONG THE OVERLAP.

8. ENSURE THE GEOTEXTILE FABRIC IS PROTECTED FROM PUNCHING OR TEARING DURING INSTALLATION OF THE FABRIC AND THE ROCK. REPAIR ANY DAMAGE BY REMOVING THE ROCK AND PLACING WITH ANOTHER PIECE OF FILTER CLOTH OVER THE DAMAGED AREA OVERLAPPING THE EXISTING FABRIC A MINIMUM OF 300mm.

9. WHERE NECESSARY, A MINIMUM 100mm LAYER OF FINE GRAVEL, AGGREGATE OR SAND SHOULD BE PLACED OVER THE FABRIC TO PROTECT IT FROM DAMAGE.

10. PLACEMENT OF ROCK SHOULD FOLLOW IMMEDIATELY AFTER PLACEMENT OF THE FILTER LAYER. PLACE ROCK SO THAT IT FORMS A DENSE, WELL-GRADED MASS OF ROCK WITH A MINIMUM OF VOIDS.

11. PLACE ROCK TO ITS FULL THICKNESS IN ONE OPERATION. DO NOT PLACE ROCK BY DUMPING THROUGH CHUTES OR OTHER METHODS THAT CAUSE SEGREGATION OF ROCK SIZES.

12. THE FINISHED SURFACE SHOULD BE FREE OF POCKETS OF SMALL ROCK OR CLUSTERS OF LARGE ROCKS. HAND PLACING MAY BE NECESSARY TO ACHIEVE THE PROPER DISTRIBUTION OF ROCK SIZES TO PRODUCE A RELATIVELY SMOOTH, UNIFORM SURFACE. THE FINISHED GRADE OF THE ROCK SHOULD BLEND WITH THE SURROUNDING AREA. NO OVERFALL OR PROTRUSION OF ROCK SHOULD BE APPARENT.

13. IMMEDIATELY UPON COMPLETION OF THE CHANNEL, VEGETATE ALL DISTURBED AREAS OR OTHERWISE PROTECT THEM AGAINST SOIL EROSION.

14. WHERE SPECIFIED, FILL ALL VOIDS WITH SOIL AND VEGETATE THE ROCK SURFACE IN ACCORDANCE WITH THE APPROVED PLAN.

MAINTENANCE

1. ROCK-LINED CHANNELS SHOULD BE INSPECTED PERIODICALLY AND AFTER SIGNIFICANT STORM EVENTS. CHECK FOR SCOUR OR DISLODGED ROCK. REPAIR DAMAGED AREAS IMMEDIATELY.

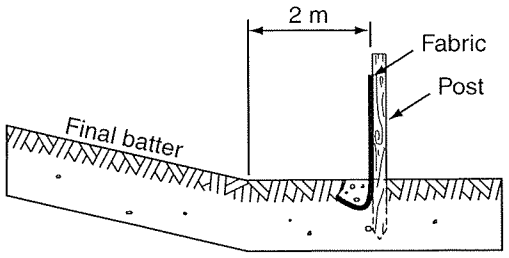
2. CLOSELY INSPECT THE OUTER EDGES OF THE ROCK PROTECTION. ENSURE WATER ENTRY INTO THE CHANNEL OR CHUTE IS NOT CAUSING EROSION ALONG THE EDGE OF THE ROCK PROTECTION.

3. CAREFULLY CHECK THE STABILITY OF THE ROCK LOOKING FOR INDICATIONS OF PIPING, SCOUR HOLES, OR BANK FAILURES.

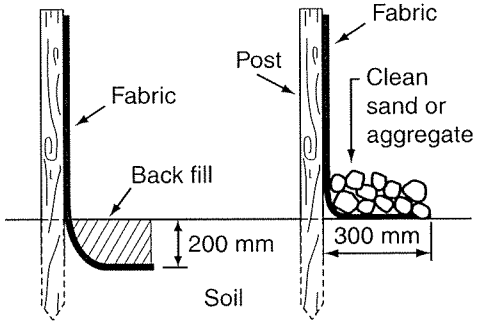
4. REPLACE ANY DISPLACED ROCK WITH ROCK OF A SIGNIFICANTLY (MINIMUM 110%) LARGER SIZE THAN THE DISPLACED ROCK.

Drawn:	Date:		
GMW	May-10	Rock Linings	RR-02

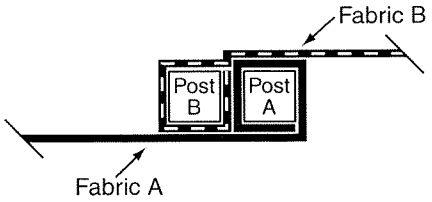
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(a) Location of fence relative to base of slope

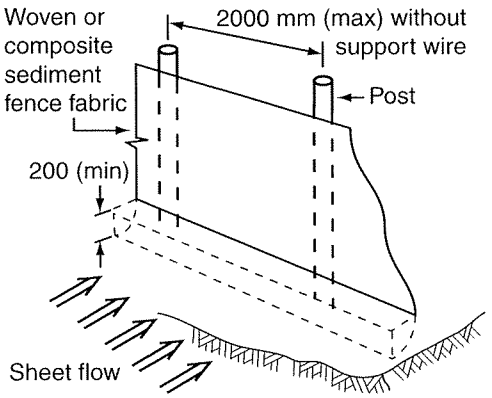


(b) Anchoring base of fabric

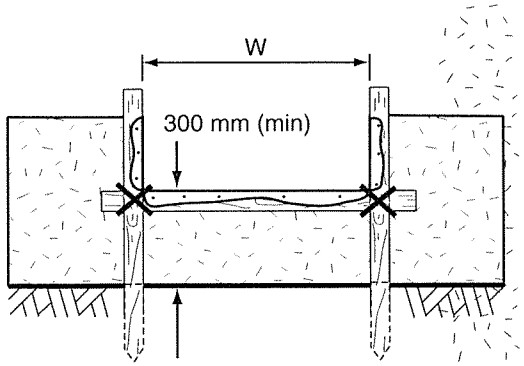


Fabric to fold around each stake one full turn.
Stake B to be drive tightly against Stake A.
The tops of both stakes to be secured with wire.

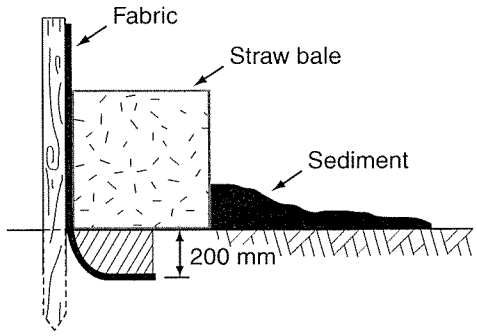
(c) Joining fabric - Method 1



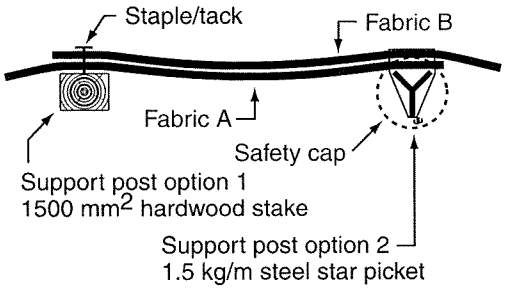
(d) Installation without backing support



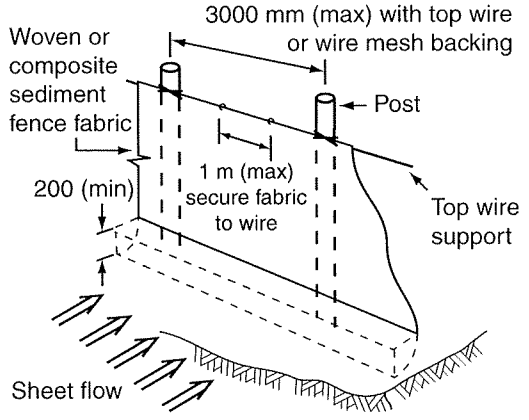
(e) Spill-through weir



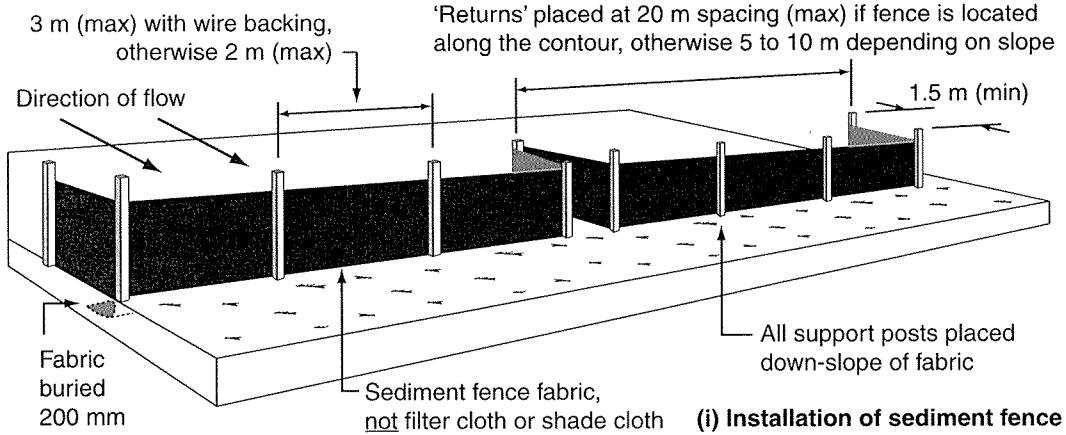
(f) Placement of up-slope straw bale



(g) Joining fabric - Method 2



(h) Installation with top wire support



(i) Installation of sediment fence

Notes:

1. Sediment fence to be installed along a line of constant ground elevation wherever practical.
2. Both end of the sediment fence to extend up the slope at least 1m.
3. Support post to be spaced a maximum 2m unless the fence is supported by a top wire or wire mesh backing, in which case 3m maximum spacing.
4. Fence 'returns' shall be installed at maximum 20m spacing if fence is installed along the contour, otherwise 5 to 10m maximum spacing.
5. Minimum 4 staples or tie wires per stake.

Drawn:	Date:		
GMW	Dec-09	Sediment Fence	SF-01

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MATERIALS

FABRIC: POLYPROPYLENE, POLYAMIDE, NYLON, POLYESTER, OR POLYETHYLENE WOVEN OR NON-WOVEN FABRIC, AT LEAST 700mm IN WIDTH AND A MINIMUM UNIT WEIGHT OF 140GSM. ALL FABRICS TO CONTAIN ULTRAVIOLET INHIBITORS AND STABILISERS TO PROVIDE A MINIMUM OF 6 MONTHS OF USEABLE CONSTRUCTION LIFE (ULTRAVIOLET STABILITY EXCEEDING 70%).

FABRIC REINFORCEMENT: WIRE OR STEEL MESH MINIMUM 14-GAUGE WITH A MAXIMUM MESH SPACING OF 200mm.

SUPPORT POSTS/STAKES: 1500mm^2 (MIN) HARDWOOD, 2500mm^2 (MIN) SOFTWOOD, OR 1.5kg/m (MIN) STEEL STAR PICKETS SUITABLE FOR ATTACHING FABRIC.

INSTALLATION

1. REFER TO APPROVED PLANS FOR LOCATION, EXTENT, AND REQUIRED TYPE OF FABRIC (IF SPECIFIED). IF THERE ARE QUESTIONS OR PROBLEMS WITH THE LOCATION, EXTENT, FABRIC TYPE, OR METHOD OF INSTALLATION CONTACT THE ENGINEER OR RESPONSIBLE ON-SITE OFFICER FOR ASSISTANCE.

2. TO THE MAXIMUM DEGREE PRACTICAL, AND WHERE THE PLANS ALLOW, ENSURE THE FENCE IS LOCATED:
(i) TOTALLY WITHIN THE PROPERTY BOUNDARIES;
(ii) ALONG A LINE OF CONSTANT ELEVATION WHEREVER PRACTICAL;
(iii) AT LEAST 2m FROM THE TOE OF ANY FILLING OPERATIONS THAT MAY RESULT IN SHIFTING SOIL/FILL DAMAGING THE FENCE.

3. INSTALL RETURNS WITHIN THE FENCE AT MAXIMUM 20m INTERVALS IF THE FENCE IS INSTALLED ALONG THE CONTOUR, OR 5 TO 10m MAXIMUM SPACING (DEPENDING ON SLOPE) IF THE FENCE IS INSTALLED AT AN ANGLE TO THE CONTOUR. THE 'RETURNS' SHALL CONSIST OF EITHER:
(i) V-SHAPED SECTION EXTENDING AT LEAST 1.5m UP THE SLOPE; OR
(ii) SANDBAG OR ROCK/AGGREGATE CHECK DAM A MINIMUM 1/3 AND MAXIMUM 1/2 FENCE HEIGHT, AND EXTENDING AT LEAST 1.5m UP THE SLOPE.

4. ENSURE THE EXTREME ENDS OF THE FENCE ARE TURNED UP THE SLOPE AT LEAST 1.5m, OR AS NECESSARY, TO MINIMISE WATER BYPASSING AROUND THE FENCE.

5. ENSURE THE SEDIMENT FENCE IS INSTALLED IN A MANNER THAT AVOIDS THE CONCENTRATION OF FLOW ALONG THE FENCE, AND THE UNDESIRABLE DISCHARGE OF WATER AROUND THE ENDS OF THE FENCE.

6. IF THE SEDIMENT FENCE IS TO BE INSTALLED ALONG THE EDGE OF EXISTING TREES, ENSURE CARE IS TAKEN TO PROTECT THE TREES AND THEIR ROOT SYSTEMS DURING INSTALLATION OF THE FENCE. DO NOT ATTACH THE FABRIC TO THE TREES.

7. UNLESS DIRECTED BY THE SITE SUPERVISOR OR THE APPROVED PLANS, EXCAVATE A 200mm WIDE BY 200mm DEEP TRENCH ALONG THE PROPOSED FENCE LINE, PLACING THE EXCAVATED MATERIAL ON THE UP-SLOPE SIDE OF THE TRENCH.

8. ALONG THE LOWER SIDE OF THE TRENCH, APPROPRIATELY SECURE THE STAKES INTO THE GROUND SPACED NO GREATER THAN 3m IF SUPPORTED BY A TOP SUPPORT WIRE OR WEIR MESH BACKING, OTHERWISE NO GREATER THAN 2m.

9. IF SPECIFIED, SECURELY ATTACH THE SUPPORT WIRE OR MESH TO THE UP-SLOPE SIDE OF THE STAKES WITH THE MESH EXTENDING AT LEAST 200mm INTO THE EXCAVATED TRENCH. ENSURE THE MESH AND FABRIC IS ATTACHED TO THE UP-SLOPE SIDE OF THE STAKES EVEN WHEN DIRECTING A FENCE AROUND A CORNER OR SHARP CHANGE OF DIRECTION.

10. WHEREVER POSSIBLE, CONSTRUCT THE SEDIMENT FENCE FROM A CONTINUOUS ROLL OF FABRIC. TO JOIN FABRIC EITHER:
(i) ATTACH EACH END TO TWO OVERLAPPING STAKES WITH THE FABRIC FOLDING AROUND THE ASSOCIATED STAKE ONE TURN, AND WITH THE TWO STAKES TIED TOGETHER WITH WIRE; OR
(ii) OVERLAP THE FABRIC TO THE NEXT ADJACENT SUPPORT POST.

11. SECURELY ATTACH THE FABRIC TO THE SUPPORT POSTS USING 25 X 12.5mm STAPLES, OR TIE WIRE AT MAXIMUM 150mm SPACING.

12. SECURELY ATTACH THE FABRIC TO THE SUPPORT WIRE/MESH (IF ANY) AT A MAXIMUM SPACING OF 1m.

13. ENSURE THE COMPLETED SEDIMENT FENCE IS AT LEAST 450mm, BUT NOT MORE THAN 700mm HIGH. IF A SPILL-THOUGH WEIR IS INSTALLED, ENSURE THE CREST OF THE WEIR IS AT LEAST 300mm ABOVE GROUND LEVEL.

14. BACKFILL THE TRENCH AND TAMP THE FILL TO FIRMLY ANCHOR THE BOTTOM OF THE FABRIC AND MESH TO PREVENT WATER FROM FLOWING UNDER THE FENCE.

ADDITIONAL REQUIREMENTS FOR THE INSTALLATION OF A SPILL-THROUGH WEIR

1. LOCATE THE SPILL-THROUGH WEIR SUCH THAT THE WEIR CREST WILL BE LOWER THAN THE GROUND LEVEL AT EACH END OF THE FENCE.

2. ENSURE THE CREST OF THE SPILL-THROUGH WEIR IS AT LEAST 300mm THE GROUND ELEVATION.

3. SECURELY TIE A HORIZONTAL CROSS MEMBER (WEIR) TO THE SUPPORT POSTS/ STAKES EACH SIDE OF THE WEIR. CUT THE FABRIC DOWN THE SIDE OF EACH POST AND FOLD THE FABRIC OVER THE CROSS MEMBER AND APPROPRIATELY SECURE THE FABRIC.

4. INSTALL A SUITABLE SPLASH PAD AND/OR CHUTE IMMEDIATELY DOWN-SLOPE OF THE SPILL-THROUGH WEIR TO CONTROL SOIL EROSION AND APPROPRIATELY DISCHARGE THE CONCENTRATED FLOW PASSING OVER THE WEIR.

MAINTENANCE

1. INSPECT THE SEDIMENT FENCE AT LEAST WEEKLY AND AFTER ANY SIGNIFICANT RAIN. MAKE NECESSARY REPAIRS IMMEDIATELY.

2. REPAIR ANY TORN SECTIONS WITH A CONTINUOUS PIECE OF FABRIC FROM POST TO POST.

3. WHEN MAKING REPAIRS, ALWAYS RESTORE THE SYSTEM TO ITS ORIGINAL CONFIGURATION UNLESS AN AMENDED LAYOUT IS REQUIRED OR SPECIFIED.

4. IF THE FENCE IS SAGGING BETWEEN STAKES, INSTALL ADDITIONAL SUPPORT POSTS.

5. REMOVE ACCUMULATED SEDIMENT IF THE SEDIMENT DEPOSIT EXCEEDS A DEPTH OF 1/3 THE HEIGHT OF THE FENCE.

6. DISPOSE OF SEDIMENT IN A SUITABLE MANNER THAT WILL NOT CAUSE AN EROSION OR POLLUTION HAZARD.

7. REPLACE THE FABRIC IF THE SERVICE LIFE OF THE EXISTING FABRIC EXCEEDS 6-MONTHS.

REMOVAL

1. WHEN DISTURBED AREAS UP-SLOPE OF THE SEDIMENT FENCE ARE SUFFICIENTLY STABILISED TO RESTRAIN EROSION, THE FENCE MUST BE REMOVED.

2. REMOVE MATERIALS AND COLLECTED SEDIMENT AND DISPOSE OF IN A SUITABLE MANNER THAT WILL NOT CAUSE AN EROSION OR POLLUTION HAZARD.

3. REHABILITATE/REVEGETATE THE DISTURBED GROUND AS NECESSARY TO MINIMISE THE EROSION HAZARD.

Drawn:	Date:		
GMW	Apr-10	Sediment Fence	SF-02

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Appendix C:
Rock Size Determination for a Perimeter Drain at Mt Carbine Mines

ERSCON
CONSULTING ENGINEERS

Rock Size Determination for a Perimeter Drain at Mt Carbine Mines

April 2022

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ERSCON
CONSULTING ENGINEERS

DOCUMENT ISSUE RECORD

Revision Code	Date Revised	Revision Details	Author	Checked	Approved
1	16/03/22	Initial Issue	MF	MT	JDM
A	4/04/22	Final Issue	MF	MT	JDM

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1 INTRODUCTION

1.1 APPLICANT DETAILS

Instructions from Client	Prepare a report that recommends the type and sizing of rock required to include in an existing perimeter drain at the EQ Resources Mine at Mt Carbine.
Type of approval sought:	RPEQ approved report
Site address:	EQ Resources - Mt Carbine Mines
Real property description:	Lot 13 on SP254833, Mt Carbine
Catchment area:	92.36Ha
Assessment manager:	NA
Owner details:	EQ Resources - Mt Carbine Mines
Applicant details:	NRA Natural Resource Assessment Pty Ltd

1.2 ASSESSMENT INSTRUMENT DETAILS

Planning scheme:	NA
Zone:	Mining – Extractive Industry
Local plan:	Mareeba Shire Council Planning Scheme
Level of assessment:	NA
Applicable codes:	Catchments and Creeks QUDM Queensland Urban Drainage Manual

1.3 PROPOSED WORKS

Determine the rock specification required to line an existing trapezoidal drain. Images received from the client indicates that the soil is highly dispersive. The client has requested for ERSCON to use the publication *Rock Linings – Drainage Control Technique* by Catchment and Creeks Pty Ltd (Version 2 – May 2010) (see Attachment A) to be used as the primary guide. The report is to be signed by an RPEQ.

Table 1: Summary of Deliverables

Report Type	Prepare a RPEQ signed report specifying the type of rock required to line an existing trapezoidal drain which has highly erodible soils.

2 SITE DETAILS

2.1 SITE DESCRIPTION

Access to the site is located on the southern side of the Mulligan Hwy, 1km to the west of Pump Road, Mt Carbine. Two diversion drains are located around the site and are called TSF4 Diversion Drain East (0.49km) and TSF4 Diversion Drain West (1.64km) (see image 1).

The drains are installed to capture external surface water and divert them away from the site.

Photos supplied by NRA indicate that the embankment of the existing trapezoidal drain exhibits highly dispersive material (see Appendix C). From the images, it appears that the proximity of the perimeter access track in relation to the drain, indicates that the surface flow into the diversion drain has created extensive rutting.

From the photos supplied, it was observed that the existing trapezoidal drain have the following dimensions:

- 4m wide base;
- 1.5m deep;
- 1 on 1 grade (internal wall to 10m wide mound next to access road);
- Vertical (external wall) – highly eroded and rutted.

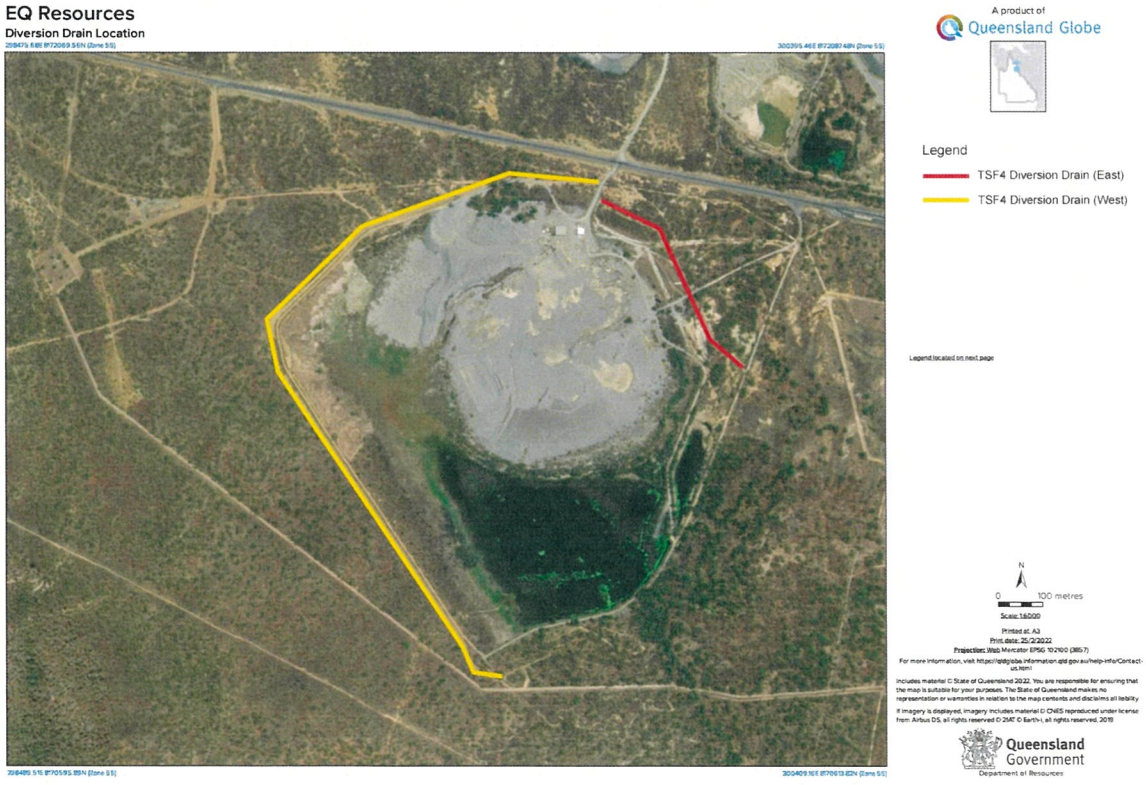


Figure 1: Diversion Drain Location
Source: Queensland Globe

Site characteristic	Description
Existing land use	The site is predominantly utilised for the extraction and processing of minerals
Existing structures	Site sheds, processing areas and storage facilities.
Frontage and access	The existing land fronts the Mulligan Highway, 1km west of Pump Road, Mt Carbine.
Topography	The site is located on the southern side of Mulligan Highway. It lies at the foothills of Mt Alto (755m) to it's south-west and Carbine Hill (515m) to the north-west. The site is generally flat and grades at 1-2% towards the foothills of Mt Alto and 2-5% towards Carbine Hill.
Existing vegetation	The land is lightly wooded and grassed.
Existing waterways	Tributaries around the area appear to all flow towards the Mitchell River located about 1km to the south.

3 ROCK LINING OF DIVERSION DRAIN

3.1 DESIGN METHOD

The stormwater assessment and design has been carried out using the Rational Method, in accordance with the *Queensland Urban Drainage Manual* (QUDM) and the Far North Queensland Regional Organisation of Councils (FNQROC). Reference has been made to the Bureau of Meteorology and FNQROC D4 Stormwater Drainage (see Appendix A).

The rock lining has been designed based on *Rock Linings – Damage Control Technique* by Catchments and Creeks Pty Ltd – May 2010.

The Hydrological Analysis undertaken includes overland flow paths and catchments and are documented in Appendix A.

To determine the rock size required to line the drain, it was required to determine the flow and velocity in different events. A check of the catchments indicated that the information supplied by NRA for the flows may have been based on smaller catchments.

3.2 HYDROLOGICAL ANALYSIS

3.2.1 Catchment Area

Catchment areas were determined from Lidar for three distinct sections of the drain. Catchment A1 and A2 which flow into the western drain and Catchment B that flows into the Eastern drain.

Surface flow occurred across the Mulligan Highway via culverts.



Figure 2: Catchment Areas
Source: Queensland Globe

3.2.2 Time of Concentration

Flow paths and average surface profiles were determined for the three catchments. This was achieved by utilising current Lidar information available from the Government website Elvis - Elevation and Depth – Foundation Spatial Data Elvis (fsdf.org.au) and converting the information into contours using the 12D software. Longest flow paths were chosen and draped across the terrain model.

Utilising the Bransby-Williams Equation, Times of Concentrations were calculated. (refer Table 1 – Catchment Area Summary and Appendix A for calculations).

Table 1: Catchment Area Summary

Catchment Label	Area (Ha)	Length (km)	Average Slope %	Time of Concentration (min)	Adopted Time of Concentration (min)
A1	82	2.062	2.4	64.6	65
A2	68	1.93	1.3	69.5	70
B	42	1.572	3.6	48.6	50

3.2.3 Determining Flow Rates

Rainfall intensities were calculated from the IFD charts accessed through the BOM site and were based on the adopted time of concentration for each catchment. A coefficient of discharge (C_{10}) of 0.7 was adopted based on medium to low soil permeability and referring to QUDM Table 4.5.4 based on an AEP of 10% (approximate occurrence every 10 years). Frequency factors were based on the relevant AEP and taken form Table 4.5.2. (Refer to Appendix A for Calculations).

Flow Calculation for Upstream Catchment

Catchment A1

Fraction Impervious = $f_i = 0$ Table Below (QUDM Table 4.5.3)

1 hour @ 10 year ARI = $^{1}I_{10} = 68.5$ mm/hr (IFD CHARTS)

$C_{10} = 0.7$ (QUDM Table 4.5.3)

AEP		63%	39%	18%	10%	5%	2%	1%		
Design ARI		1	2	5	10	20	50	100		
Frequency Factor	F_Y	0.8	0.85	0.95	1	1.05	1.15	1.2		(QUDM Table 4.5.2)
Coefficient of Discharge	C_Y	0.56	0.595	0.665	0.7	0.735	0.805	0.84		(QUDM Equation 4.3)
Time of Concentration	T_C	65	65	65	65	65	65	65	min	
Rainfall Intensity	$^{65min}I_{10}$	42	47	61	71	79	90	97	mm/hr	(IFD CHARTS)
Area	A	82	82	82	82	82	82	82.00	Ha	
Flow A1		**5.33**	**6.34**	**9.29**	**11.26**	**13.25**	**16.41**	**18.56**	**m^3/s**	
Velocity		**0.96**	**1.01**	**1.14**	**1.21**	**1.29**	**1.39**	**1.45**	**m/s**	Taken from ERSCON Super Drain Table
Height		**1.10**	**1.21**	**1.45**	**1.65**	**1.79**	**2.01**	**2.14**	**m**	

Flow Calculation for Upstream Catchment

Catchment A1+A2

Fraction Impervious = f_i = 0 Table Drain (QUDM Table 4.5.3)

1 hour @ 10 year ARI = $^{1}I_{10}$ = 68.5 mm/hr (IFD CHARTS)

C_{10} = 0.7 (QUDM Table 4.5.3)

AEP		63%	39%	18%	10%	5%	2%	1%		
Design ARI		**1**	**2**	**5**	**10**	**20**	**50**	**100**		
Frequency Factor	F_Y	0.8	0.85	0.95	1	1.05	1.15	1.2		(QUDM Table 4.5.2)
Coefficient of Discharge	C_Y	0.56	0.595	0.665	0.7	0.735	0.805	0.84		(QUDM Equation 4.3)
Time of Concentration	T_C	70.0	70	70	70	70	70	70.0	min	
Rainfall Intensity	$^{70min}I_{10}$	43	48	63	73	82	92	100	mm/hr	(IFD CHARTS)
Area	A	68	68	68	68	68	68	68	Ha	
Flow A2		**4.55**	**5.41**	**7.93**	**9.61**	**11.31**	**14.02**	**15.87**	**m^3/s**	
Cumulative Flow A1 + A2		**9.88**	**11.74**	**17.22**	**20.87**	**24.57**	**30.43**	**34.43**	**m^3/s**	
Velocity		**0.95**	**1.02**	**1.17**	**1.26**	**1.34**	**1.45**	**1.53**	**m/s**	Taken from ERSCON Super Drain Table
Height		**1.80**	**1.97**	**2.42**	**2.69**	**2.94**	**3.31**	**3.55**	**m**	

Flow Calculation for Upstream Catchment

Catchment B

Fraction Impervious = f_i = 0 Table Drain (QUDM Table 4.5.3)

1 hour @ 10 year ARI = $^{1}I_{10}$ = 68.5 mm/hr (IFD CHARTS)

C_{10} = 0.7 (QUDM Table 4.5.3)

AEP		63%	39%	18%	10%	5%	2%	1%		
Design ARI		**1**	**2**	**5**	**10**	**20**	**50**	**100**		
Frequency Factor	F_Y	0.8	0.85	0.95	1	1.05	1.15	1.2		(QUDM Table 4.5.2)
Coefficient of Discharge	C_Y	0.56	0.595	0.665	0.7	0.735	0.805	0.84		(QUDM Equation 4.3)
Time of Concentration	T_C	50.0	50	50	50	50	50	50	min	
Rainfall Intensity	$^{50min}I_{10}$	37	42	55	63	71	80	87	mm/hr	(IFD CHARTS)
Area	A	42	42	42	42	42	42	42	Ha	
Flow B		**2.44**	**2.90**	**4.24**	**5.14**	**6.05**	**7.50**	**8.49**	**m^3/s**	
Velocity		**0.89**	**0.95**	**1.08**	**1.15**	**1.22**	**1.30**	**1.36**	**m/s**	Taken from ERSCON Super Drain Table
Height		**0.59**	**0.66**	**0.82**	**0.91**	**1.00**	**1.12**	**1.20**	**m**	

3.2.4 Existing Trapezoidal Drains

Cross sections of drains taken from the Lidar information (supplied by NRA) and also from the Government website indicates that the extrapolated cross sections are shaped as a V-Drain. However, the photos supplied by NRA indicate that the majority of the drains are trapezoidal in shape with measurements of approximately 4m across the base and 1.5m high with a nominal 1 on 1 batter slope.

The calculations to determine depth of flow and velocity were based on the trapezoidal shape (refer to Appendix B for ERSCON Super Drain Table).

3.3 ROCK SIZE DETERMINATION

The equation to determine rock sizing was taken from Table 1 – Equation (1) the Preferred Equation for bed slopes S_o<50% of Rock Linings – Catchments & Creeks (version 2 – 2010).

$$D_{50} = \frac{1.27 \times SF \times K_1 \times K_2 \times S_o^{0.5} \times q^{0.5} \times y^{0.25}}{(s_r - 1)}$$

Where:

SF = 1. 5 [Safety Factor = 1.5 (see Table 2)]

K_1 = 1.0 (Angular Rock)

K_2 = 1.0 (unknown rock grading)

S_o =

Bed Slope (m/m)		
A1	A2	B
0.4%	0.2%	0.7%

q =

	Flow/unit width for 1% AEP ($m^3/s/m$)		
	A1	A1+A2	B
Q (m^3/s)	18.56	34.43	8.49
q ($m^3/s/m$)	3.71	6.89	1.70

y =

Depth of Flow (m)		
A1	A1+A2	B
2.14	3.55	1.20

s_r = 2.5 (Specific Gravity of Rock)

Therefore:

	d_{50}		
	A1	**A1+A2**	**B**
Calculated d_{50} (m)	0.187	0.205	0.145
Nominal Rock Size d_{50} (m)	**0.20**	**0.20**	**0.15**

4 CONCLUSION

After reviewing the supplied information and further discussions with our client, it was decided to prepare updated catchment areas and flow paths based on the most current available data. This would result in new flow rates and velocities for application when calculating rock sizing.

Existing drain sizes were referenced against cross sections taken from Lidar and compared against supplied images of the drain. The images indicated a consistent trapezoidal shape with a length approximately 100m long, 4m wide base and a 1 on 1 batter to a depth of 1.5m. The images also showed the outside batter to be highly dispersive.

The profile adopted was visually taken from the supplied images (see Appendix C).

The client asked that we prepare rock sizing based on Rock Lining - Catchments & Creeks.

Our calculations indicate that if the profile of the drain was shaped as mentioned above, inundation of the bank would occur in a AEP 39% event in the lower length of the Western Drain.

Due to the potential of dispersive soils, all precautions and constructability should follow the instructions mentioned in Rock Linings – Catchments and Creeks Version 2 – 2010.

As a result of our review of the catchment areas, flows to the drains (in multiple normal rainfall events) and consideration of the site characteristics, we have determined the rock sizing to be provided to the drains is as follows:

- **Western drain - Catchment A1** **d_{50} = 0.20m**
- **Western drain - Catchment A1+A2** **d_{50} = 0.20m**
- **Eastern drain - Catchment B** **d_{50} = 0.20m**

The rock type should be resistant to weathering and shaped so that its length is a maximum of 3 times it's width. It should also be angular (fractured) for interlocking purposes and to reduce movement under high stream flow. The minimum thickness of rock (T) should be 0.34m

It is suggested that the drain be constructed in accordance with *Figure 2 of Rock Linings – Damage Control Techniques Version 2 – May 2010* by Catchment and Creeks Pty Ltd

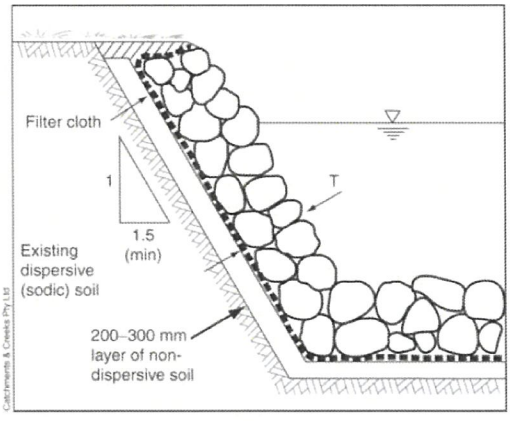


Figure 2 – Rock placement (without vegetation) on dispersive soil

APPENDIX A

Site Hydrological Calculations

Label: Mt Carbine
Mt Carbine
Easting: 299026
Northing: 8171529
Zone: 55

Table

Annual Exceedance Probability (AEP)

Duration	63.20%	50%#	20%*	10%	5%	2%	1%
1 min	2.41	2.7	3.55	4.09	4.59	5.21	5.66
2 min	4.31	4.81	6.27	7.18	8.01	8.94	9.57
3 min	6.04	6.74	8.81	10.1	11.3	12.6	13.6
4 min	7.61	8.51	11.2	12.8	14.3	16.1	17.4
5 min	9.07	10.1	13.3	15.3	17.2	19.4	21
10 min	15.1	16.9	22.2	25.6	28.8	32.8	35.7
15 min	19.6	22	29	33.4	37.5	42.7	46.5
20 min	23.4	26.2	34.4	39.7	44.5	50.7	55.1
25 min	26.5	29.7	39	44.9	50.4	57.3	62.3
30 min	29.3	32.7	42.9	49.4	55.4	62.9	68.4
45 min	35.7	39.9	52.3	60.2	67.5	76.4	82.9
50 min	37.3	41.7	54.7	63.0	70.6	79.9	86.6
1 hour	40.6	45.4	59.5	68.5	76.8	86.8	94
65 min	41.8	46.8	61.3	70.6	79.2	89.5	97.0
70 min	43.0	48.1	63.1	**72.7**	81.5	92.2	100.0
1.5 hour	47.8	53.5	70.4	81.1	90.9	103	112
2 hour	53.2	59.6	78.7	90.8	102	116	126
3 hour	61.2	68.8	91.5	106	120	137	149
4.5 hour	69.8	78.8	106	124	140	162	178
6 hour	76.5	86.7	118	138	158	184	203
9 hour	87.1	99.3	137	163	187	221	247
12 hour	95.8	110	153	183	212	253	285
18 hour	110	127	180	218	256	309	351
24 hour	122	141	203	247	293	356	407
30 hour	133	154	223	273	325	397	457
36 hour	143	165	240	296	354	434	500
48 hour	160	185	271	335	403	496	573
72 hour	187	217	319	396	478	587	677
96 hour	209	242	354	439	530	648	745
120 hour	226	261	381	471	566	688	788
144 hour	239	276	401	493	589	713	814
168 hour	249	288	415	508	603	727	827

Note:
The 50% AEP IFD does not correspond to the 2 year Average Recurrence Interval (ARI) IFD. Rath
* The 20% AEP IFD does not correspond to the 5 year Average Recurrence Interval (ARI) IFD. Rath

JOB NO: 900-047
JOB: Mt Carbine Mines
TITLE : Catchment A1
DATE: 8/03/2022

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Time of concentration Calculation
(Using Bransby-Williams' Equation)

Proportionality Factor P= 58 (for Ha)

Length of Flow Path L= 2.062 km
Top of Catchment (RL) RL = 513 m
Area of Catchment A = 82.00 Ha

Catchment Profile 358.3 [to utilise graph area better]

Chainage	RL	RL	Area under Graph (m²)
0	358.3	0	-----
520	360	1.7	442
878	366.7	8.4	1810
954	380	21.7	1144
1495	387	28.7	13633
1764	400	41.7	9469
1897	419	60.7	6810
2062	513	154.7	17771
2062	513	154.7	0
2062	513	154.7	0

Average Slope Calculation	
Outlet Chainage	0
Catchment length	2062
Outlet RL	0
Top RL (Av Slope)	49.5

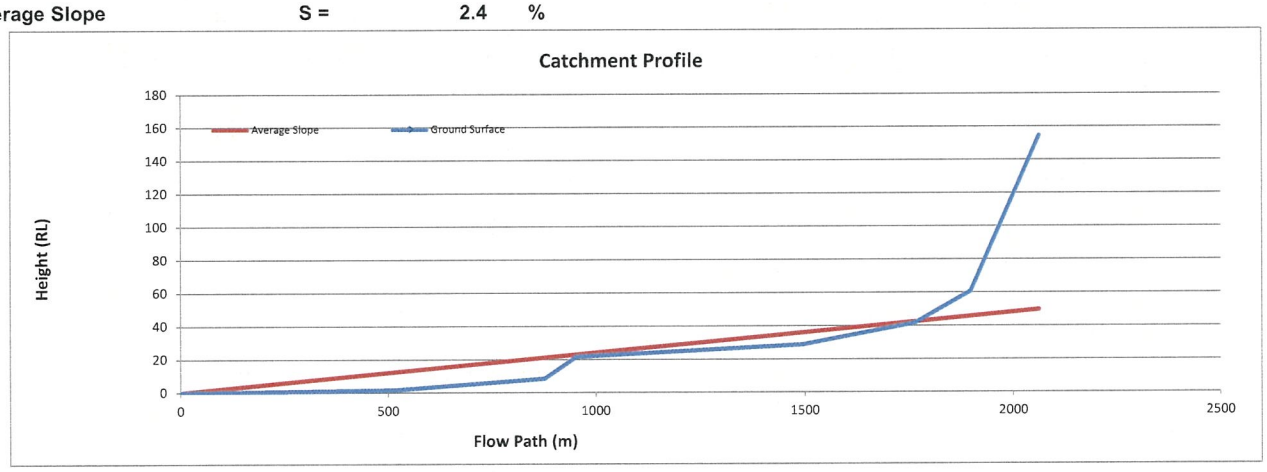
$$Tc = \frac{P \times L}{(A \wedge 0.1) \times (S \wedge 0.2)}$$

Tc = 64.6 min

Adpoted Tc 65.0 **min**

Total area under graph **51078** m^2
Area below outlet level 0 m^2
Area above outlet 51078 m^2

Height for average slope 49.54 m
Average Slope **S =** **2.4** **%**



Flow Calculation for Upstream Catchment

Catchment A1

Fraction Impervious = f_i = 0 Table Below (QUDM Table 4.5.3)
1 hour @ 10 year ARI = $^1I_{10}$ = 68.5 mm/hr (IFD CHARTS)
C_{10} = 0.7 (QUDM Table 4.5.3)

AEP		63%	39%	18%	10%	5%	2%	1%		
Design ARI		**1**	**2**	**5**	**10**	**20**	**50**	**100**		
Frequency Factor	F_Y	0.8	0.85	0.95	1	1.05	1.15	1.2		(QUDM Table 4.5.2)
Coefficient of Discharge	C_Y	0.56	0.595	0.665	0.7	0.735	0.805	0.84		(QUDM Equation 4.3)
Time of Concentration	T_C	65	65	65	65	65	65	65	min	
Rainfall Intensity	$^{65min}I_{10}$	42	47	61	71	79	90	97	mm/hr	(IFD CHARTS)
Area	A	82	82	82	82	82	82	82.00	Ha	
Flow A1		**5.33**	**6.34**	**9.29**	**11.26**	**13.25**	**16.41**	**18.56**	**m^3/s**	
Velocity		**0.96**	**1.01**	**1.14**	**1.21**	**1.29**	**1.39**	**1.45**	**m/s**	Taken from ERSCON Super Drain Table
Height		**1.10**	**1.21**	**1.45**	**1.65**	**1.79**	**2.01**	**2.14**	**m**	

JOB NO: 900-047
JOB: Mt Carbine Mines
TITLE : Catchment A2
DATE: 4/03/2022

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Time of concentration Calculation
(Using Bransby-Williams' Equation)

Proportionality Factor P= 58 (for Ha)

Length of Flow Path L= 1.93 km
Top of Catchment (RL) RL = 429.4 m
Area of Catchment A = 68.00 Ha

Catchment Profile 355.7 [to utilise graph area better]

Chainage	RL	RL	Area under Graph (m²)
0	355.7	0	-----
850	357.1	1.4	595
1372	369	13.3	3837
1456	376	20.3	1411
1647	383	27.3	4546
1778	400	44.3	4690
1856	420.5	64.8	4255
1927	429.4	73.7	4917
1927	429.4	73.7	0
1927	429	73.7	0

Average Slope Calculation	
Outlet Chainage	0
Catchment length	1927
Outlet RL	0
Top RL (Av Slope)	25.2

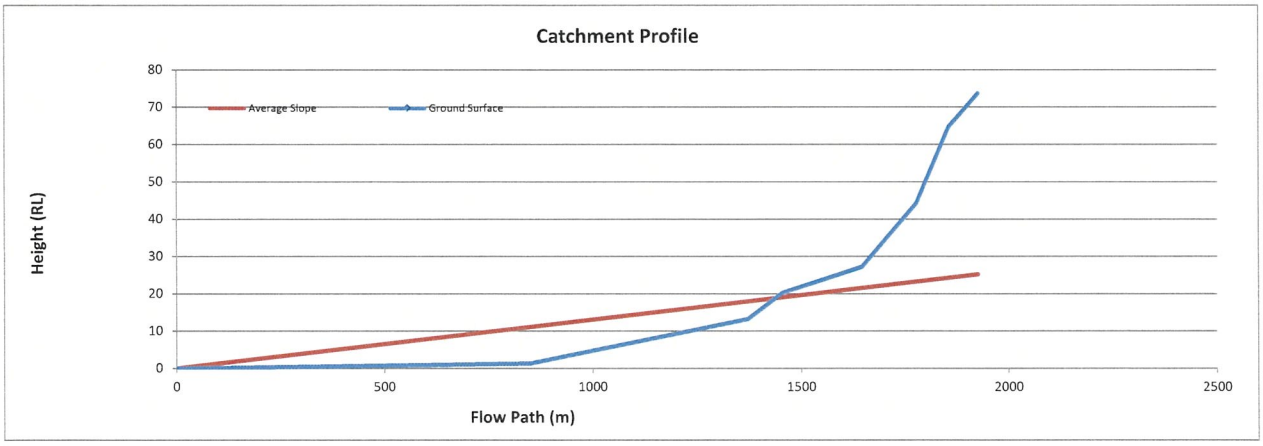
$$Tc = \frac{P \times L}{(A \wedge 0.1) \times (S \wedge 0.2)}$$

Tc = 69.5 min

Adpoted Tc 70.0 **min**

Total area under graph 24250 m^2
Area below outlet level 0 m^2
Area above outlet 24250 m^2

Height for average slope 25.17 m
Average Slope **S =** **1.3** **%**



Flow Calculation for Upstream Catchment

Catchment A1+A2

Fraction Impervious = f_i = 0 Table Drain (QUDM Table 4.5.3)
1 hour @ 10 year ARI = $^1I_{10}$ = 68.5 mm/hr (IFD CHARTS)
C_{10} = 0.7 (QUDM Table 4.5.3)

AEP		63%	39%	18%	10%	5%	2%	1%		
Design ARI		**1**	**2**	**5**	**10**	**20**	**50**	**100**		
Frequency Factor	F_Y	0.8	0.85	0.95	1	1.05	1.15	1.2		(QUDM Table 4.5.2)
Coefficient of Discharge	C_Y	0.56	0.595	0.665	0.7	0.735	0.805	0.84		(QUDM Equation 4.3)
Time of Concentration	T_C	70.0	70	70	70	70	70	70.0	min	
Rainfall Intensity	$^{70min}I_{10}$	43	48	63	73	82	92	100	mm/hr	(IFD CHARTS)
Area	A	68	68	68	68	68	68	68	Ha	
Flow A2		**4.55**	**5.41**	**7.93**	**9.61**	**11.31**	**14.02**	**15.87**	**m^3/s**	
Cumulative Flow A1 + A2		**9.88**	**11.74**	**17.22**	**20.87**	**24.57**	**30.43**	**34.43**	**m^3/s**	
Velocity		**0.95**	**1.02**	**1.17**	**1.26**	**1.34**	**1.45**	**1.53**	**m/s**	Taken from ERSCON Super Drain Table
Height		**1.80**	**1.97**	**2.42**	**2.69**	**2.94**	**3.31**	**3.55**	**m**	

JOB NO: 900-047
JOB: Mt Carbine Mines
TITLE : Catchment B
DATE: 8/03/2022

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Time of concentration Calculation
(Using Bransby-Williams' Equation)

Proportionality Factor P= 58 (for Ha)

Length of Flow Path L= 1.572 km
Top of Catchment (RL) RL = 504 m
Area of Catchment A = 42.00 Ha

Catchment Profile 355.5 [to utilise graph area better]

Chainage	RL	RL	Area under Graph (m²)
0	355.5	0	-----
68	358.1	2.6	88
450	362	6.5	1738
620	370	14.5	1785
936	374	18.5	5214
1011	385	29.5	1800
1290	392	36.5	9207
1401	423	67.5	5772
1561	503	147.5	17200
1572	504	148.5	1628

Average Slope Calculation	
Outlet Chainage	0
Catchment length	1572
Outlet RL	0
Top RL (Av Slope)	56.5

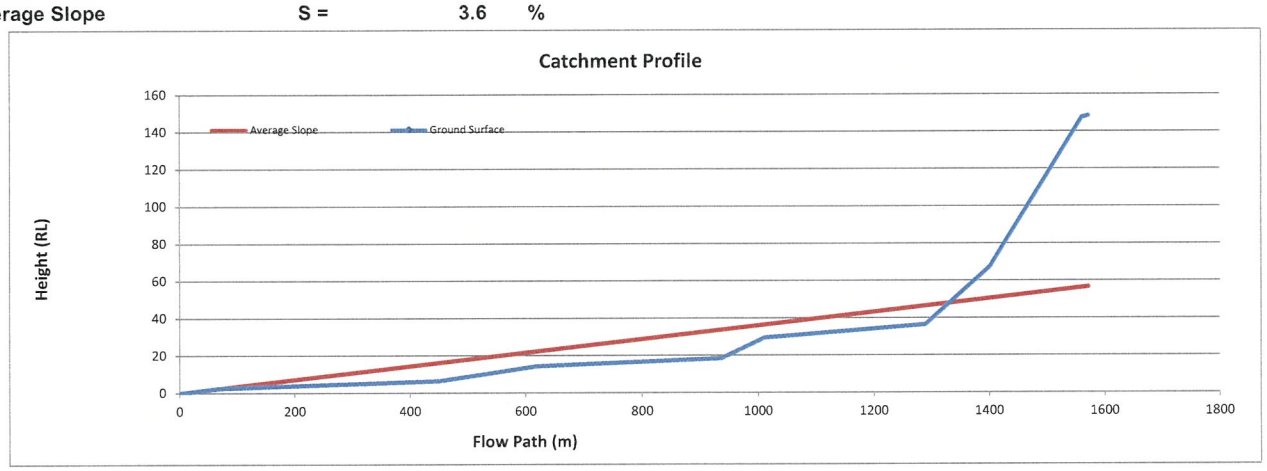
$$Tc = \frac{P \times L}{(A \wedge 0.1) \times (S \wedge 0.2)}$$

Tc = 48.6 min

Adpoted Tc 50.0 **min**

Total area under graph 44433 m^2
Area below outlet level 0 m^2
Area above outlet 44433 m^2

Height for average slope 56.53 m
Average Slope **S =** **3.6** **%**



Flow Calculation for Upstream Catchment

Catchment B

Fraction Impervious = f_i = 0 Table Drain (QUDM Table 4.5.3)
1 hour @ 10 year ARI = $^{1}I_{10}$ = 68.5 mm/hr (IFD CHARTS)
C_{10} = 0.7 (QUDM Table 4.5.3)

AEP		63%	39%	18%	10%	5%	2%	1%		
Design ARI		**1**	**2**	**5**	**10**	**20**	**50**	**100**		
Frequency Factor	F_Y	0.8	0.85	0.95	1	1.05	1.15	1.2		(QUDM Table 4.5.2)
Coefficient of Discharge	C_Y	0.56	0.595	0.665	0.7	0.735	0.805	0.84		(QUDM Equation 4.3)
Time of Concentration	T_C	50.0	50	50	50	50	50	50	min	
Rainfall Intensity	$^{50min}I_{10}$	37	42	55	63	71	80	87	mm/hr	(IFD CHARTS)
Area	A	42	42	42	42	42	42	42	Ha	
Flow B		**2.44**	**2.90**	**4.24**	**5.14**	**6.05**	**7.50**	**8.49**	**m^3/s**	
Velocity		**0.89**	**0.95**	**1.08**	**1.15**	**1.22**	**1.30**	**1.36**	**m/s**	Taken from ERSCON Super Drain Table
Height		**0.59**	**0.66**	**0.82**	**0.91**	**1.00**	**1.12**	**1.20**	**m**	

APPENDIX B

ERSCON Super Drain Templates

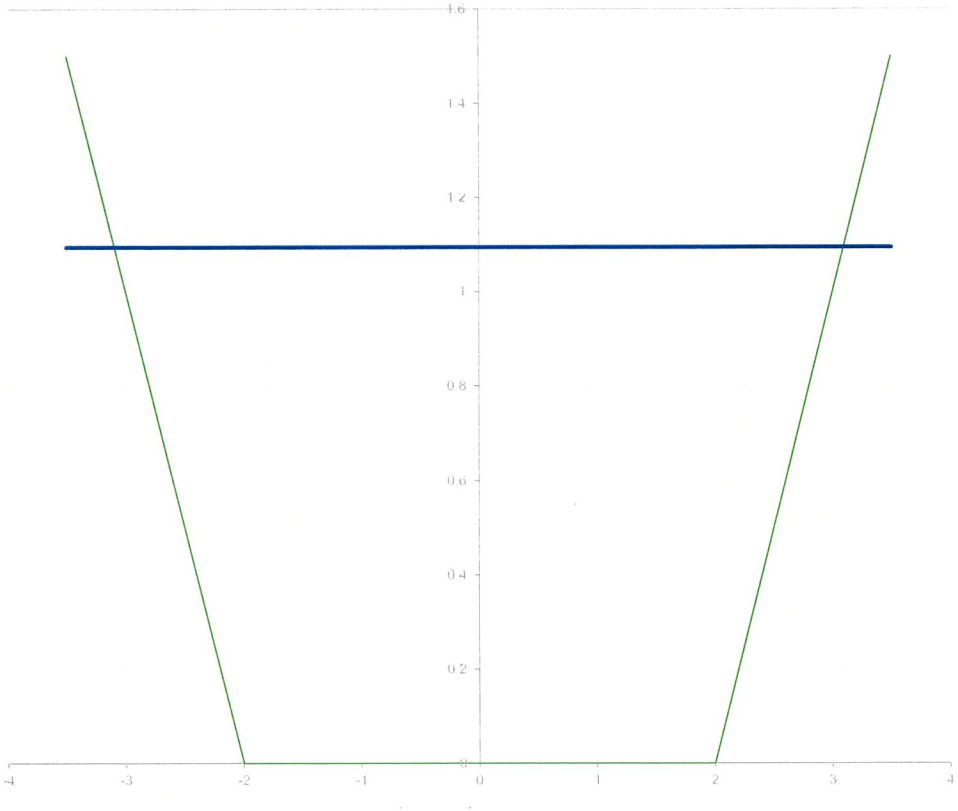
PROJECT
DRAIN A1
63% AEP

Q =	5.33	Slope	0.366 %	63% AEP	Depth	1.095	n	0.0539	q	5.33	A	5.576	v	0.9558

Label	Constraints		Horizontal (m)	Vertical (m)	Grade %	Surface		n
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lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
		Invert Line						
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
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Left of Invert

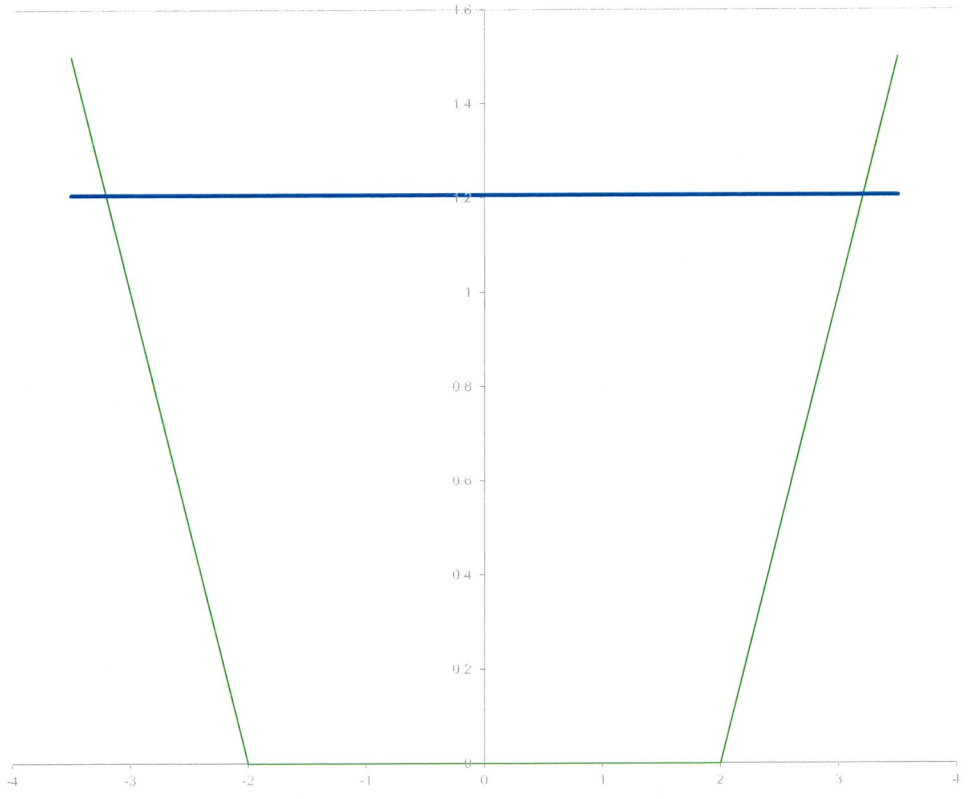
Right of Invert



PROJECT
DRAIN A1
39% AEP

Q =	6.34	Slope	0.366 %	39% AEP	Depth	1.206	n	0.0536	q	6.34	A	6.277	v	1.01

Label	Constraints		Horizontal (m)	Vertical (m)	Grade %	Surface		n	
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		1							
lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	Left of Invert
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	
			Invert Line						
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	Right of Invert
lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	
		1							
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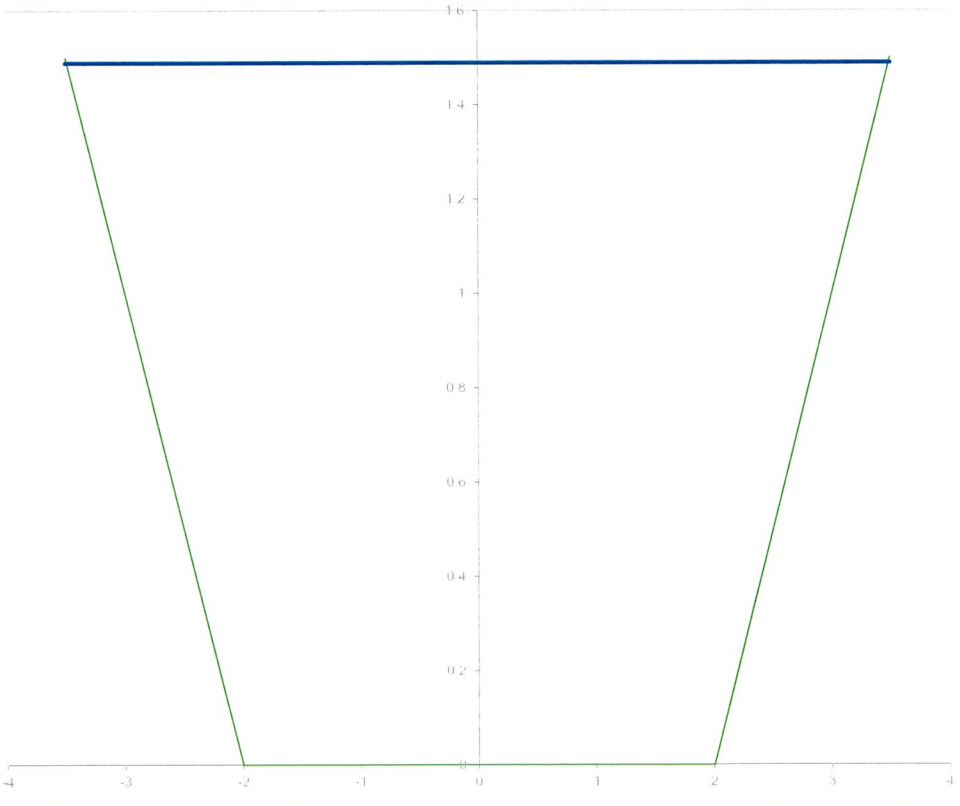
PROJECT
DRAIN A1
18% AEP

Q =	9.29	Slope	0.366 %	18% AEP	Depth	1.489	n	0.0531	q	9.2899	A	8.174	v	1.1365

Label	Constraints		Horizontal (m)	Vertical (m)	Grade %	Surface		n
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lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
	Invert Line							
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
		1						
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Left of Invert

Right of Invert



PROJECT
DRAIN A1
10% AEP

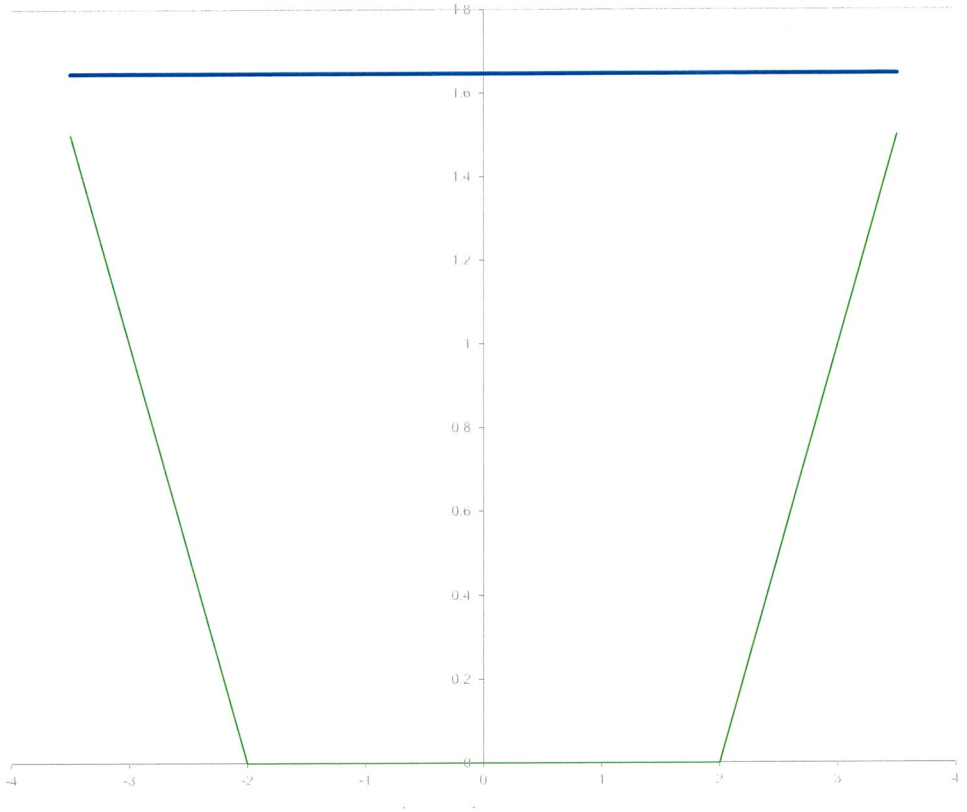
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Q =	11.26	Slope	0.366 %	10% AEP	Depth	1.646	n	0.0539	q	11.26	A	9.275	v	1.214

Label	Constraints		Horizontal (m)	Vertical (m)	Grade %	Surface		n
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lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
			Invert Line					
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
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Left of Invert

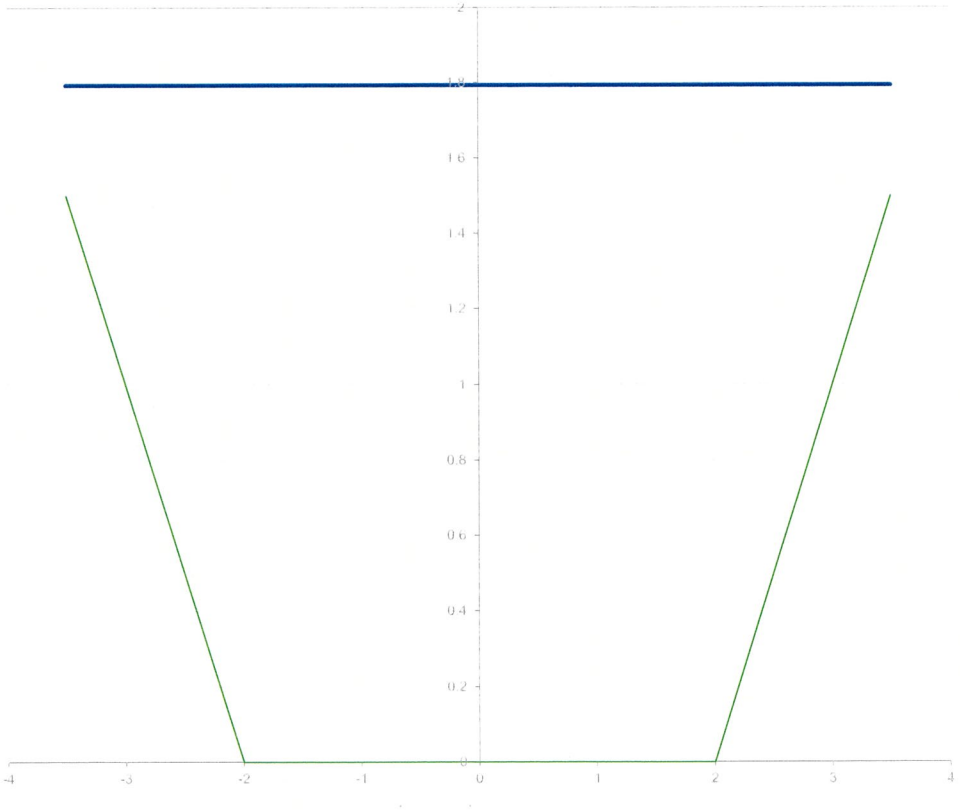
Right of Invert



PROJECT
DRAIN A1
5% AEP

Q =	13.25	Slope	0.366 %	5% AEP	Depth	1.793	n	0.0546	q	13.25	A	10.3	v	1.2862

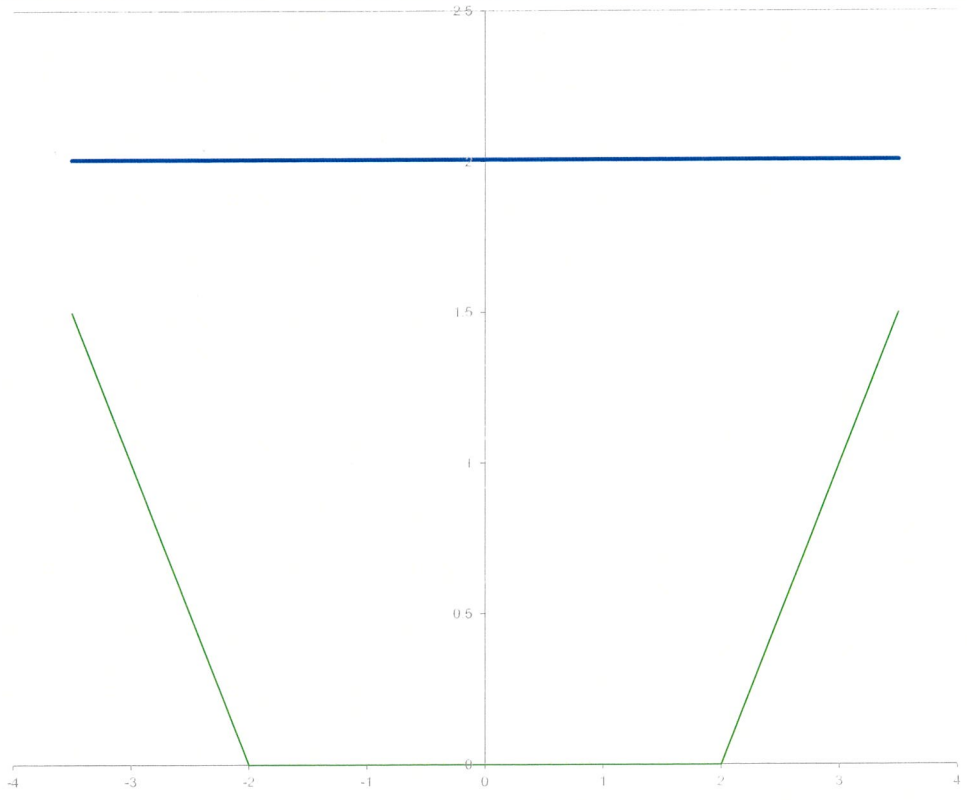
Label	Constraints		Horizontal (m)	Vertical (m)	Grade %	Surface		n	
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lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	Left of Invert
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	
	Invert Line								
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	Right of Invert
lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	
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PROJECT
DRAIN A1
2% AEP

Q =	16.41	Slope	0.366 %	2% AEP	Depth	2.008	n	0.0553	q	16.41	A	11.81	v	1.3901

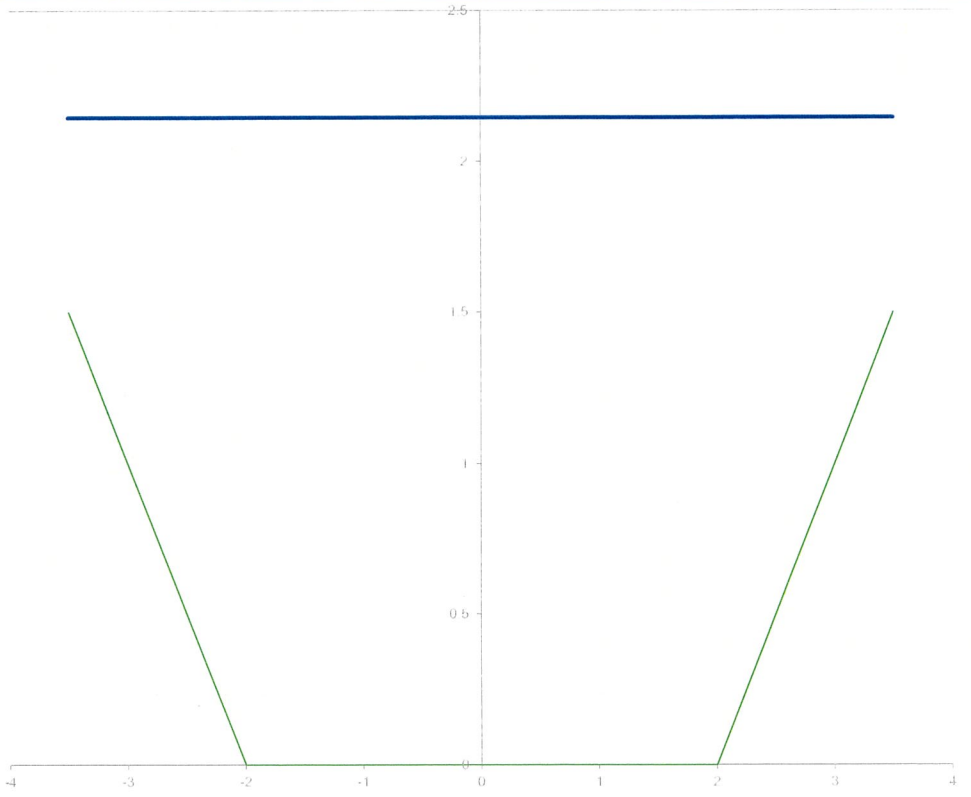
Label	Constraints		Horizontal (m)	Vertical (m)	Grade %	Surface		n	
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lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	Left of Invert
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	
			Invert Line						
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	Right of Invert
lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	
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PROJECT
DRAIN A1
1% AEP

Q =	18.56	Slope	0.366 %	1% AEP	Depth	2.144	n	0.0557	q	18.56	A	12.76	v	1.4546

Label	Constraints	Horizontal (m)	Vertical (m)	Grade %	Surface		n	
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lip of cor	2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	Left of Invert
Invert Lir	2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	
		Invert Line						
Invert Lir	2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	Right of Invert
lip of cor	2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	
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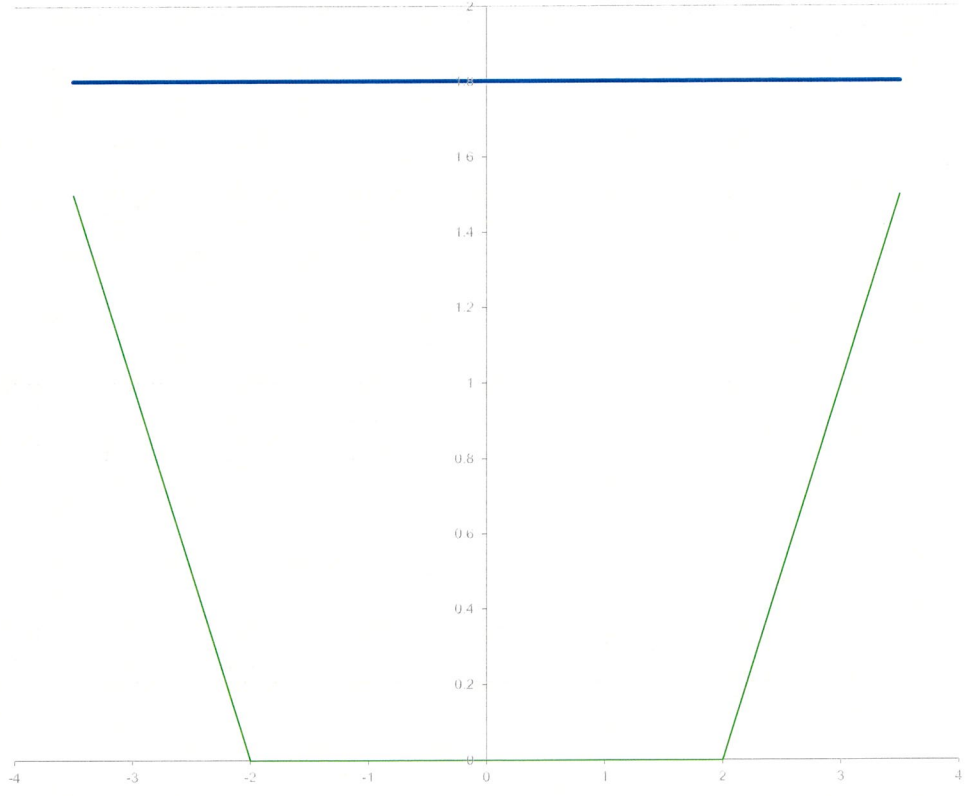
PROJECT
DRAIN A1 + A2
63% AEP

Q =	9.88	Slope	0.2 %	63% AEP	Depth	1.801	n	0.0546	q	9.8799	A	10.36	v	0.9538

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lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
	Invert Line							
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
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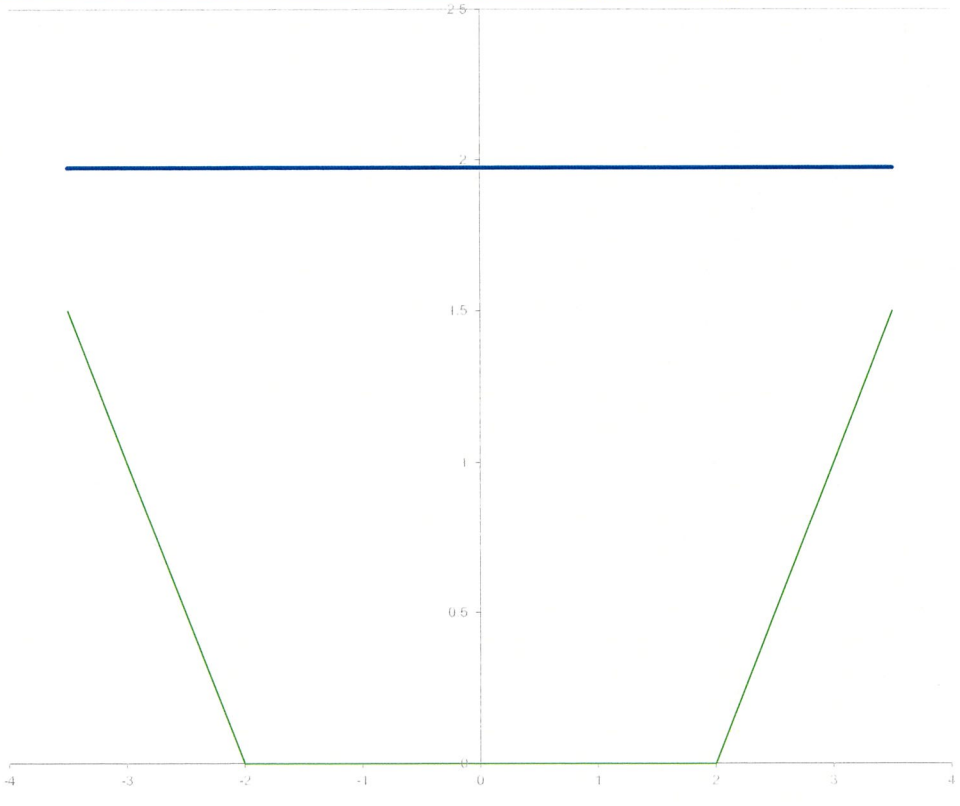
PROJECT
DRAIN A1 + A2
39% AEP

Q =	11.74	Slope	0.2 %	39% AEP	Depth	1.973	n	0.0552	q	11.74	A	11.56	v	1.0153

Label	Constraints		Horizontal (m)	Vertical (m)	Grade %	Surface		n
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lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
			Invert Line					
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
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Left of Invert

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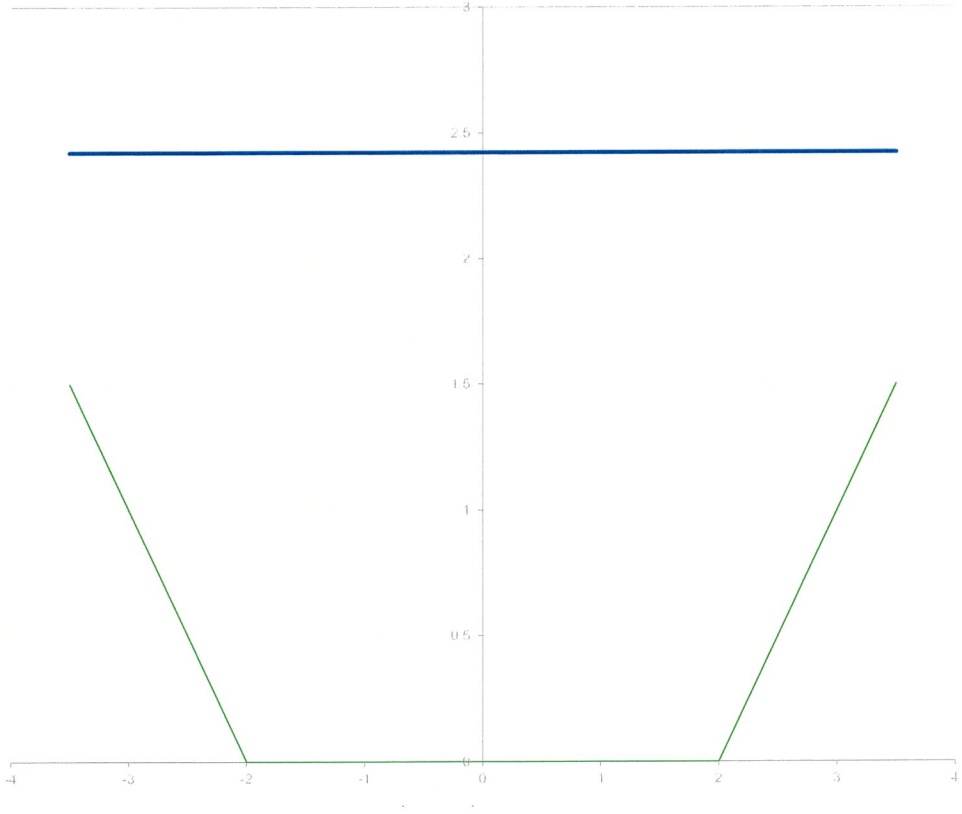
PROJECT
DRAIN A1 + A2
18% AEP

Q =	17.22	Slope	0.2 %	18% AEP	Depth	2.423	n	0.0562	q	17.22	A	14.71	v	1.1705

Label	Constraints		Horizontal (m)	Vertical (m)	Grade %	Surface		n
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lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
			Invert Line					
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
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Left of Invert

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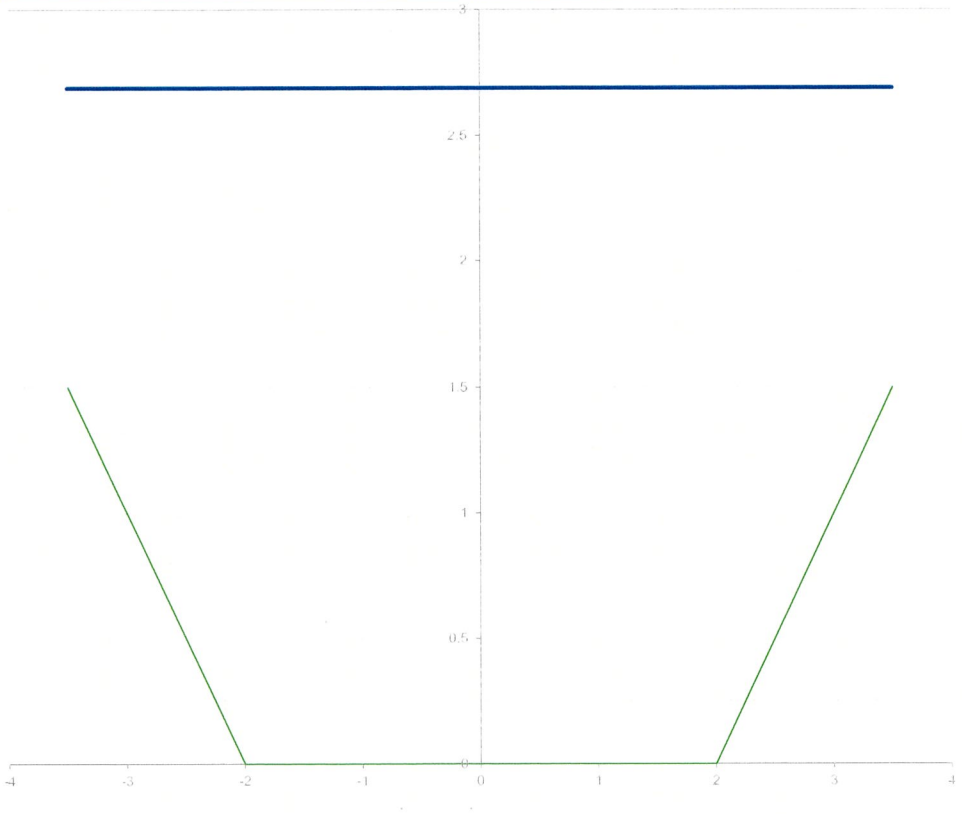


PROJECT
DRAIN A1 + A2
10% AEP

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Q =	20.87	Slope	0.2 %	10% AEP	Depth	2.690	n	0.0566	q	20.87	A	16.58	v	1.2588

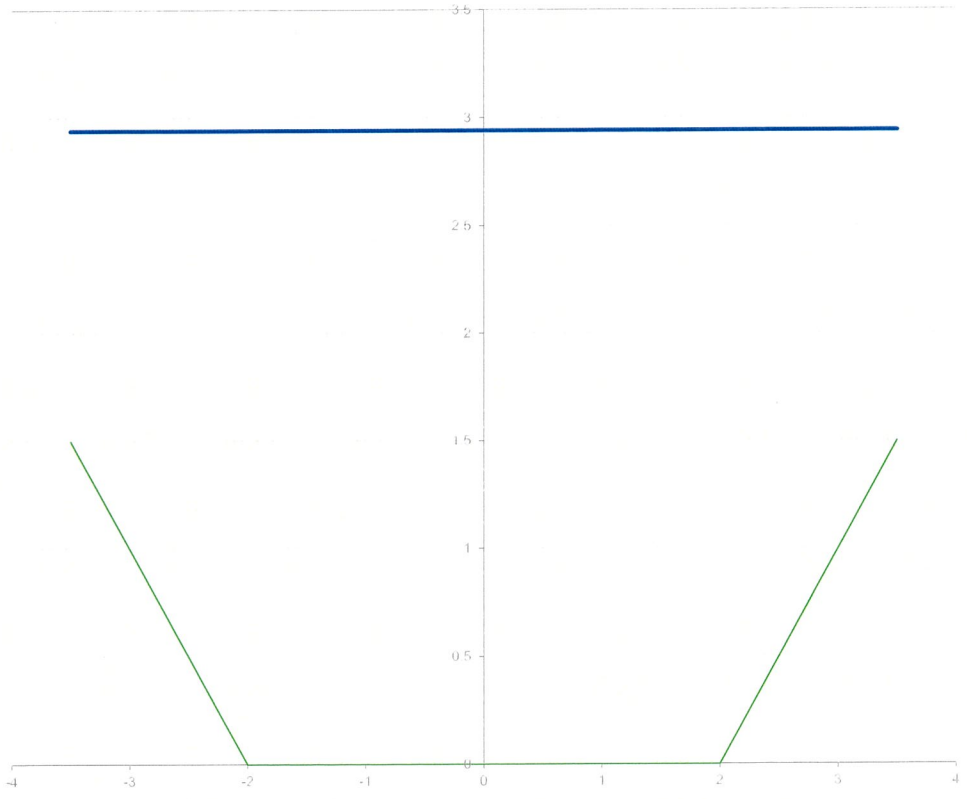
Label	Constraints	Horizontal (m)	Vertical (m)	Grade %	Surface		n	
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lip of cor	2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	Left of Invert
Invert Lir	2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	
		Invert Line						
Invert Lir	2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	Right of Invert
lip of cor	2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	
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PROJECT
DRAIN A1 + A2
5% AEP

Q =	24.57	Slope	0.2 %	5% AEP	Depth	2.941	n	0.0569	q	24.57	A	18.34	v	1.3397

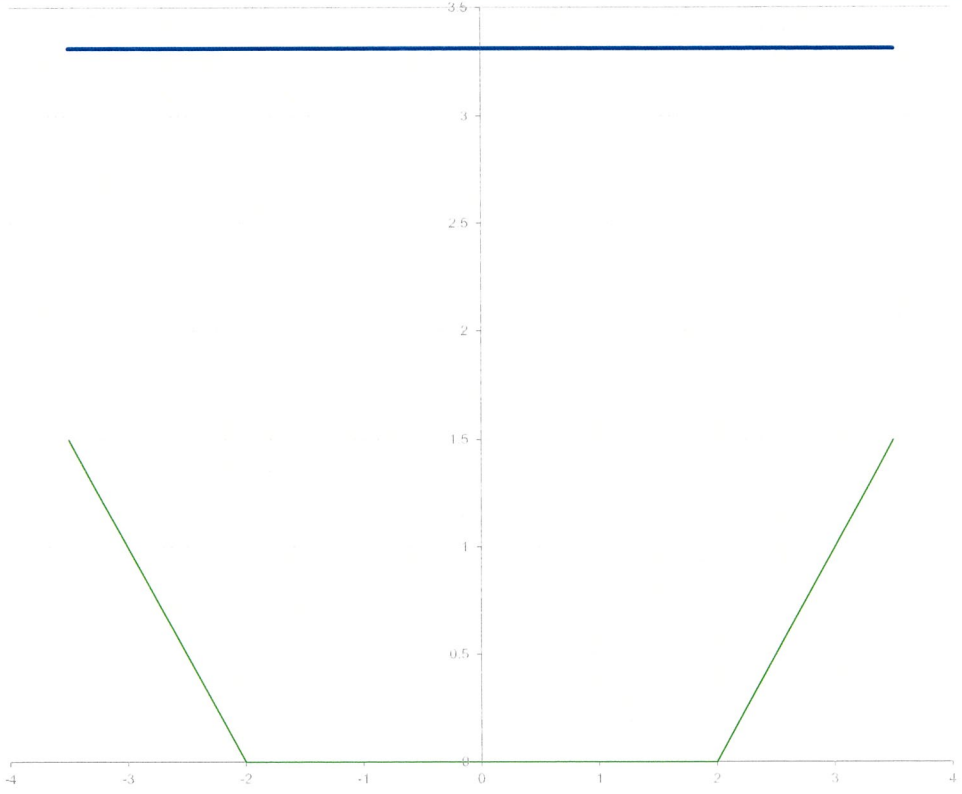
Label	Constraints		Horizontal (m)	Vertical (m)	Grade %	Surface		n	
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		1							
lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	Left of Invert
			Invert Line						
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	Right of Invert
lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	
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PROJECT
DRAIN A1 + A2
2% AEP

Q =	30.43	Slope	0.2 %	2% AEP	Depth	3.310	n	0.0572	q	30.43	A	20.92	v	1.4546

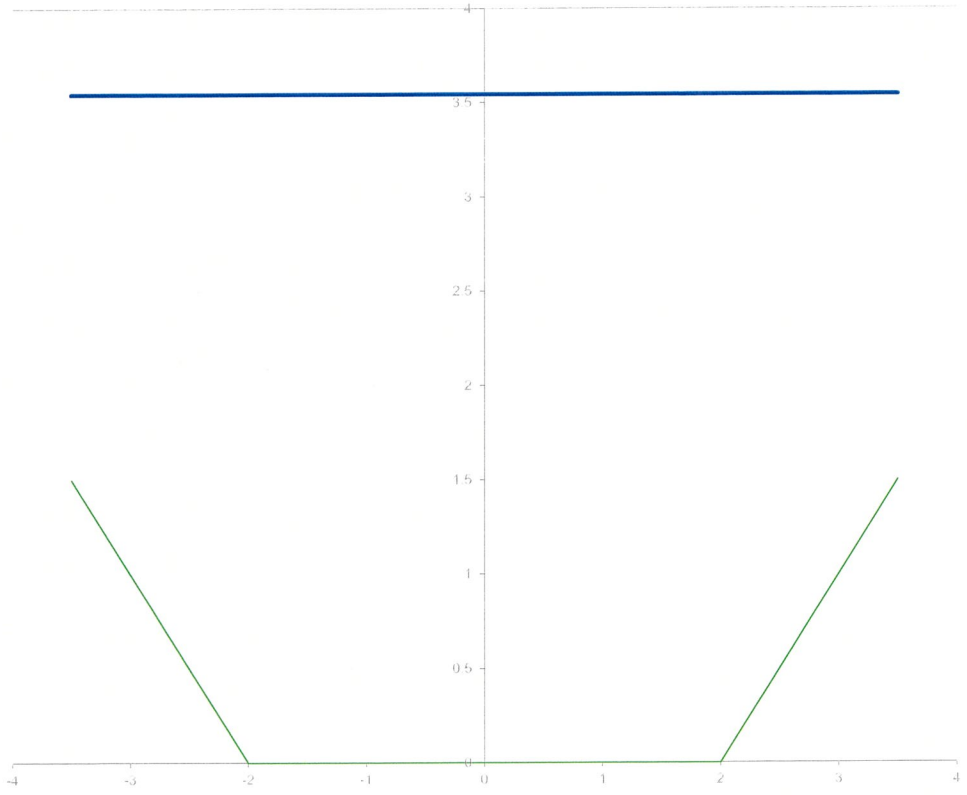
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lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	Left of Invert
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	
			Invert Line						
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	Right of Invert
lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	
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PROJECT
DRAIN A1 + A2
1% AEP

Q =	34.43	Slope	0.2 %	1% AEP	Depth	3.545	n	0.0574	q	34.43	A	22.57	v	1.5257

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lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	Left of Invert
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	
			Invert Line						
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	Right of Invert
lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	
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PROJECT
DRAIN B
63% AEP

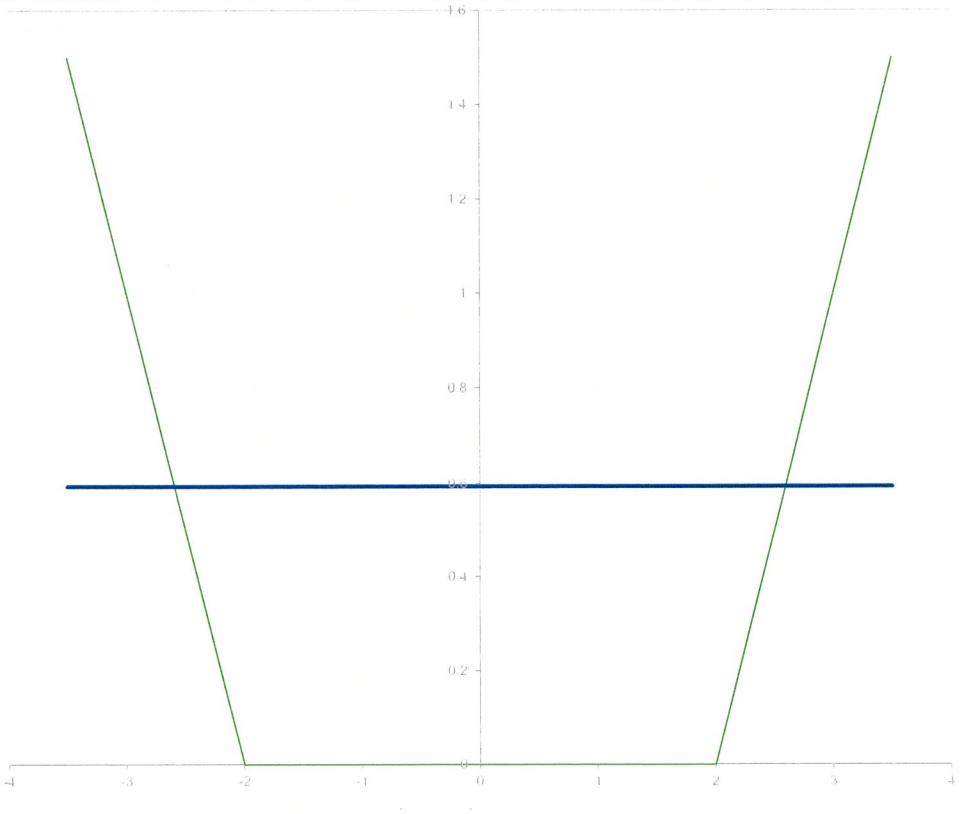
ERSCON CONSULTING ENGINEERS

Q =	2.44	Slope	0.66 %	63% AEP	Depth	0.594	n	0.0557	q	2.4399	A	2.728	v	0.8945

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lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
			Invert Line					
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
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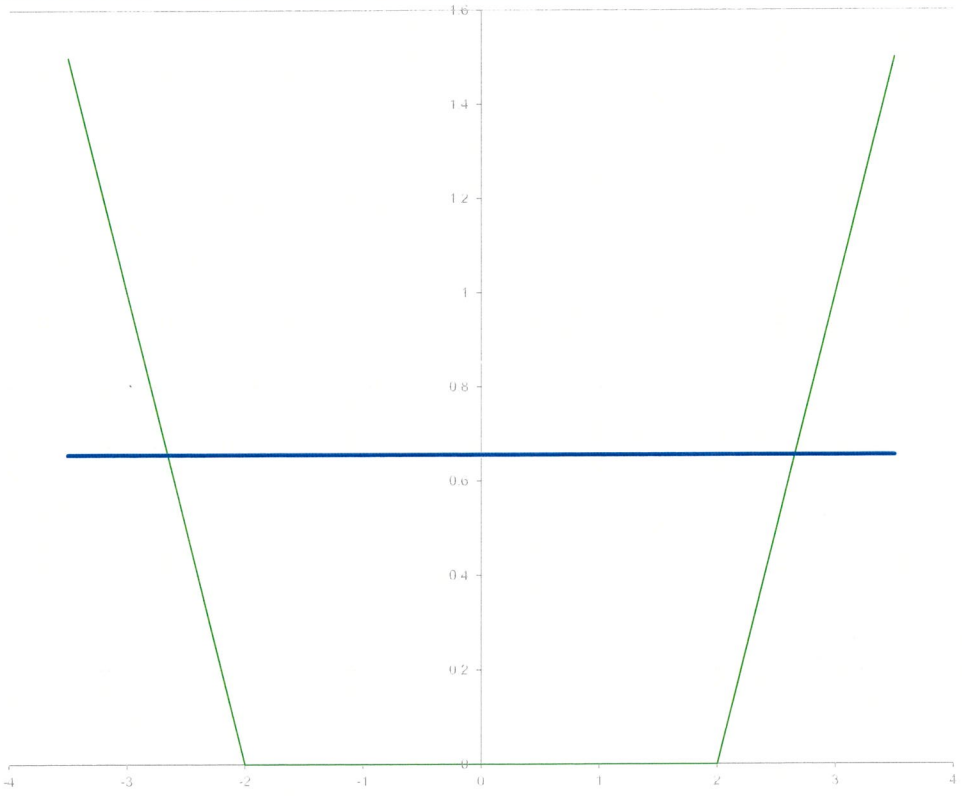
Right of Invert



PROJECT
DRAIN B
39% AEP

Q =	2.9	Slope	0.66 %	39% AEP	Depth	0.656	n	0.0554	q	2.8999	A	3.053	v	0.9498

Label	Constraints		Horizontal (m)	Vertical (m)	Grade %	Surface		n	
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lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	Left of Invert
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	
			Invert Line						
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	Right of Invert
lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	
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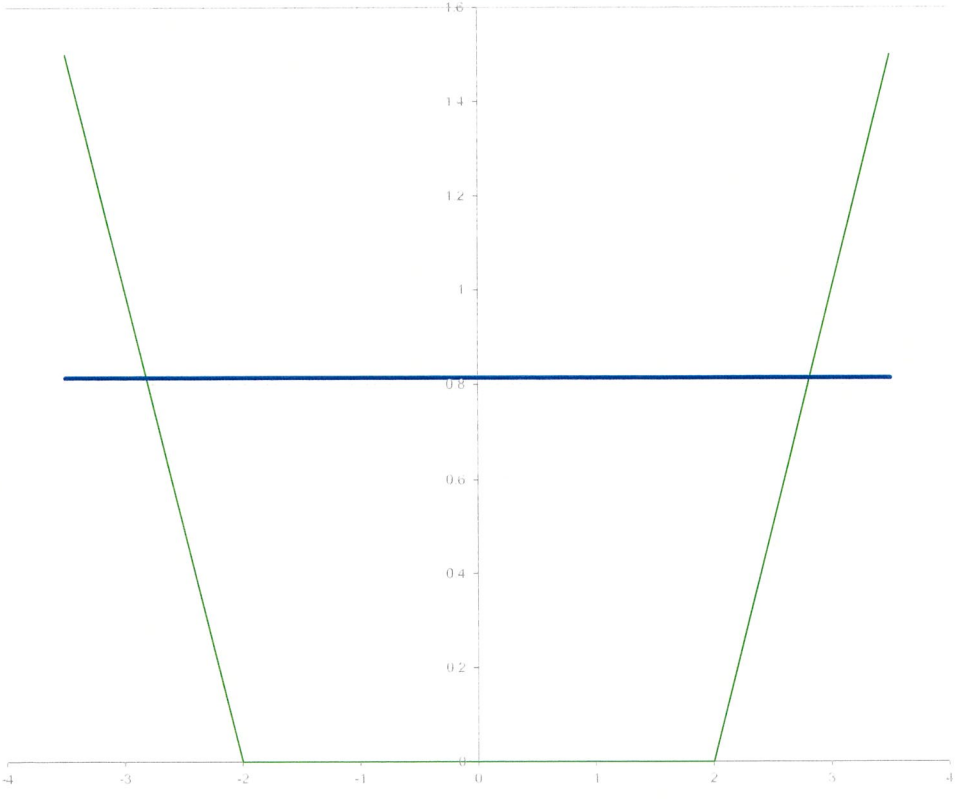


PROJECT
DRAIN B
18% AEP

ERSCON
CONSULTING ENGINEERS

Q =	4.24	Slope	0.66 %	18% AEP	Depth	0.815	n	0.0548	q	4.24	A	3.922	v	1.081

Label	Constraints		Horizontal (m)	Vertical (m)	Grade %	Surface		n	
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lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	Left of Invert
			Invert Line						
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	
lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	Right of Invert
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PROJECT
DRAIN B
10% AEP

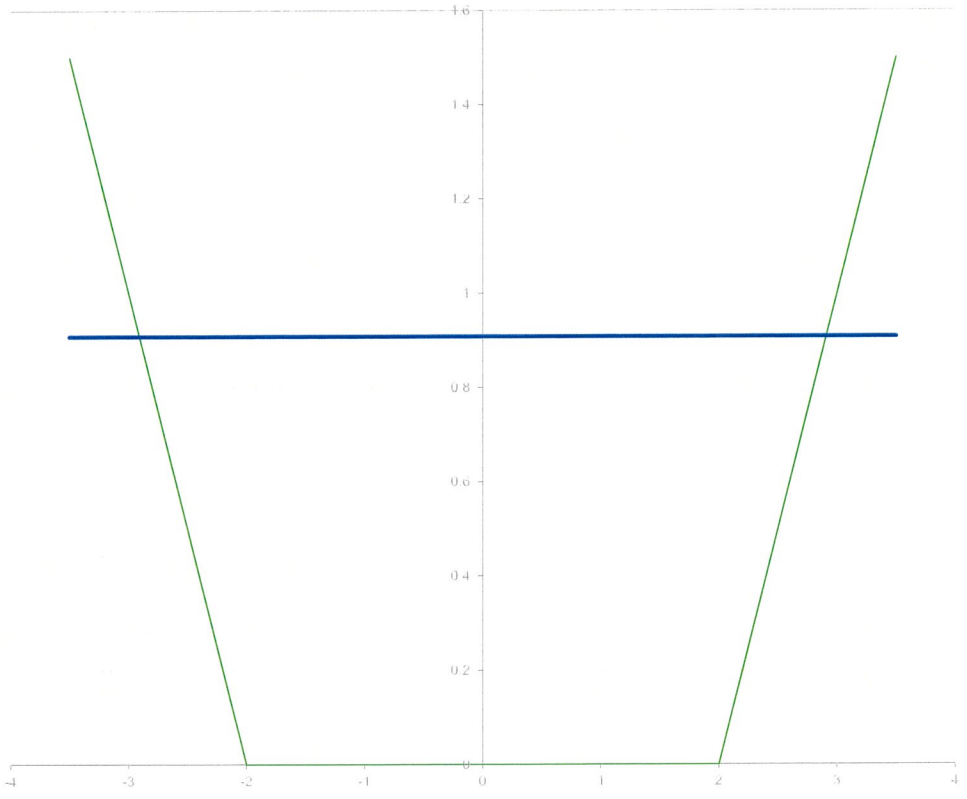
ERSCON CONSULTING ENGINEERS

Q =	5.14	Slope	0.66 %	10% AEP	Depth	0.909	n	0.0544	q	5.1399	A	4.46	v	1.1525

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lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
			Invert Line					
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
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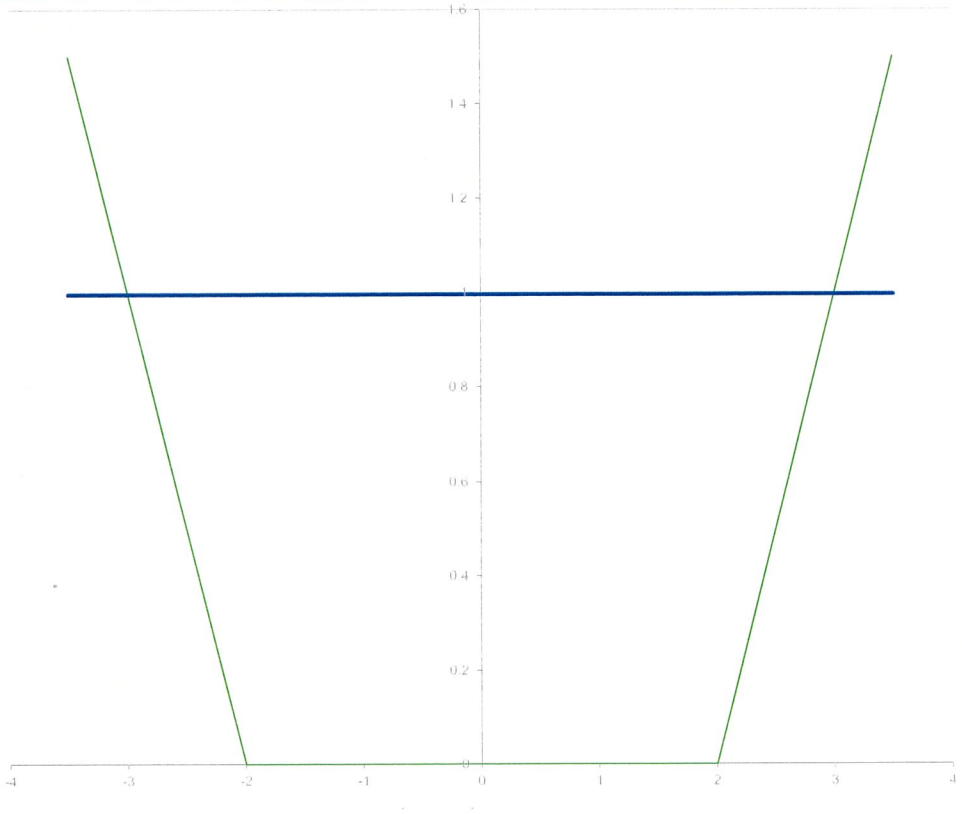


PROJECT
DRAIN B
5% AEP

ERSCON
CONSULTING ENGINEERS

Q =	6.05	Slope	0.66 %	5% AEP	Depth	0.996	n	0.0542	q	6.0499	A	4.976	v	1.2157

Label	Constraints		Horizontal (m)	Vertical (m)	Grade %	Surface		n	
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lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	Left of Invert
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lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	
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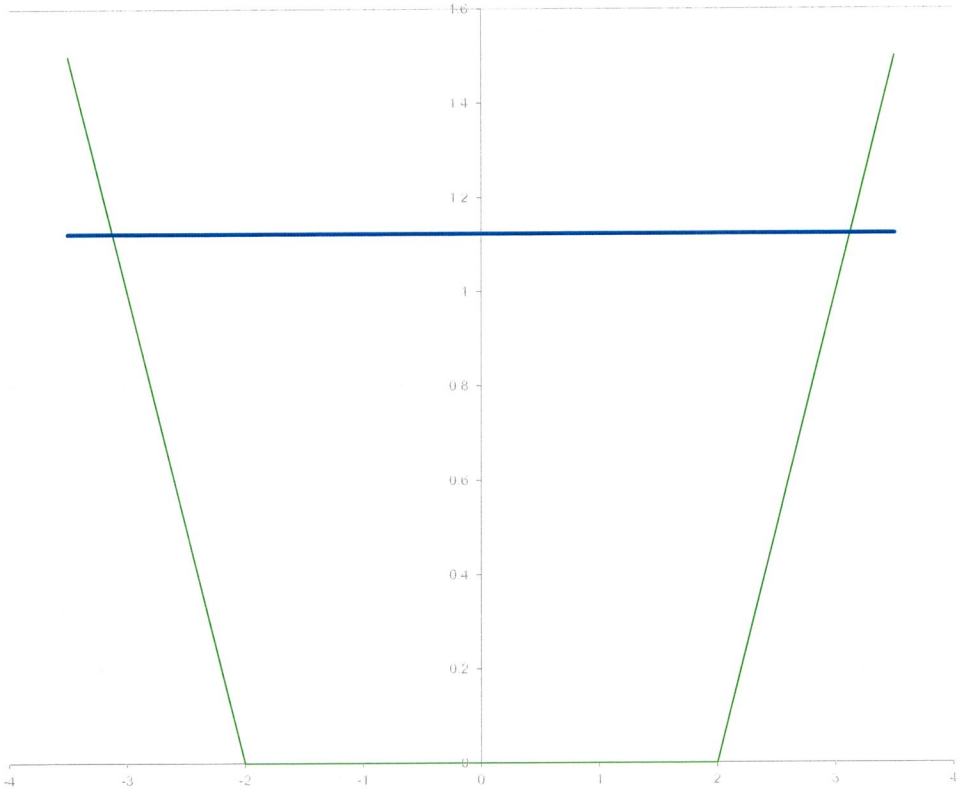
PROJECT
DRAIN B
2% AEP

Q =	7.5	Slope	0.66 %	2% AEP	Depth	1.124	n	0.0538	q	7.4999	A	5.757	v	1.3028

Label	Constraints		Horizontal (m)	Vertical (m)	Grade %	Surface		n
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lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
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Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06
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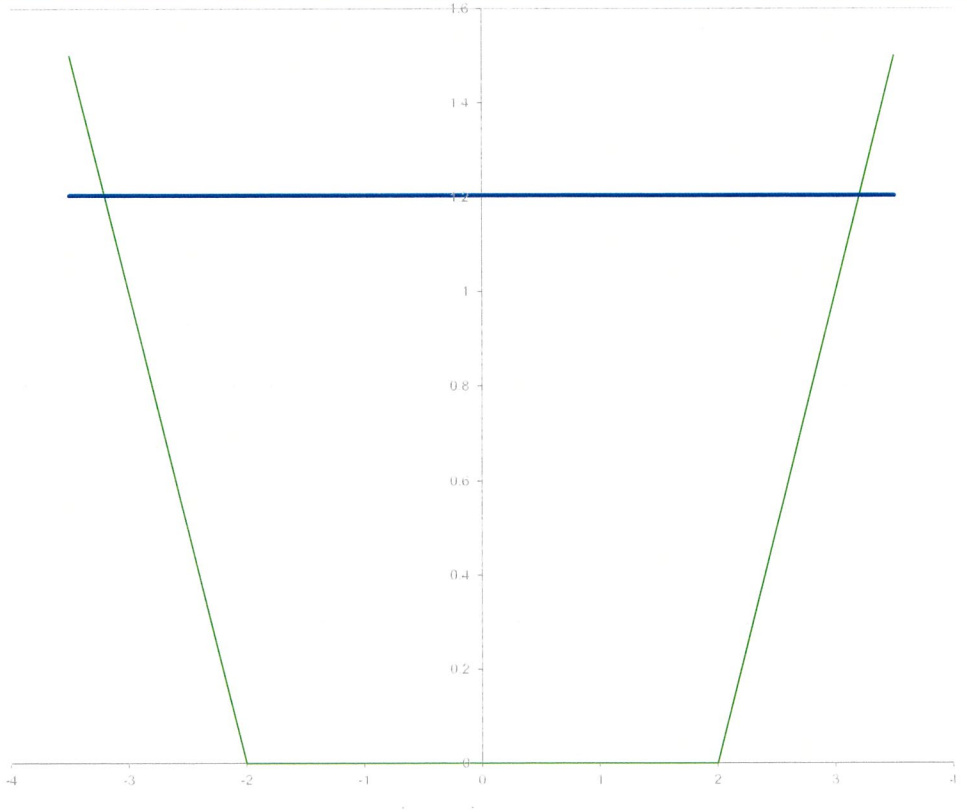
Right of Invert



PROJECT
DRAIN B
1% AEP

Q =	8.49	Slope	0.66 %	1% AEP	Depth	1.204	n	0.0536	q	8.49	A	6.265	v	1.355

Label	Constraints		Horizontal (m)	Vertical (m)	Grade %	Surface		n	
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Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	
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Invert Lir		2	2	0	0.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	Right of Invert
lip of cor		2	1.5	1.5	100.0%	Mountain streams, no vegetation in channel -	Bottom of gravel, c	0.06	
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APPENDIX C

NRA supplied Images

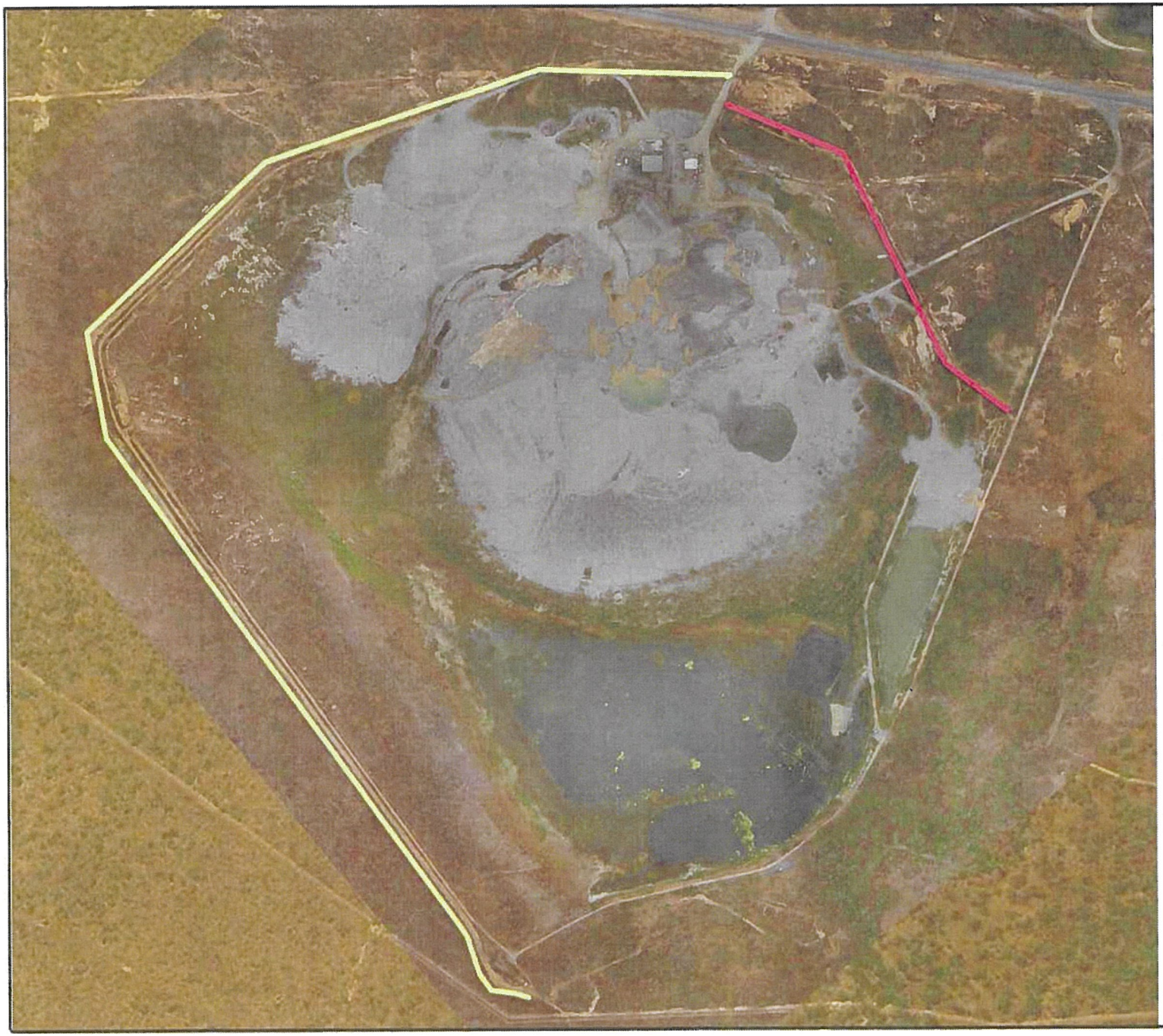


Figure 3b: Diversion drainage

Project: EQ Resources Erosion and Sediment Control Plan

TSF4 diversion drainage east
TSF4 diversion drainage west

N

0 0.3
Kilometres

Source:Bing Aerial 2022

NRA Ref: 380008.02
Date: February 2022

T:_Temp Mapping 2022\380\380008.02\380008.02_DrainageDiversion_b_220216.wor

Recommended print size: A4





APPENDIX D

Form 15 Certification

Form 15 Compliance certificate for building design or specification

Queensland Government

This form is to be used by an appointed competent person for the purposes of section 10 of the *Building Act 1975* and sections 73 and 77 of the Building Regulation 2021 (Design-specification certificate) stating that an aspect of building work or specification will, if installed or carried out as stated in this form, comply with the building assessment provisions.

Additional explanatory information is included in the Appendix at the end of this form.

1. Property description

This section need only be completed if details of street address and property description are applicable.

E.g. in the case of (standard/generic) pool design/shell manufacture and/or patio and carport systems this section may not be applicable.

The description must identify all land the subject of the application.

The lot and plan details (e.g. SP/RP) are shown on title documents or a rates notice.

If the plan is not registered by title, provide previous lot and plan details.

Street address *(include number, street, suburb/locality and postcode)*

.....

..... State ..... Postcode .....

Lot and plan details *(attach list if necessary)*

Lot 14 on SP254833

Local government area the land is situated in

Mt Carbine

2. Description of aspect/s certified

Clearly describe the extent of work covered by this certificate, e.g. all structural aspects of the steel roof beams.

This cerificate specifically covers the size and shape of rock required to line an existing perimeter drain at the mine site, located on the southern side of the Mulligan Highway, Mt Carbine.

3. Basis of certification

Detail the basis for giving the certificate and the extent to which tests, specifications, rules, standards, codes of practice and other publications were relied upon.

The rock sizing was determined from an in-house assessment of catchment areas, LIDAR information and a report extraction supplied from NRA. The standards used to base calculations were from QUDM and Catchment and Creeks publication "Rock Lining" - May 2010. Calculations were prepared using ERSCON in-house spreadsheets "External Catchments" and "Super Drain". The results were cross checked with manual calculations.

4. Reference documentation Clearly identify any relevant documentation, e.g. numbered structural engineering plans.	All information relating to the determination of rock sizing is contained in the report 900-047 "Rock Size Determination for a Perimeter Drain at Mt Carbine Mines" - April 2022.

5. Building certifier reference number and building development application number	Building certifier reference number 05085 Building development application number *(if available)*

6. Appointed competent person details Under Part 6 of the Building Regulation a person must be assessed as a competent for the type of work (design-specification) by the relevant building certifier.	Name *(in full)* John Dale Martin Company name *(if applicable)*: ERSCON Consulting Engineers Contact person: Mark Freeman Business phone number: 0742 428479 Mobile number: 0410 724 331 Email address johnmartin@erscon.com.au Postal address Suite 11, 320 Sheridan Street Cairns State QLD Postcode 4870 Licence class or registration type *(if applicable)* RPEQ No 5085 Licence or registration number *(if applicable)*

7. Signature of appointed competent person This certificate must be signed by the individual assessed and appointed by the building certifier as competent to give design-specification help.	Signature  Date 4/04/22

LOCAL GOVERNMENT USE ONLY

Date received		**Reference number/s**	

Appendix – explanatory information

IMPORTANT NOTE: it is an offence for a competent person to give a building certifier a document, including this form, that the person knows or reasonably suspects, is false or misleading.

Who can complete this certificate? (sections 10 of the *Building Act 1975* (Building Act) and 73 of Building Regulation 2021 (BR 2021))
A building certifier can accept from a competent person (design – specifications) a certificate stating that the competent person has assessed the building design or specification for the aspect of building work, and it will, if installed or carried out under the certificate, comply with the building assessment provisions, including any relevant standards and codes.

Schedule 10 of the BR 2021 defines *building design or specification* as any material, system, method of building or other thing related to the design of or specifications for building work.

For a competent person to meet the regulation requirements (section 77 of the BR 2021) they must substantially complete all sections of this form, including information, such as the design of a particular material, system, method of building or that a building element complies with the Building Code of Australia or a provision of the Queensland Development Code. It is also important that the details of the relevant reference documents are included, for example, the applicable Australian Standards or other technical provisions that may be applicable to the subject work.

What is the purpose of this form? (section 10 of the *Building Act 1975*)
The information in this form informs the building certifier's decision making when they are assessing a building development application and issuing the building development approval for the building work the subject of the certificate (form).

When is this form <u>not</u> required?
The assessment of some building applications will be entirely within the expertise of the relevant building certifier and therefore they may not seek the help of a competent person. In these instances, this form is not required.

Is a manufacturer or supplier required under the BR 2021 to complete and sign this Form 15, if requested?

No. A manufacturer or supplier of building materials is not required to complete and give this form or any aspect and inspection certificates if requested by a construction contractor, builder, appointed competent person, or a building certifier.

However, a manufacturer or supplier <u>may give</u> the construction contractor, builder, competent person or the building certifier evidence of suitability such as a manufacturers statement for an aspect or material that it is compliant with the relevant reference documents in the BCA i.e. the applicable Australian Standard/s.

What if there is not enough space for all the supporting material/documents?
Items 2, 3 and 4 requires the competent person to clearly identify the extent of the assessment that was undertaken for aspect/s of work identified in this form.

For instance, there is provision for material such as specifications, standards, codes or other relevant publications to be referenced in the form. However, if the space in the form is not sufficient to accommodate all of this material, you can create and refer to additional material in an addendum or attachment to the form.

The form is also available in a Microsoft Word version, that you can download and edit to include additional material in the relevant parts of the form. Note that editing the form in the Microsoft Word version may cause the relevant boxes to expand and increase the length of the document. This is acceptable and does not change the approved form, provided the section text (description on the left-hand side of the page) is not altered.

Appointed competent person (design or specification) – (sections 34 and 36 of the BR 2021)
A building certifier must assess and decide to appoint an individual as a competent person before they can, as a competent person, give design-specification help. The building certifier is required to keep detailed records about what was considered when appointing a competent person.

A building certifier must be satisfied that an individual is competent to give the type of inspection help having regard to the individual's experience, qualifications and skills and if required by law to hold a licence or registration, that the individual is appropriately registered or licensed.

An individual is appointed as competent to give design-specification help on or from a particular day. The building certifier can also decide an individual is a competent person (design-specification) and a competent person (inspection) at the same time or for the same systems or components of the work.

For further information about assessment of someone as a competent person refer to the **Guideline for the assessment of competent persons.**

PRIVACY NOTICE
The Department of Energy and Public Works is collecting personal information as required under the *Building Act 1975*. This information may be stored by the Department, and will be used for administration, compliance, statistical research and evaluation of building laws. Your personal information will be disclosed to other government agencies, local government authorities and third parties for purposes relating to administering and monitoring compliance with the *Building Act 1975*. Personal information will otherwise only be disclosed to third parties with your consent or unless authorised or required by law.

Appendix B:
Mt Carbine Geotechnical Inspection, 24/05/23 (GTS 2023a)

5/36 Finchley Street
PO Box 1404
Milton QLD 4064 Australia

T: 07 3367 1855
M: 0408 729 760
E: info@geotek.com.au

GeoTek Solutions Pty Ltd
Geotechnical & Geological Engineers

ABN 84 090 367 409

Date: 1/06/23

Our Reference: gts-mtc-230524-inspcn-v0.1

Golding Contractors Pty Ltd
Mt Carbine Mine

Attention: Steven Page

Dear Mr Page

Mt Carbine Geotechnical Inspection, 24/05/23

This letter presents the results of an inspection by GeoTek Solutions (GTS) that I carried out of the Mt Carbine open cut mine on 24/05/23.

1 SUMMARY

Since my last visit in July 2022 the pit has been pumped dry as can be seen in Figure 1.



Figure 1. Mt Carbine pit pumped dry.

The pit walls were in remarkably good condition reflecting the high strength of each of the rock types and the ore-bearing quartz veins. Along the South Wall Fault (SWF) the cable anchors had failed and were dangling in space, as they had been for some time. The rock had broken back to the footwall of the Southern Wall Fault. The absence of debris suggests that this had occurred while mining was still taking place in the 1980s and that there has been no further breakback since mining ended in 1986.

The exposed in situ rock is fractured. The joints were tight and clean with little by way of clay coated geological defects apart from the Southern Wall Fault. Consequently, the undamaged, in situ rock was mostly strongly interlocked.
Blast damage had loosened the wall rock particularly along bench crests but there had been very little fresh rockfall.

There was little visible groundwater seeping through the walls and no evidence of groundwater pressure induced instability. This observation provides confirmation of Lait's (2012) groundwater study which inferred:

- Low hydraulic conductivity of the Hodgkinson Formation aquifers; and
- No conclusive links between groundwater and surface water chemistry at the site

As noted in the Lait report the pit is hydraulic sink and the absence of any major seepage appears to confirm that the rock is tight.

Bunds were in place to enforce the 10m exclusion zone and were considered to be adequate for the most likely rockfall hazards i.e. a loosened rock falling from a damaged crest.

The pit designs suggested by Piteau remain essentially valid and have been incorporated in the current pit shell.

The dump design suggested in GTS (2022) of 40 m lifts and 10 m catch benches remains valid.

2 BACKGROUND INFORMATION

The following is taken from the GTS (2022) review and is provided here by way of background.

A very good summary of prior geotechnical investigations is provided in Chapter 4 of The Mt Carbine Bankable Feasibility Study (2021). For the purposes of this review greatest reliance has been place on the two early reports:

1. Piteau & Associates' (1982) "Report on Slope Stability Analysis and Design of Open Pits". This report is based on 6 months of field work by a geologist and subsequent design analysis and recommendations from two world-recognised slope stability experts. It is an outstanding report. The excellent condition of the existing pit void attests to the appropriateness of the Piteau recommendations and this review reaffirms their validity.
2. Golder Associates (1984) "Report to R.B. Mining Pty Ltd on Mt. Carbine Review of Rock Mechanics". This report pays particular attention to the proposed underground mining proposal and the transition from open pit to underground mining. It includes the results of seven post-Piteau diamond drill holes that were drilled during May – June 1984. Like the Piteau report, the Golder report was prepared by a world class rock mechanics expert.

The original data for both the Piteau and Golder reports appears to have been lost. Consequently, reliance has been placed on the tables and plots presented in those reports and the only way to delve into the data more deeply is to digitise plans, logs and plots and even then, the digitised information would be very high-level. As an example, the appended modified Piteau Figure 14 was developed by merging scanned and, current design data.

A further report, HCOVG (2020) "Brief review and structural assessment/scoping of Iron Duke-Peteresens-MtCarbine EPM14872", focusses on the detailed structural geology and the

sequence of geological events in and around Mount Carbine. It is less directly relevant to the geotechnical issues.
More recently, drilling by EQ Resources has produced core in which the orientation of the veins has been measured. The orientation data is contained within EQ Resources' database for drillholes EQ001 to EQ026. These data were compared with the results presented in the Piteau and Golder reports and found to be in strong agreement.

Mine north is 50.6° east of MGA94z55 north i.e. the mine grid has been rotated approximately 51° anticlockwise from MGA94z55 north. The means to make this correction has been embedded in the spreadsheet "Grid Conversion to local.xlsx". In this report the local grid system will be referenced, unless otherwise stated, e.g. when referring to compass directions such as "north" this will mean north relative to local grid north.

3 BACKGROUND GEOLOGY

This section, taken from GTS (2022), presents a simplified summary of the site geology. It is based mainly on the published paper by Forsythe and Higgins (1990) "Mount Carbine Tungsten Deposit" but with some information from the Piteau and Golder reports. An internal report by Forsythe (1983) referenced by Golder appears to have been lost and was not available.

The Mount Carbine tungsten ore is contained within wolframite and scheelite mineralisation of a quartz vein system. Orientation measurements of the veins indicates that the system dips near-vertically towards both the north and south.

The deposit is hosted in sedimentary strata of the Hodgkinson Formation which are Siluro-Devonian in age. Within the pit, regional and local metamorphism have altered the rocks. And within the ore zone pneumatolytic alteration by geologically introduced gases and silicification has occurred altering the engineering properties of the original strata by making them stronger and tougher. Locally, the Hodgkinson Formation consists of three lithological units:

- Arenite (coarse grained) unit in which sandstone, greywacke and conglomerate alternate with siltstone shale and minor chert;
- A basic (basaltic) volcanic-chert unit with interbedded shale; and
- An argillite (fine grained) unit lacking coarser clastics and consisting of shale and thinly interbedded siltstone and chert.

Within the pit, the fine-grained unit predominates, and it has been metamorphosed to a hornfels.

The volcanic-chert unit is a marker horizon that outlines the large scale folding of the Hodgkinson Formation.

These strata have been subject to at least three stages of deformation designated D1 – D3. Mineralisation occurred at the end of the third stage. Quartz and quartz-feldspathic veins were injected along foliations that had been induced by an earlier phase of deformation. The source of the veins is likely to be the underlying Mossman Batholith, part of the Permian age Mareeba granite suite. However, the deepest cored holes to date, MTCB005, at 741.4 m, and CB18 at 700.0 m have not intersected granite.

The major structures in the pit are the South Wall Fault (SWF) and the Central Fault (CF) which post-date the mineralisation.

The SWF is a major regional structure that dips towards the north at 70°. It marks the southern boundary of the mineralised belt and has faulted off a large part of the original deposit at depth. On the north side of the fault is hornfels and on the southern side of the fault the rock is a green schist i.e. more slatey in character. The fault contains between 0.5 and 2 m of fault gouge.

Central Fault is a less distinct feature which limits major mineralisation but does not truncate the quartz vein system. The fault is sub-vertical and strikes ESE. It is narrow and often difficult to distinguish in drill cores, although it is sometimes associated with intense calcite veining.

4 OBSERVATIONS AND COMMENTS

4.1 Wall Condition

The walls were in very good condition despite having being extensively fractured by multiple tectonic events. Most of the apparent damage appeared to have occurred due earlier poor blasting practice. It is understood that Golding will implement a smooth wall blast design by firing the back row first to create a pre-split fracture and then the remaining holes thereby isolating the new face from the main blast shock wave.

4.1.1 South Wall

The south wall was in very good condition and a view is shown in Figure 2. Most of the blast damaged rock will be removed by scaling the walls but some will remain because it is inaccessible. The fact that there has been little deterioration of the wall in the nearly 40 years of exposure and inundation implies that the risk of rockfall is low and it will be controlled by constructing toe bunds to intercept falling rocks.

There were two hazards that pose an elevated risk:

- The smooth faced discontinuities, sometimes known as slippery backs and circled in red in Figure 2, that daylight out of the wall at angle steeper than the angle of friction of interface. This means that the rock in front of the slippery back can slide out.
- The damaged rock towards the western end of the South Wall which had been bunded off.

Operators will need to know to be able to identify these hazards. The damaged rock has been bunded off but slippery backs can appear at any time operators will need take particular care when working around them.

4.1.2 South Wall Fault

The SWF was in very good condition and confirms Golder's observation that "there is no fundamental reason why the south wall should not be mined along fault plane." However, the current mine plan provides for a cutback behind the fault in the upper benches thereby eliminating any issues that may arise due to the fault.

Current areas that might be susceptible to elevated rock fall risk had been bunded as can be seen in Figure 2.



Figure 2. View of the South Wall Fault with adverse structures highlighted in red.



Figure 3. Closer view of slippery backs and damaged wall rock in front of the SWF.

4.1.3 East Wall

Views of the East Wall are shown in Figures 4 and 5.

The weathered benches were essentially debris-free and stable.

The fresh walls above the work area where the drill rig was located had been well scaled. The rock fabric exposed in the East Wall generally trended perpendicular to the wall and consequently is geotechnically benign.

The wall was dry.



Figure 4. View of the East Wall taken form the lookout.



Figure 5. View of the East Wall taken from the floor.

4.1.4 North Wall

The North Wall was mostly in very good condition. A panoramic view of it is shown in Figure 6.



Figure 6 View of North Wall from pit floor.

Joints from Piteau Joint Set B which is parallel with tungsten bearing quartz veins were highly visible in the North Wall as shown in Figure 8. This joint set dips steeply towards the north. Mostly this joint set create geotechnical hazards but where there is a change in pit wall or bench orientation such as identified in Figure 7 then a slabbing type failure may occur and care should be taken while working in the vicinity.



Figure 7. North Wall with joints from Set B highlighted as potential hazards.

Piteau Set C joints are very obvious in the North Wall. A few have been highlighted in Figure 8. The structures dip at flat angles towards the east and consequently are unlikely to fail because they dip at angles significantly less than the friction angle of the defect.



Figure 8 Section of North Wall highlighting long defects dipping to the east.

The wall was dry.

4.1.5 West Wall

Figure 9 shows a view of the West Wall. It is a relatively short length of wall because the North Wall trends NE-SW as it meets up with the West Wall.

Overall the wall was in good condition but had been blast damaged. Protection from falling rocks was provided by a bund located 10m out from the toe of the wall and can be seen in Figure 9.



Figure 9. View of the West Wall.

The pit will develop to the west and this will permit re-drilling and smooth blasting of this wall in future cutbacks to improve wall stability.

The wall was dry.

4.2 Groundwater

Almost all of the walls were entirely dry. In 2012 Lait reported groundwater levels from dedicated monitoring wells that were mostly in the range of 12 to 25 m below surface level. The current well levels are unknown, but it is likely that pumping the pit dry has initiated a cone of depression in the groundwater system. Nevertheless some water must be flowing through the ground as evidenced by the water in the floor sump.

It is recommended to continue to monitor water levels in the wells not just for environmental purposes but also for geotechnical purposes. Both Piteau and Golders referred to the possibility of needing horizontal dewatering holes, particularly in the south wall. There is no evidence yet that they are needed but water level data from the monitoring wells may assist in making a decision.

5 MAPPING

The original mapping data by Piteau and Golder have been lost. All that remains are images of stereoplots and identification of joint sets. EQ Resources has generated limited orientation data from exploration boreholes. Consideration could be given either by Golding or the Owner to undertake mapping of the pit to at least identify the location and orientations of the more significant structures.

There is a variety of ways of doing this using either drone data or terrestrial photographs. Analysis could be carried out with dedicated software life Datamine's Sirovision or 3GSM ShapeMetrix or in Maptek's GeologyCore or PointStudio with the geotechnical add-in. The benefit of doing this would be to provide a database of spatially located structure which could assist with the systematic identification of geotechnically adverse structures.

Cored exploration boreholes could be another source of structural data using Optical Televiewer (OTV) or Acoustic Televiewer (ATV) geophysical tools to scan the boreholes. OTV data is much clearer than ATV data and the tool may return data from non-cored holes where the ATV would fail.

6 REVIEW OF DESIGNS

The pit designs suggested by Piteau remain valid and have, essentially, been incorporated into the current pit shell. For completeness, the Piteau Design Table IX and a partially redrawn Figure 14 Distribution of Design Sectors that were re-generated for the GTS 2022 report are appended.

Since the original geotechnical designs were generated three significant aspects have changed:

- The current design will dig through the SWF in the upper levels. Provided the rock behind the SWF is sufficiently strong, this will eliminate the need for reinforcement as envisaged by Piteau and Golder.
- There is no evidence, yet, of excessive groundwater pressures that would require relief by horizontal drain holes. Water levels in the existing monitoring wells need to be measured to help in the assessment of groundwater pressures.
- The detailed geological face mapping undertaken by Piteau and the orientation data derived from the Golder drilling for the proposed underground mining does not exist for the western extension of the pit. Efforts should be made to generate that data to minimise the risk of geotechnical surprises from unknown geological structure.

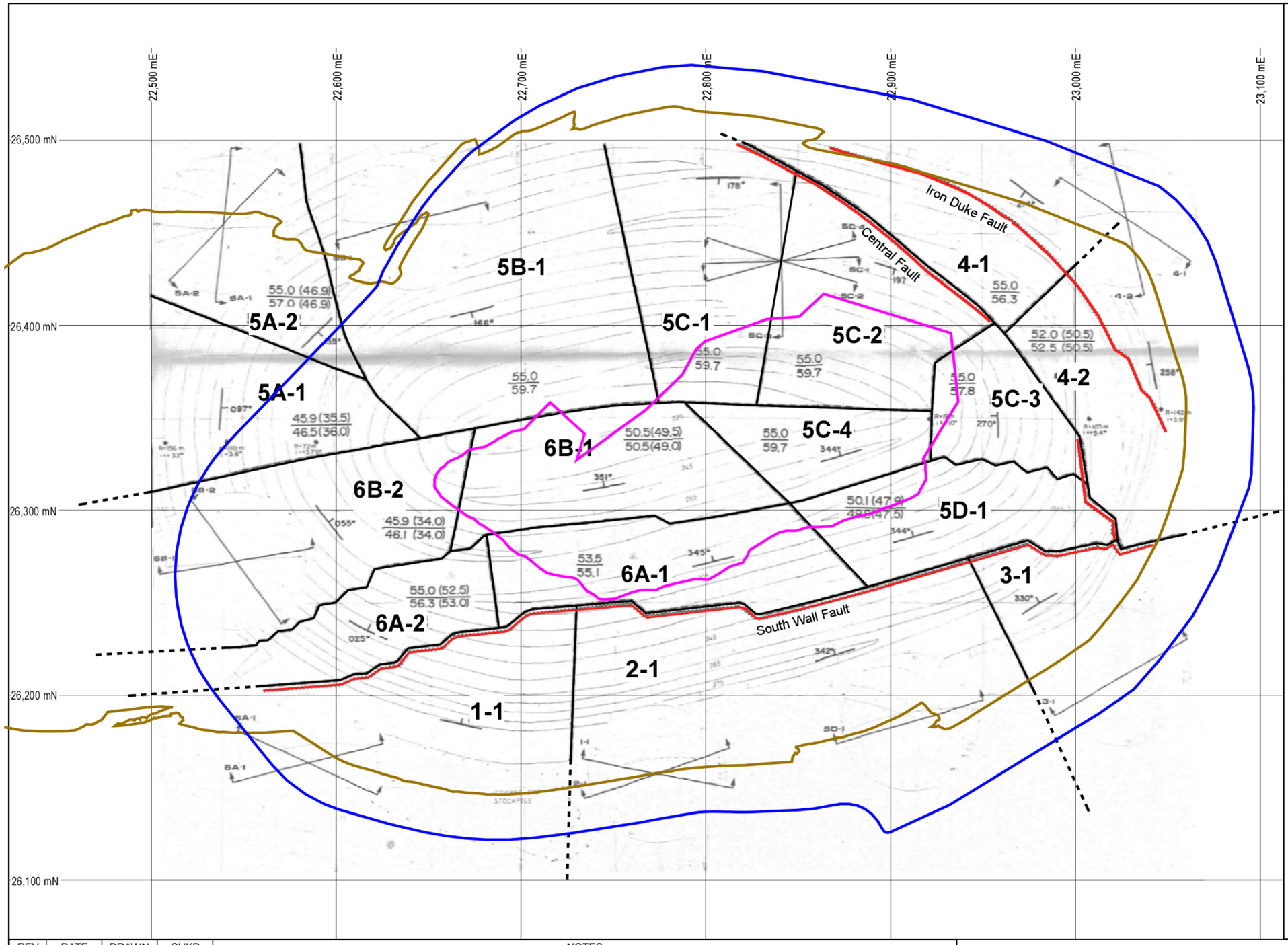
The GTS (2022) comment regarding dump designs remains unchanged that "geotechnically, out of pits dumps can be constructed in 40 m lifts with 10 m catch benches. Founded on flat stable ground the dumps could be constructed to a height of 100 m and the factor of safety against overall failure would be greater than 1.3".



A. Paul Maconochie RPEQ 5828
Principal Geotechnical Engineer

7 REFERENCES

1. EQ Resources, 2021. Mt Carbine Bankable Feasibility Study, Chapter 4 Mining.
2. Forsythe DL, 1983. Geology of Mount Carbine Area, North Queensland. R.B. Mining Pty Ltd report dated August 1983.
3. Forsythe, DL and Higgins NC, 1990 Mount Carbine Tungsten Deposit in Geology of the Mineral Deposits of Australia and Papua New Guinea (ed. FE Hughes) pp 1557-1560. AusIMM.
4. GeoTek Solutions, 2022. Report to R.B. Mining Pty Ltd on Mount Carbine Review of Rock Mechanics.
5. HCOV Global, 2020 Brief review and structural assessment/scoping of Iron Duke-Petersens-Mt Carbine EPM14872.
6. Rob Lait & Associates, 2012. Carbine Tungsten Groundwater Study.
7. Piteau & Associates, 1982. R.B. Mining Pty Ltd Mount Carbine Mine Report on Slope Stability Analysis and Design of Open Pit Slopes.



SYMBOLS

Pit Design V3 Stage 1 Perimeter

Pit Design V3 Stage 2 Perimeter

Pit Design V3 Stage 3 Perimeter

Design Sector Boundary

Extrapolated Design Sector Boundary

5C-1

Design Sector Number

258°

Orientation and dip direction of final pit wall

Bench H = 20m 55.0 (46.9)
Bench H = 30m 57.0 (47.2)

Optimum interramp slope angle for Design Sectors with and ( ) without adequate groundwater depressurisation.

Fault

NOTES

1. Design sector boundaries are based on structural domain boundaries and boundaries of straight slope segments.
2. Results of kinematic statistical analyses were not used for design of slopes in Design Sectors 1-1, 2-1 and 3-1. Separate design of slopes and remedial measures for individual benches south of the South Wall Fault are discussed in Piteau (1982) Section 8.7.

REV	DATE	DRAWN	CHKD	NOTES
1	30/10/22	P. Maconochie		Plan created from scanned image in Piteau (1982) and pit design V3 triangulation

MOUNT CARBINE MINE

EQ RESOURCES

GOLDING CONTRACTORS

Piteau (1982) Fig 14
DISTRIBUTION OF DESIGN SECTORS AND KINEMATICALLY POSSIBLE FAILURE MODES

Job No.: 22-138 | Datum: Local Grid | Scale: as shown

Fig ###

Piteau (1982) Table IX Summary of Slope Information, Stability Analysis Results and Slope Design Recommendations for Design Sectors

DESCRIPTION OF DESIGN SECTORS					MAIN MODES OF SLOPE FAILURE WHICH CONTROL SLOPE STABILITY	STABILITY ANALYSIS RESULTS FOR KINEMATICALLY POSSIBLE FAILURE MODES [1,2]								OPTIMUM INTERRAMP SLOPE DESIGN FOR DRY SLOPES BASED ON KINEMATIC ANALYSES RESULTS (SLOPE DESIGN FOR SLOPES WITH HIGH GROUNDWATER PRESSURES ARE GIVEN IN BRACKETS WHERE DIFFERENT)						POSSIBLE INCREASE IN SLOPE ANGLE DUE TO PLAN RADIUS OF CURVATURE (°)	RECOMMENDED INTERRAMP SLOPE DESIGN FOR DRY OR DRAINED SLOPES OR SLOPES WITH ADEQUATE GROUNDWATER DEPRESSURISATION 4							DESIGN SECTOR
						AVERAGE DIP OR APPARENT PLUNGE OF FAILURE FOR WORST CASE WHERE STATISTICAL ANALYSIS NOT USED		APPARENT PLUNGE OF WEDGES CORRESPONDING TO A CUMULATIVE PERCENTAGE OF 20%		APPARENT PLUNGE OF WEDGES CORRESPONDING TO THE BREAK IN THE CUMULATIVE FREQUENCY PLOT				BENCH HEIGHT = 20m			BENCH HEIGHT = 30m				BENCH HEIGHT = 20m BETWEEN 305m AND 345m ELEVATION			BENCH HEIGHT = 30 m ABOVE 345m AND BELOW 305m ELEVATION			REMEDIAL MEASURES AND COMMENTS [5,6,7]	
DESIGN SECTOR	STRUCTURAL DOMAIN	SLOPE DIP DIRECTION (°)	MAXIMUM SLOPE HEIGHT (m)	No. OF HAUL ROADS		F < 2.0	F < 1.2	F < 2.0	F < 1.2	F < 20 CUM PERCENT	F < 20 APPARENT PLUNGE	F < 1.2 CUM PERCENT	F < 1.2 APPARENT PLUNGE	OPTIMUM BENCH FACE ANGLE (°)	TOTAL BERM WIDTH[3] (m)	INTER RAMP SLOPE ANGLE (°)	OPTIMUM BENCH FACE ANGLE (°)	TOTAL BERM WIDTH[3] (m)	INTER RAMP SLOPE ANGLE (°)		BENCH FACE ANGLE (°)	BERM WIDTH (m)	INTER RAMP SLOPE ANGLE (°)	BENCH FACE ANGLE (°)	BERM WIDTH (m)	INTER RAMP SLOPE ANGLE (°)		
1-1	1 and 2	012	85	-	Rotational failure in weathered rocks at pit crest. Wedge failures formed by combination of joints of Joint Set A and Joint Set D.	40	[44]	58	54°	15	53˚	10	56˚	-	-	-	-	-	-	-	-	-	.	-	-	Statistical analysis and design techniques were not used in Design Sectors 1-1, 2-1 and 3-1 because slope stability is controlled by rotational failure in weathered rocks as well as kinematically possible failure modes. Slope design and remedial measures in this area are discusser, in section 8.7.	**1-1**
2-1	1 and 2	342	85	-	Rotational failure in weathered rocks at pit crest. Plane failures along joints of Joint Set A and Joint Set G.	47	[47]	50	50	-	-	-	-	-	-		-			-	-	-	-	-	-	-		**2-1**
3-1	3	330	30	1	Rotational failure in weathered rock at pit crest. Plane failure along joints of Joint Set B.	44	[44]	44	44	6	44	6	44	-			-			-	-	-	-	-	-	-		**3-1**
4 -1	4	214	60	1	Plane failure along joints of Joint Set A. Wedge failures formed by combination o joints of Joint Set A and Joint Set D.	[69]	[69]	69	69	-	-	-	-	80	10.5	55.0	80	14.7	56.3	+4°	80	10.5	55	80	14.7	56		**4-1**
4-2	4	258	60	[1]	Wedge failure formed by combination of joints of Joint Set A and Joint Set B.	52	56	[52]	[58]	-	-	-	-	80 (70)	12.1 (16.5)	52.1 (50.5)	70 (70)	23.0 (24.7)	52.5° (50.5)	-	80	10.5	55	80	14.4	56.5	Slope angle of 55° is recommended for 20m high benches to provide access to the south wall. Drainholes may be required to control groundwater pressures.	**4-2**
5A-1	5A	097	170	2	Wedge failures formed by combination of joints, faults, shears and veins.	27	42	[36]	[46]	-	-	22	66	70 (70)	19.1 (28.0)	45.9 (35.5)	70 (70)	28.9 (41.4)	46.1 (36.0)	+3°	70	17.4	49	70	26.1	49	Slopes below 305m elevation could be increased to 50° based on increased effects of plan radius of curvature. Horizontal drainholes may be required.	**5A-1**
5A-2	5A	135	170	1	Wedge failures formed by combination of joints, faults, shears and veins.	34	70	[47]	[70]	-	-	-	-	80 (70)	10.5 (18.7)	55.0 (46.9)	80 (70)	14.2 (28.1)	57.0 (46.9)	-	80	10.5	55	80	19.5	57	Horizontal drainholes may be required in specific areas on benches to control groundwater pressures in the slope.	**5A-2**
5B-1	58	166	260	2	Wedge failures formed by combination of joints, faults, shears and veins.	59	76	[75]	76	12	[74]	-	-	80	10.5	55.0	80	12.2	59.7	-	BO	10.5	55	80	12.0	60		**5B-1**
5C-1	5C	178	260	2	Wedge failures formed by combination of joints, faults, shears and veins.	57	80	[79]	[80]	23	79	-	-	80	10.5	55.0	80	12.2	59.7	-	80	10.5	55	80	12.0	60		**5C-1**
5C-2	5C	197	120	2	Wedge failures formed by combination of joints, faults, shears and veins.	77	77	[84]	[84]	-	-	-	-	80	10.5	55.0	80	12.2	59.7	-	80	10.5	55	80	12.0	60		**5C-2**
5C-3	5C	270	100	1	Wedge failure formed by combination of joints, faults, shears and veins.	68	68	[71]	[71]	-	-	-	-	80	10.5	55.0	80	13.6	57.8	+5°	80	10.5	55	80	12.0	60	Maximum slope angles of 55° are recommended for 20m high benches in the design sector to ensure reliable access to the south wall.	**5C-3**
5C-4	5C	344	50	1	Wedge failures formed by combination of joints, faults, shears and veins.	43	43	[74]	[74]	18	74	11	74	8O	10.5	55.0	BO	12.2	59.7	-	70	16.7	50	70	25.3	50	Maximum interramp slopes of 50° are recommended below 305m elevation due to sensitive nature of slope in this area and possible requirements for remedial measures.	**5C-4**
5D-1	5D	344	100	2	Wedge failures formed by combination of joints, faults, shears and veins.	26	40	[48]	[51]	-	-	.	.	70 (70)	16.7 (18.1)	50.1 (47.9)	70 (70)	25.4 (27.5)	49.8 (47.5)	-	70	18.7	47	N/A	N/A	N/A	20 m high benches and maximum inter-ramp slope angles of 47° are recommended above the haul road (300 m elevation) in Design Sectors 5D-1 and 6A-1 due to the sensitive nature of the slope and possible requirements for remedial measures. Horizontal drainholes may be required.	**5D-1**
6A-1	6A	345	60	1	Wedge failures formed by combination of joints, faults, shears and veins.	47	53	[64]	[64]	20	65	20	66	so	11.3	53.5	70	20.9	55.1	-	70	18.7	47	70	25.3	50		**6A-1**
6A-2	6A	025	120	1	Wedge failures formed by combination of joints. faults, shears and veins.	34	36	[59]	[69]	25	70	16	68	80 (80)	10.5 (12.0)	55.0 (52.2)	80 (70)	14.7 (22.6)	56.3 (53.0)	-	70	17.4	49	70	26.1	49	Interramp slope angles of 49° are recommended in this design sector for blending of slope designs between adjacent sectors. Horizontal drainholes may be required.	**6A-2**
6B-1	6B	351	50	1	Plane failure along joints of Joint Set Gl. Wedge failures formed by combination of joints, faults shears and veins.	47	49	[50]	[52]	-	-	.	-	70 (70)	16.5 (17.1)	511.5 (49.5)	70 (70)	24.7 (26.1)	50.5 (49.0)	-	N/A	N/A	N/A	70	25.3	50	Same as comments for Design Sector 5C-4. Horizontal drainholes may be required.	**6B-1**
6B-2	6B	055	170	2	Wedge failures formed by combination of joints, faults, shears and veins.	27	40	[34]	[36]	-	-	-	-	70 (70)	19.1 (30.7)	45.9 (34.0)	70 (70)	28.9 (44.4)	46.1 (34.0)	+3°	70	17.4	49	70	26.1	49	Slopes below 305m elevation could be increased to 50° based on increased effects of plan radius of curvature. Horizontal drainholes may be required.	**6B-2**

NOTES

1. Analyses results are presented for F < 2.0 and F < 1.2 which relate to un-dewatered and dry, drained or dewatered slopes respectively.
2. The dip or apparent plunge which is considered to control slope stability is in squared brackets for both un-dewatered (F < 2.0) and drained (F < 1.2) conditions in each design sector.
3. Total berm width is calculated based on berm width required to catch failed material with consideration of anticipated breakback of bench crests.
4. Feasibility of using 30m high benches should be verified by assessment of trial slopes.
5. Control blasting is recommended in all areas of the final slope to ensure minimal disturbance to the rock and maintain cohesion in the slope.
6. If control blasting Is not adequate or undue failures occur-in certain areas, grouted dowels may be required to ensure the integrity of haul roads or other critical installation.
7. Remedial measures are recommended to control groundwater and surface water. Sealed drainage ditches graded berms and horizontal drainholes are recommended in critical areas as required. If adequate groundwater control is not obtained using drainholes additional hydrogeological studies may be required.

Appendix C:
Mt Carbine Geotechnical Inspection, 1/11/23 (GTS 2023b)

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M: 0408 729 760
E: info@geotek.com.au

GeoTek Solutions Pty Ltd
Geotechnical & Geological Engineers

ABN 84 090 367 409

Date: 6/11/23

Our Reference: gts-mtc-231101-inspcn-v0.1

Golding Contractors Pty Ltd
Mt Carbine Mine

Attention: Wade Smith

Dear Mr Smith

Mt Carbine Geotechnical Inspection, 1/11/23

This letter presents the results of an inspection by GeoTek Solutions (GTS) that I carried out of the Mt Carbine open cut mine on 1/11/23. I had previously inspected the pit at the start of operations on 24/05/23. The purpose of the visit was to check that the geotechnical conditions matched the design assumptions in compliance with requirements of the Ground Control Management Plan.

1 SUMMARY

Since my last visit in May 2023 the pit has been developed mainly towards the east but also towards the west. In Figure 1 a pre-strip drill pattern can be seen at the western side of the pit (LHS). This represents the start of Stage 2 of the pit. Inside the pit a drill was operating on the western side.



Figure 1. Mt Carbine pit from lookout.

The pit walls were in excellent condition reflecting the high strength of each of the rock types and the ore-bearing quartz veins. Draining of the pit and the subsequent drying of the wall rocks had not resulted in any deterioration of the wall rocks. Notably along the

South Wall Fault (SWF) the wall had remained stable despite the cable anchors no longer being effective.

There had been a possible concern that draining of the pit would generate groundwater pressures behind the pit walls. However, there was almost no visible groundwater seeping through the walls and no evidence of groundwater pressure induced instability. This observation provides confirmation of Lait's (2012) groundwater study which inferred:

- Low hydraulic conductivity of the Hodgkinson Formation aquifers; and
- No conclusive links between groundwater and surface water chemistry at the site

As noted in the Lait report the pit is hydraulic sink and the absence of any major seepage appears to confirm that the rock is tight.

The exposed in situ rock is fractured. The joints were tight and clean with little by way of clay coated geological defects apart from the Southern Wall Fault. Consequently, the undamaged, in situ rock was mostly strongly interlocked.

Blast damage had loosened the wall rock particularly along bench crests but there had been very little fresh rockfall.

Bunds were in place to enforce the 10m exclusion zone and were considered to be adequate for the most likely rockfall hazards i.e., a loosened rock falling from a damaged crest.

The pit designs suggested by Piteau remain essentially valid and have been incorporated in the current pit shell.

The dump design suggested in GTS (2022) of 40 m lifts and 10 m catch benches remains valid.

2 BACKGROUND INFORMATION

The Ground Control Management Plan contains a summary of the background geology. The background information included in the May 2023 inspection report is repeated here so that this report can be read as a standalone report.

A very good summary of prior geotechnical investigations is provided in Chapter 4 of The Mt Carbine Bankable Feasibility Study (2021). For the purposes of this review greatest reliance has been place on the two early reports:

1. Piteau & Associates' (1982) "Report on Slope Stability Analysis and Design of Open Pits". This report is based on 6 months of field work by a geologist and subsequent design analysis and recommendations from two world-recognised slope stability experts. It is an outstanding report. The excellent condition of the existing pit void attests to the appropriateness of the Piteau recommendations and this review reaffirms their validity.
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A further report, HCOVG (2020) “Brief review and structural assessment/scoping of Iron Duke-Peteresens-MtCarbine EPM14872”, focusses on the detailed structural geology and the sequence of geological events in and around Mount Carbine. It is less directly relevant to the geotechnical issues.

More recently, drilling by EQ Resources has produced core in which the orientation of the veins has been measured. The orientation data is contained within EQ Resources’ database for drillholes EQ001 to EQ026. These data were compared with the results presented in the Piteau and Golder reports and found to be in strong agreement.

Mine north is 50.6° east of MGA94z55 north i.e. the mine grid has been rotated approximately 51° anticlockwise from MGA94z55 north. The means to make this correction has been embedded in the spreadsheet “Grid Conversion to local.xlsx”. In this report the local grid system will be referenced, unless otherwise stated, e.g. when referring to compass directions such as “north” this will mean north relative to local grid north.

3 BACKGROUND GEOLOGY

This section, taken from GTS (2022), presents a simplified summary of the site geology. It is based mainly on the published paper by Forsythe and Higgins (1990) “Mount Carbine Tungsten Deposit” but with some information from the Piteau and Golder reports. An internal report by Forsythe (1983) referenced by Golder appears to have been lost and was not available.

The Mount Carbine tungsten ore is contained within wolframite and scheelite mineralisation of a quartz vein system. Orientation measurements of the veins indicates that the system dips near-vertically towards both the north and south.

The deposit is hosted in sedimentary strata of the Hodgkinson Formation which are Siluro-Devonian in age. Within the pit, regional and local metamorphism have altered the rocks. And within the ore zone pneumatolytic alteration by geologically introduced gases and silicification has occurred altering the engineering properties of the original strata by making them stronger and tougher. Locally, the Hodgkinson Formation consists of three lithological units:

- Arenite (coarse grained) unit in which sandstone, greywacke and conglomerate alternate with siltstone shale and minor chert;
- A basic (basaltic) volcanic-chert unit with interbedded shale; and
- An argillite (fine grained) unit lacking coarser clastics and consisting of shale and thinly interbedded siltstone and chert.

Within the pit, the fine-grained unit predominates, and it has been metamorphosed to a hornfels.

The volcanic-chert unit is a marker horizon that outlines the large scale folding of the Hodgkinson Formation.

These strata have been subject to at least three stages of deformation designated D1 – D3. Mineralisation occurred at the end of the third stage. Quartz and quartz-feldspathic veins were injected along foliations that had been induced by an earlier phase of deformation. The source of the veins is likely to be the underlying Mossman Batholith, part of the Permian age Mareeba granite suite. However, the deepest cored holes to date, MTCB005, at 741.4 m, and CB18 at 700.0 m have not intersected granite.

The major structures in the pit are the South Wall Fault (SWF) and the Central Fault (CF) which post-date the mineralisation.

The SWF is a major regional structure that dips towards the north at 70°. It marks the southern boundary of the mineralised belt and has faulted off a large part of the original deposit at depth. On the north side of the fault is hornfels and on the southern side of the fault the rock is a green schist i.e., more slatey in character. The fault contains between 0.5 and 2 m of fault gouge.

Central Fault is a less distinct feature which limits major mineralisation but does not truncate the quartz vein system. The fault is sub-vertical and strikes ESE. It is narrow and often difficult to distinguish in drill cores, although it is sometimes associated with intense calcite veining.

4 OBSERVATIONS AND COMMENTS

4.1 Wall Condition

The walls were in very good condition despite having being extensively fractured by multiple tectonic events. Most of the apparent damage appeared to have occurred due earlier poor blasting practice. It is understood that Golding will implement a smooth wall blast design by firing the back row first to create a pre-split fracture and then the remaining holes thereby isolating the new face from the main blast shock wave.

4.1.1 South Wall

The south wall was in very good condition and is shown on Figure 2. It was virtually untouched since the May 2023 inspection. Most of the blast damaged rock will be

removed by scaling the walls but some will remain because it is inaccessible. The fact that there has been little deterioration of the wall in the nearly 40 years of exposure and inundation implies that the risk of rockfall is low and it will be controlled by constructing toe bunds to intercept falling rocks. While there had been discussion of the potential for instability on the South Wall none had occurred since the May 2023 inspection.



Figure 2. View of the South Wall.

4.1.2 South Wall Fault

The SWF was in very good condition and remained unchanged from the May 2023 inspection. Its good condition confirms Golder's observation that "there is no fundamental reason why the south wall should not be mined along the fault plane." However, the current mine plan provides for a cutback behind the fault in the upper benches thereby eliminating any issues that may arise due to the fault.

4.1.3 East Wall

A view of the East Wall is shown in Figure 3. As can be seen the pit has developed to the east compared with the May 2023 inspection.

The batters were stable, assisted by the E-W strike of a lot of the geological structure. i.e., it is perpendicular to the East Wall and this assists with wall stability.

The wall was dry.



Figure 3. View of the East Wall taken from the lookout.

4.1.4 North Wall

The North Wall was little changed form the previous inspection. It was mostly in very good condition. It was dry. A panoramic view of the North Wall is shown in Figure 4.



Figure 4. View of North Wall from pit floor.

It was noted in the previous inspection report that very steep defects parallel with the veins, the Piteau Joint Set B, could give rise to toppling failures particularly when the structures dip into the pit wall. This risk is elevated when swinging through from the North Wall to the East Wall and is illustrated by the intersection of the ore body with the pit walls shown in Figure 5.

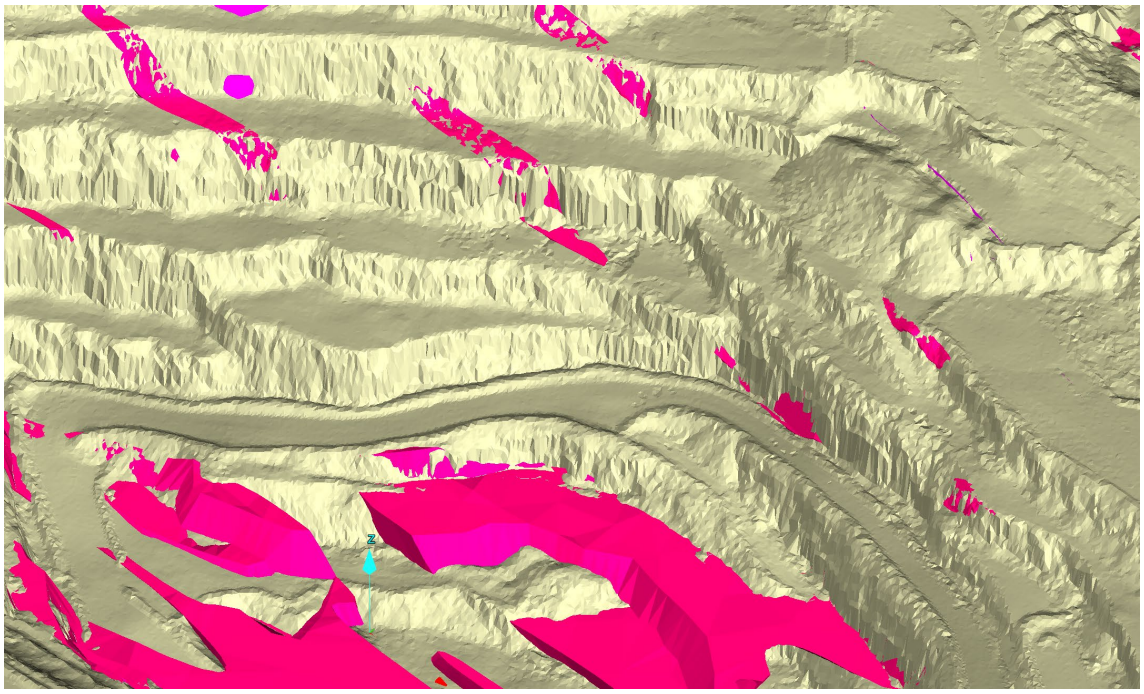


Figure 5. View of modelled ore body as it intersects current pit walls.

As part of routine inspections attention should be paid to these joints and observations made to assess whether they are dilating. These observations could be assisted and systematised by using simple wireline extensometers such as the ClockIT device.

It is considered that apart from large scale wedges, toppling is the hazard with the highest risk.

4.1.5 West Wall

Figure 5 shows a view of the West Wall. It is a relatively short length of wall because the North Wall trends NE-SW as it meets up with the West Wall.

Despite being blast damaged, overall, the wall was in good condition and had not changed significantly sine the May 2023 inspection.

The pit will develop to the west, and this will permit re-drilling and smooth blasting of this wall in future cutbacks to improve wall stability.

The wall was dry.



Figure 6. View of the West Wall.

4.2 Groundwater

The pit was almost entirely dry. In 2012 Lait reported groundwater levels from dedicated monitoring wells that were mostly in the range of 12 to 25 m below surface level. The current well levels are unknown, but it is likely that pumping the pit dry has initiated a cone of depression in the groundwater system. The observation of just minor seepage into the floor sump suggests that there are very low volumes of water behind the pit walls but the flow rates may also be a result of highly impermeable rock.

Both Piteau and Golder referred to the possibility of needing horizontal dewatering holes, particularly in the south wall. There is no evidence yet that they are needed but water level data from the monitoring wells would help in making a more informed decision.

5 MAPPING

It was noted in the May 2023 inspection report that the original geotechnical mapping data by Piteau and Golder have been lost. All that remains are images of stereoplots and identification of joint sets. EQ Resources has generated vein orientation data from exploration boreholes that is consistent with the Piteau and Golder data. EQ Resources has also developed surfaces for the major faults, and these are available as Vulcan triangulations. In the future it may be necessary to undertake bench scale mapping to assess the risk of bench scale planar and wedge scale failures.

There is a variety of ways of doing this using either drone data or terrestrial photographs. Analysis could be carried out with dedicated software life Datamine's Sirovision or 3GSM ShapeMetrix or in Maptek's GeologyCore or PointStudio with the geotechnical add-in. The benefit of doing this would be to provide a database of spatially located structure which could assist with the systematic identification of geotechnically adverse structures. Cored exploration boreholes could be another source of structural data using Optical Televiewer (OTV) or Acoustic Televiewer (ATV) geophysical tools to scan the boreholes. OTV data is much clearer than ATV data and the tool may return data from non-cored holes where the ATV would fail.

6 MONITORING

For the present, deformation monitoring is not required. Should there be signs of movement then wireline extensometers like the ClockIT would be a cheap device for measuring movement across multiple fractures.

Beyond simple wireline extensometers there are increasingly sophisticated, and expensive, means of monitoring that include automated extensometers, prisms, prisms and automated total station, high resolution laser scans and slope stability radar. None of these are required for now.

7 REVIEW OF DESIGNS

The pit designs suggested by Piteau remain valid and have, essentially, been incorporated into the current pit shell. For completeness, the Piteau Design Table IX and a partially redrawn Figure 14 Distribution of Design Sectors that were re-generated for the GTS 2022 report are appended.

Since the original geotechnical designs were generated three significant aspects have changed:

- The current design will dig through the SWF in the upper levels. Provided the rock behind the SWF is sufficiently strong, this will eliminate the need for reinforcement as envisaged by Piteau and Golder.
- There is no evidence of excessive groundwater pressures that would require relief by horizontal drain holes. Water levels in the existing monitoring wells need to be measured to help in the assessment of groundwater pressures.

- The detailed geological face mapping undertaken by Piteau and the orientation data derived from the Golder drilling for the proposed underground mining does not exist for the western extension of the pit. It is understood that the decline, which was partially installed during the 1980s, will be remediated to allow access for exploration. It could also be used to gather structural orientation data.

Dump design recommendations remain as out of pits dumps can be constructed in 40 m lifts with 10 m catch benches. Dumps that are founded on level and stable ground could be constructed to a height of 100 m and the factor of safety against overall failure would be greater than 1.3".

8 GROUND CONTROL MANAGEMENT PLAN

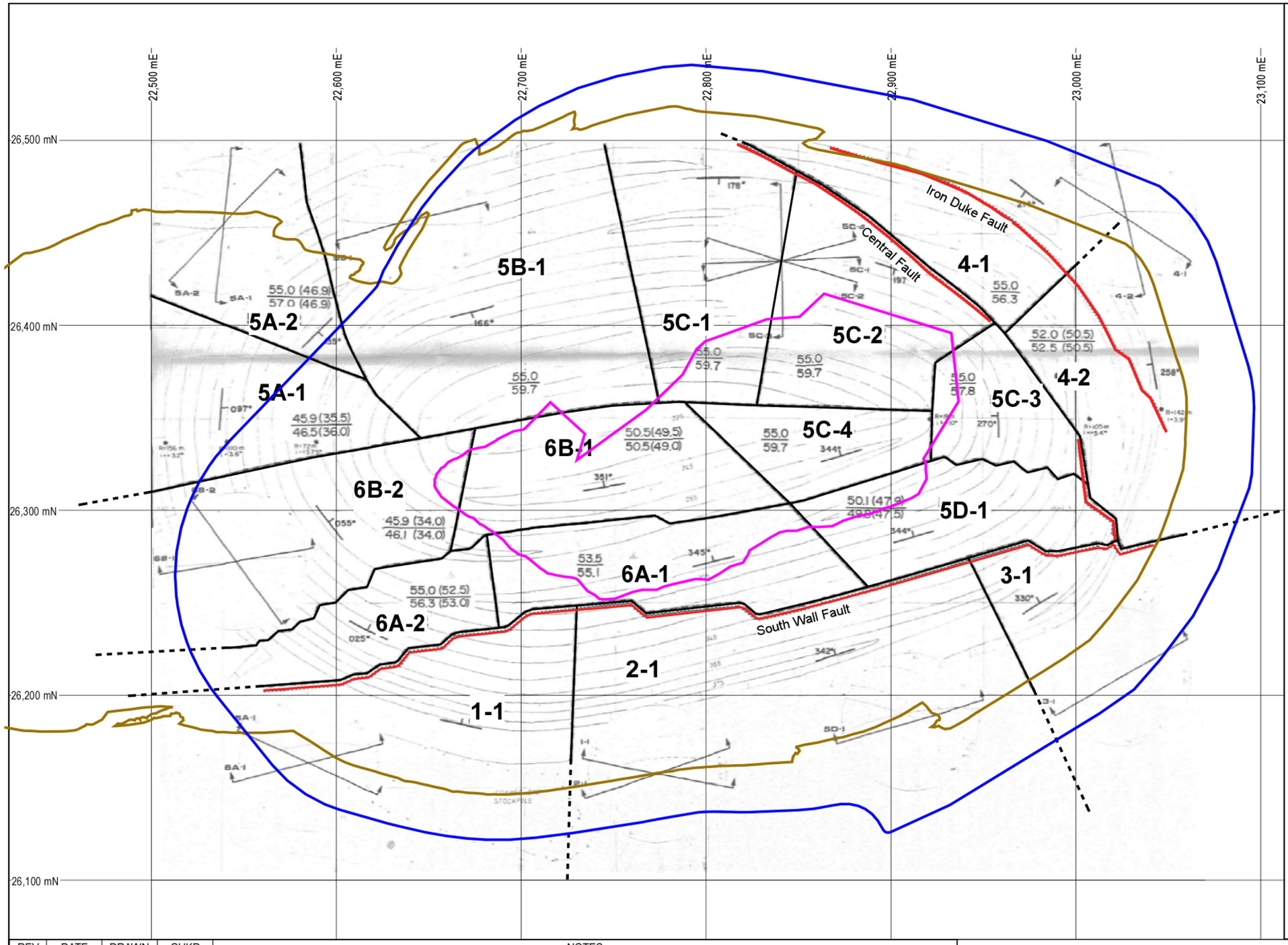
Since the last inspection The Ground Control Management Plan Version 1 has been developed by Golding's Wade Smith. The plan was reviewed and comments have been provided.



A. Paul Maconochie RPEQ 5828
Principal Geotechnical Engineer

9 REFERENCES

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SYMBOLS

Pit Design V3 Stage 1 Perimeter

Pit Design V3 Stage 2 Perimeter

Pit Design V3 Stage 3 Perimeter

Design Sector Boundary

Extrapolated Design Sector Boundary

5C-1

Design Sector Number

258°

Orientation and dip direction of final pit wall

Bench H = 20m 55.0 (46.9)
Bench H = 30m 57.0 (47.2)

Optimum interramp slope angle for Design Sectors with and ( ) without adequate groundwater depressurisation.

Fault

NOTES

1. Design sector boundaries are based on structural domain boundaries and boundaries of straight slope segments.
2. Results of kinematic statistical analyses were not used for design of slopes in Design Sectors 1-1, 2-1 and 3-1. Separate design of slopes and remedial measures for individual benches south of the South Wall Fault are discussed in Piteau (1982) Section 8.7.

REV	DATE	DRAWN	CHKD	NOTES
1	30/10/22	P. Maconochie		Plan created from scanned image in Piteau (1982) and pit design V3 triangulation

MOUNT CARBINE MINE

EQ RESOURCES

GOLDING CONTRACTORS

Piteau (1982) Fig 14
DISTRIBUTION OF DESIGN SECTORS AND KINEMATICALLY POSSIBLE FAILURE MODES

Job No.: 22-138 | Datum: Local Grid | Scale: as shown

Fig ###

Piteau (1982) Table IX Summary of Slope Information, Stability Analysis Results and Slope Design Recommendations for Design Sectors

DESCRIPTION OF DESIGN SECTORS					MAIN MODES OF SLOPE FAILURE WHICH CONTROL SLOPE STABILITY	STABILITY ANALYSIS RESULTS FOR KINEMATICALLY POSSIBLE FAILURE MODES [1,2]								OPTIMUM INTERRAMP SLOPE DESIGN FOR DRY SLOPES BASED ON KINEMATIC ANALYSES RESULTS (SLOPE DESIGN FOR SLOPES WITH HIGH GROUNDWATER PRESSURES ARE GIVEN IN BRACKETS WHERE DIFFERENT)						POSSIBLE INCREASE IN SLOPE ANGLE DUE TO PLAN RADIUS OF CURVATURE (°)	RECOMMENDED INTERRAMP SLOPE DESIGN FOR DRY OR DRAINED SLOPES OR SLOPES WITH ADEQUATE GROUNDWATER DEPRESSURISATION 4						REMEDIAL MEASURES AND COMMENTS [5,6,7]	DESIGN SECTOR
						AVERAGE DIP OR APPARENT PLUNGE OF FAILURE FOR WORST CASE WHERE STATISTICAL ANALYSIS NOT USED		APPARENT PLUNGE OF WEDGES CORRESPONDING TO A CUMULATIVE PERCENTAGE OF 20%		APPARENT PLUNGE OF WEDGES CORRESPONDING TO THE BREAK IN THE CUMULATIVE FREQUENCY PLOT				BENCH HEIGHT = 20m			BENCH HEIGHT = 30m				BENCH HEIGHT = 20m BETWEEN 305m AND 345m ELEVATION			BENCH HEIGHT = 30 m ABOVE 345m AND BELOW 305m ELEVATION				
DESIGN SECTOR	STRUCTURAL. DOMAIN	SLOPE DIP DIRECTION (°)	MAXIMUM SLOPE HEIGHT (m)	No. OF HAUL ROADS						F < 20		F < 1.2		OPTIMUM BENCH FACE ANGLE (°)	TOTAL BERM WIDTH[3] (m)	INTER RAMP SLOPE ANGLE (°)	OPTIMUM BENCH FACE ANGLE (°)	TOTAL BERM WIDTH[3] (m)	INTER RAMP SLOPE ANGLE (°)		BENCH FACE ANGLE (°)	BERM WIDTH (m)	INTER RAMP SLOPE ANGLE (°)	BENCH FACE ANGLE (°)	BERM WIDTH (m)	INTER RAMP SLOPE ANGLE (°)		
						F < 2.0	F < 1.2	F < 2.0	F < 1.2	CUM PERCENT	APPARENT PLUNGE	CUM PERCENT	APPARENT PLUNGE															
1-1	1 and 2	012	85	-	Rotational failure in weathered rocks at pit crest. Wedge failures formed by combination of joints of Joint Set A and Joint Set D.	40	[44]	58	54°	15	53°	10	56°	-	-	-	-	-	-	-	-	-	-	.	-	-	Statistical analysis and design techniques were not used in Design Sectors 1-1, 2-1 and 3-1 because slope stability is controlled by rotational failure in weathered rocks as well as kinematically possible failure modes. Slope design and remedial measures in this area are discusser, in section 8.7.	**1-1**
2-1	1 and 2	342	85	-	Rotational failure in weathered rocks at pit crest. Plane failures along joints of Joint Set A and Joint Set G.	47	[47]	50	50	-	-	-	-	-	-		-			-	-	-	-	-	-	-		**2-1**
3-1	3	330	30	1	Rotational failure in weathered rock at pit crest. Plane failure along joints of Joint Set B.	44	[44]	44	44	6	44	6	44	-			-			-	-	-	-	-	-	-		**3-1**
4 -1	4	214	60	1	Plane failure along joints of Joint Set A. Wedge failures formed by combination o joints of Joint Set A and Joint Set D.	[69]	[69]	69	69	-	-	-	-	80	10.5	55.0	80	14.7	56.3	+4°	80	10.5	55	80	14.7	56		**4-1**
4-2	4	258	60	[1]	Wedge failure formed by combination of joints of Joint Set A and Joint Set B.	52	56	[52]	[58]	-	-	-	-	80 (70)	12.1 (16.5)	52.1 (50.5)	70 (70)	23.0 (24.7)	52.5° (50.5)	-	80	10.5	55	80	14.4	56.5	Slope angle of 55° is recommended for 20m high benches to provide access to the south wall. Drainholes may be required to control groundwater pressures.	**4-2**
5A-1	5A	097	170	2	Wedge failures formed by combination of joints, faults, shears and veins.	27	42	[36]	[46]	-	-	22	66	70 (70)	19.1 (28.0)	45.9 (35.5)	70 (70)	28.9 (41.4)	46.1 (36.0)	+3°	70	17.4	49	70	26.1	49	Slopes below 305m elevation could be increased to 50° based on increased effects of plan radius of curvature. Horizontal drainholes may be required.	**5A-1**
5A-2	5A	135	170	1	Wedge failures formed by combination of joints, faults, shears and veins.	34	70	[47]	[70]	-	-	-	-	80 (70)	10.5 (18.7)	55.0 (46.9)	80 (70)	14.2 (28.1)	57.0 (46.9)	-	80	10.5	55	80	19.5	57	Horizontal drainholes may be required in specific areas on benches to control groundwater pressures in the slope.	**5A-2**
5B-1	58	166	260	2	Wedge failures formed by combination of joints, faults, shears and veins.	59	76	[75]	76	12	[74]	-	-	80	10.5	55.0	80	12.2	59.7	-	BO	10.5	55	80	12.0	60		**5B-1**
5C-1	5C	178	260	2	Wedge failures formed by combination of joints, faults, shears and veins.	57	80	[79]	[80]	23	79	-	-	80	10.5	55.0	80	12.2	59.7	-	80	10.5	55	80	12.0	60		**5C-1**
5C-2	5C	197	120	2	Wedge failures formed by combination of joints, faults, shears and veins.	77	77	[84]	[84]	-	-	-	-	80	10.5	55.0	80	12.2	59.7	-	80	10.5	55	80	12.0	60		**5C-2**
5C-3	5C	270	100	1	Wedge failure formed by combination of joints, faults, shears and veins.	68	68	[71]	[71]	-	-	-	-	80	10.5	55.0	80	13.6	57.8	+5°	80	10.5	55	80	12.0	60	Maximum slope angles of 55° are recommended for 20m high benches in the design sector to ensure reliable access to the south wall.	**5C-3**
5C-4	5C	344	50	1	Wedge failures formed by combination of joints, faults, shears and veins.	43	43	[74]	[74]	18	74	11	74	8O	10.5	55.0	BO	12.2	59.7	-	70	16.7	50	70	25.3	50	Maximum interramp slopes of 50° are recommended below 305m elevation due to sensitive nature of slope in this area and possible requirements for remedial measures.	**5C-4**
5D-1	5D	344	100	2	Wedge failures formed by combination of joints, faults, shears and veins.	26	40	[48]	[51]	-	-	.	.	70 (70)	16.7 (18.1)	50.1 (47.9)	70 (70)	25.4 (27.5)	49.8 (47.5)	-	70	18.7	47	N/A	N/A	N/A	20 m high benches and maximum inter-ramp slope angles of 47° are recommended above the haul road (300 m elevation) in Design Sectors 5D-1 and 6A-1 due to the sensitive nature of the slope and possible requirements for remedial measures. Horizontal drainholes may be required.	**5D-1**
6A-1	6A	345	60	1	Wedge failures formed by combination of joints, faults, shears and veins.	47	53	[64]	[64]	20	65	20	66	so	11.3	53.5	70	20.9	55.1	-	70	18.7	47	70	25.3	50		**6A-1**
6A-2	6A	025	120	1	Wedge failures formed by combination of joints. faults, shears and veins.	34	36	[59]	[69]	25	70	16	68	80 (80)	10.5 (12.0)	55.0 (52.2)	80 (70)	14.7 (22.6)	56.3 (53.0)	-	70	17.4	49	70	26.1	49	Interramp slope angles of 49° are recommended in this design sector for blending of slope designs between adjacent sectors. Horizontal drainholes may be required.	**6A-2**
6B-1	6B	351	50	1	Plane failure along joints of Joint Set Gl. Wedge failures formed by combination of joints, faults shears and veins.	47	49	[50]	[52]	-	-	.	-	70 (70)	16.5 (17.1)	511.5 (49.5)	70 (70)	24.7 (26.1)	50.5 (49.0)	-	N/A	N/A	N/A	70	25.3	50	Same as comments for Design Sector 5C-4. Horizontal drainholes may be required.	**6B-1**
6B-2	6B	055	170	2	Wedge failures formed by combination of joints, faults, shears and veins.	27	40	[34]	[36]	-	-	-	-	70 (70)	19.1 (30.7)	45.9 (34.0)	70 (70)	28.9 (44.4)	46.1 (34.0)	+3°	70	17.4	49	70	26.1	49	Slopes below 305m elevation could be increased to 50° based on increased effects of plan radius of curvature. Horizontal drainholes may be required.	**6B-2**

NOTES

1. Analyses results are presented for F < 2.0 and F < 1.2 which relate to un-dewatered and dry, drained or dewatered slopes respectively.
2. The dip or apparent plunge which is considered to control slope stability is in squared brackets for both un-dewatered (F < 2.0) and drained (F < 1.2) conditions in each design sector.
3. Total berm width is calculated based on berm width required to catch failed material with consideration of anticipated breakback of bench crests.
4. Feasibility of using 30m high benches should be verified by assessment of trial slopes.
5. Control blasting is recommended in all areas of the final slope to ensure minimal disturbance to the rock and maintain cohesion in the slope.
6. If control blasting Is not adequate or undue failures occur-in certain areas, grouted dowels may be required to ensure the integrity of haul roads or other critical installation.
7. Remedial measures are recommended to control groundwater and surface water. Sealed drainage ditches graded berms and horizontal drainholes are recommended in critical areas as required. If adequate groundwater control is not obtained using drainholes additional hydrogeological studies may be required.

Appendix D:
Geotechnical Review, Mt Carbine Mine, QLD, 11/11/22 (GTS 2022)

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GeoTek Solutions Pty Ltd
Geotechnical & Geological Engineers

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11/11/22

Our ref.: gts-mtc-220711-review-v0.1

Golding Contractors
Attn: B McIntyre

Dear Mr McIntyre,

Geotechnical Review, Mt Carbine Mine, QLD.

1. SUMMARY

EQ Resources has commissioned Golding Contractors to prepare a mine plan and mining proposal for the recommencement of open cut mining at the Mount Carbine tungsten deposit.

As part of the preparation for mining, GeoTek Solutions has carried out a geotechnical review of the pit, previous geotechnical investigations and proposed mine plans.

There has been little original geotechnical work carried out since the very thorough investigations carried out by Piteau & Associates (1982) and Golder Associates (1984). Consequently, this report is largely a review of the earlier work in the context of a site inspection that was carried out in July 2022.

The existing pit walls were in very good condition, confirming the suitability of the Piteau (1982). And this assessment endorses that report and its recommendations. Golder (1982) was targeted an underground mining proposal and thus the Golder (1982) report is of less immediate relevance. It did, however, confirm the orientations of geological structures reported by Piteau (1982) thereby providing strong, independent confirmation of the data in the earlier report.

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2. INTRODUCTION

EQ Resources (EQR) is planning to reactivate open pit mining for tungsten at Mt Carbine. This report presents the results of a geotechnical review. The review encompassed available reports, , an inspection of the existing operation on 11/07/22 and an analysis of structural orientation data derived from recent drilling by EQR.

Mount Carbine is located about 130 km by road, NW of Cairns as shown in Figure 1. A satellite view, rotated to the local grid system, is shown in Figure 2.

The first recorded production was in 1895. Open cut mining combined with underground adits continued, intermittently, depending on the price of tungsten, until 1986. Mineralisation continues at depth and a transition from open to underground mining was planned during the 1980s. Development of the access decline had begun when all mining ceased, for the last time, in 1986. (Forsythe and Higgins, 1990). Since then, reprocessing of the waste dumps has occurred to produce a concentrate for further processing off-site while large boulders of barren rock have are sold as coastal erosion protection armour.



Figure 1. Regional map showing Mount Carbine in red rectangle (QLD GeoResGlobe, 2022).

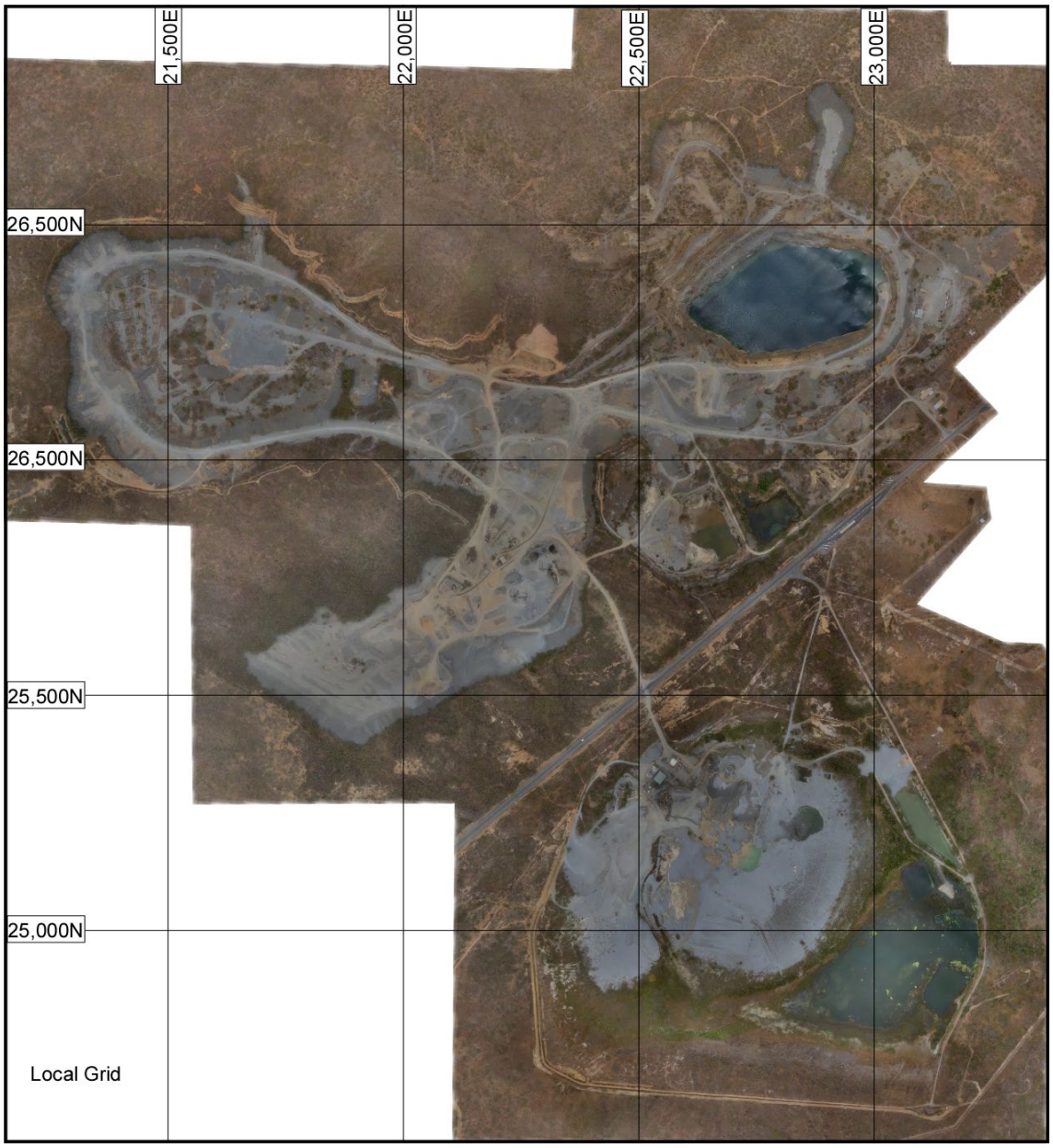


Figure 2. Satellite map of Mount Carbine, rotated to the local mine grid system (QLD GeoResGlobe, 2022).

3. BACKGROUND INFORMATION

A very good summary of prior geotechnical investigations is provided in Chapter 4 of The Mt Carbine Bankable Feasibility Study (2021). For the purposes of this review greatest reliance has been place on the two early reports:

1. Piteau & Associates' (1982) "Report on Slope Stability Analysis and Design of Open Pits". This report is based on 6 months of field work by a geologist and subsequent design analysis and recommendations from two world-recognised slope stability experts. It is an outstanding report. The excellent condition of the existing pit void attests to the appropriateness of the Piteau recommendations and this review reaffirms their validity.
2. Golder Associates (1984) "Report to R.B. Mining Pty Ltd on Mt. Carbine Review of Rock Mechanics". This report pays particular attention to the proposed underground mining

proposal and the transition from open pit to underground mining. It includes the results of seven post-Piteau diamond drill holes that were drilled during May – June, 1984. Like the Piteau report, the Golder report was prepared by a world class rock mechanics expert.

Unfortunately, the original data for both Piteau (1982) and Golder (1984) appears to have been lost. Consequently, reliance has been placed on the tables and plots presented in those reports and the only way to delve into the data more deeply is to digitise plans, logs and plots and even then the digitised information would be very high-level. As an example, Figure 12 was developed by merging scanned and, current design data.

A further report, HCOVG (2020) “Brief review and structural assessment/scoping of Iron Duke-Peteresens-MtCarbine EPM14872”, focusses on the detailed structural geology and the sequence of geological events in and around Mount Carbine. It is less directly relevant to the geotechnical issues.

More recently, drilling by EQ Resources has produced core in which the orientation of the veins has been measured. The orientation data is contained within EQ Resources’ database for drillholes EQ001 to EQ026 and these have been plotted in stereoplots to check for congruence with the earlier work by Piteau (1982) and Golder (1984)

Mine north is 50.6° east of MGA94z55 north i.e. the mine grid has been rotated approximately 51° anticlockwise from MGA9z55 north. The means to make this correction has been embedded in the spreadsheet “Grid Conversion to local.xlsx”. In this report the local grid system will be referenced, unless otherwise stated, e.g. when referring to compass directions such as “north” this will mean north relative to local grid north.

4. BACKGROUND GEOLOGY

This section presents a simplified summary of the site geology. It is based mainly on the published paper by Forsythe and Higgins (1990) “Mount Carbine Tungsten Deposit” but with some information from Piteau (1982) and Golder (1984). An internal report by Forsythe (1983) referenced by Golder (1984) was not available.

The Mount Carbine tungsten ore is contained within wolframite and scheelite mineralisation of a quartz vein system. Orientation measurements of the veins indicates that the system dips near-vertically towards both the north and south.

The deposit is hosted in sedimentary strata of the Hodgkinson Formation which are Siluro-Devonian in age. Locally, this formation consists of three lithological units:

- Arenite (coarse grained) unit in which sandstone, greywacke and conglomerate alternate with siltstone shale and minor chert;
- A basic volcanic-chert unit with interbedded shale; and
- An argillite (fine grained) unit lacking coarser clastics and consisting of shale and thinly interbedded siltstone and chert.

Within the pit, the argillite unit predominates and it has been metamorphosed to a hornfels.

The volcanic-chert unit is a marker horizon that outlines the large scale folding of the Hodgkinson Formation.

These strata have been subject to at least three stages of deformation designated D1 – D3. Mineralisation occurred at the end of the third stage. Quartz and quartz-feldspathic veins were injected along foliations that had been induced by an earlier phase of deformation. The source of the veins is likely the Mossman Batholith, part of the Mareeba granite suite, which is of Permian age. Mount Carbine is thought to be underlain by granite but the deepest cored holes to date, MTCB005, at 741.4 m, and CB18 at 700.0 m have not intersected granite.

The major structures in the pit are the South Wall Fault (SWF) and the Central Fault which post-date the mineralisation.

The SWF is a major regional structure that dips towards the north at 70°. It marks the southern boundary of the mineralised belt and has faulted off a large part of the original deposit at depth. On the north side of the fault is hornfels and on the southern side of the fault the rock is a green schist i.e. more slatey in character. The fault contains between 0.5 and 2 m of fault gouge.

The Central fault is a less distinct feature which limits major mineralisation but does not truncate the quartz vein system. The fault is sub-vertical and strikes ESE. It is narrow and often difficult to distinguish in drill cores, although it is sometimes associated with intense calcite veining.

5. SITE OBSERVATIONS

Figure 3 shows the inspection route and stop off points during the site inspection on 11/07/22. Note the plan is referenced to MGA94z55 UTM coordinates.

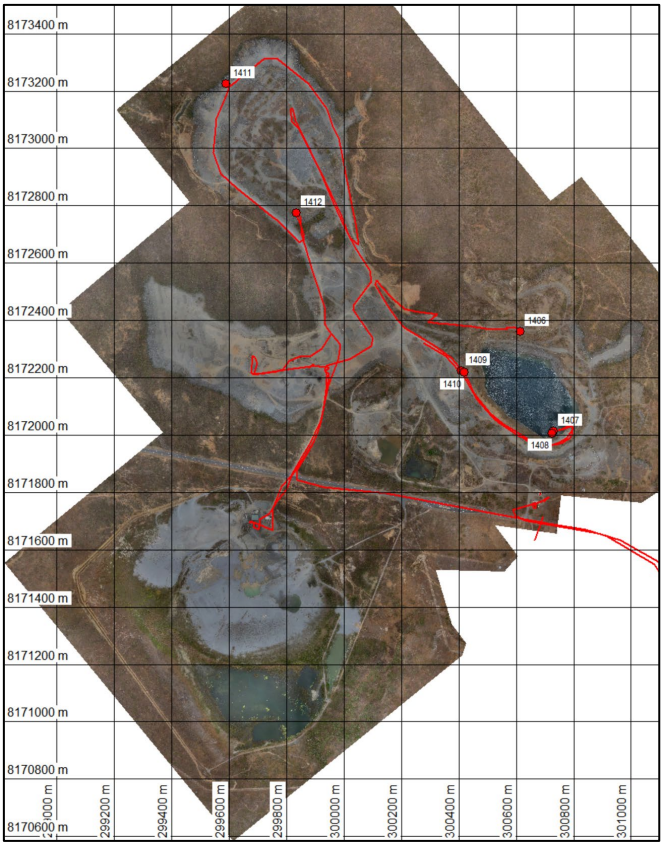


Figure 3. Inspection route and stop off points (MGA94z55).



Figure 4. View from northern wall towards south wall fault.

5.1 Pit Walls

The existing pit floor is shown at RL 315 m. At the time of inspection the pit was almost full of water, reported to be about 40 m deep. When Piteau (1982) mapped the pit walls the floor was reported as being at RL 355 m and when Golder (1984) inspected the pit the floor was at RL 325 m and dry. Thus, the pit walls that were visible during the inspection can be considered the same as those exposed for the past 40 years, at least.

All walls were satisfactory and additional observations are provided for the Noth and South Walls.

5.2 North Wall

The pit walls were in very good condition despite their age or that they had been inundated. Just as Golder (1984) reported although the exposures were not analysed “there is no evidence to contradict Piteau (1982). A view of the northern pit wall, shown in Figure 5 is illustrative of the good condition that the exposed wall is in. It is presumed that since the walls above the water line were intact, the walls below the water line were also intact otherwise any failures at lower elevations would most likely have propagated upwards.



Figure 5. View of North Wall.

Figure 6 shows a view of the batter at the northern highwall lookout. Key features are that despite the rock being distinctly weathered and fractured and not smooth-blasted the batter is intact despite over 50 years of exposure. This is indicative of high strength rock substance and high strength joints that is the result of the silicification and metamorphism of the original fine grained

sedimentary rocks. The condition of this batter is representative of much of the rest of the pit giving confidence in the original Piteau (1982) observations and recommendations.



Figure 6. View of batter above northern highwall lookout at location #1406.

5.3 South Wall

A view of the South Wall is shown in Figure 7. Relevant observations are that the wall had broken back to the footwall of the South Wall Fault (SWF) leaving the reinforcing cables dangling and no longer providing any support. Most of the wall has a greenish tinge to it and this is consistent with Piteau (1982) mapping the rock as green argillaceous schist. Towards the western end of the pit (RHS in Figure 7) the darker colours are indicative of a transition to siliceous greywacke.

Piteau (1982) recommended installing drainage holes in the South Wall. It is not known whether this was done. Groundwater levels were reported at depths of 20 to 30 m. Undrained the groundwater pressure would have had a significant impact on slope stability calculations. If there are any open exploration boreholes dipping them to measure groundwater levels is recommended.

It is worth noting that the upper bench of the SWF has remained intact. A possible explanation is that the steepness of the foliation in the green schist is such that for the most part it is unable to daylight in the wall or break out through the rock substance to form failure surfaces. Thus, over relatively low batter heights, despite the low strength of the foliations in the schist, minimal bench scale failure has occurred. It will be instructive to see the wall when the water has been pumped from the pit.



Figure 7. South Wall, now broken back to behind the SWF.

6. STRUCTURAL DOMAINS

Piteau (1982) divided the pit into 6 main structural domains (1 – 6), which, in some cases, were further subdivided, indicated by alpha suffixes (A – C). Combining the structural domains with assessments of rock and defect strengths 17 design sectors were identified and analysed for stability.

A detailed description of the structural geological features is provided by Piteau (1982) Chapter 5 and will not be repeated here. However, Piteau (1982) Table II, showing the orientation of the discontinuity sets in the open is reproduced (with one minor correction) as Table 1 because of the importance of knowing the principal orientations of the structures and to make the data more accessible. Unfortunately, the original database of measurements is not available.

Table 1. Piteau (1982) Table II Orientation of discontinuity sets in the open pit

Structural Domain	Foliation					Foliation Joints					Joints															Veins				
						Joint Set A					n	Joint Set B				Joint Set C				Joint Set D				Miscellaneous Joint Sets							
	n	Set	DDN	Dip	%	n	Set	DDN	Dip	%		Set	DDN	Dip	%	Set	DDN	Dip	%	Set	DDN	Dip	%	Set	DDN	Dip	%	n	Set	DDN	Dip	%
1 & 2	81	FN1	010	85	19	15	A1	001	62	>35	215	B1	352	74	4	-	-	-	-	D1	316	59	7	G1	340	48	3	-	-	-	-	-
		FN2	002	63	15		A2	005	45	10		B2	203	88	7					D2	114	51	5									
		FN3	342	44	6															D3	131	67	4									
3	43	FN1	067	67	21	43	A1	067	67	21	88	B1	004	78	10	-	-	-	-	-	-	-	-	E1	051	76	5	-	-	-	-	-
												B2	354	74	9																	
		FN2	083	77	18		A2	083	77	18		B3	002	52	10																	
												B4	328	45	6																	
4	138	FN1	228	72	16	63	A1	225	67	16	570	B1	003	80	7	C1	105	30	7	D1	315	80	6	-	-	-	-	73	V1	358	82	35
		FN2	056	75	12		A2	060	69	16																						
							A3	062	46	17																							
5A	111	FN1	230	71	17	82	A1	229	66	33	400	B1	333	86	7	C1	115	19	6	D1	286	80	6	G1	000	50	2	48	V1	165	89	22
		FN2	221	21	6							B2	359	83	6														V2	181	85	19
5B	115	FN1	047	77	22	63	A1	047	69	36	342	B1	333	86	12	C1	105	18	9	D1	290	82	6	-	-	-	-	69	V1	336	87	27
							A2	225	16	6																			V2	019	83	10
5C	104	FN1	229	80	21	16	A1	277	76	27	368	B1	324	80	5	C1	100	32	7	D1	299	86	68	G1	009	43	3	50	V1	331	79	17
												B2	344	85	6														V2	339	84	17
												B3	004	89	4														V3	001	88	15
5D	42	FN1	041	80	26	12	A1	049	72	>35	91	B1	354	72	8	C1	084	33	7	D1	275	78	8	M1	326	50	9	13	V1	350	79	>35
												B2	025	67	5									M2	300	41	7		V2	020	84	31
6A	59	FN1	056	85	19	35	A1	057	83	18	228	B1	343	70	6	C1	060	36	5	D1	320	82	4	M1	328	62	4	4	V1	351	69	6
		FN2	223	83	13		A2	220	65	14		B2	021	76	6														V2	024	84	28
		FN3	239	73	14		A3	245	70	24																						
6B	119	FN1	239	71	29	40	A1	235	73	32	243	B1	176	88	6	C1	092	32	5	D1	327	77	4	G1	356	50	4	134	V1	356	90	78
																C2	031	41	6					E1	050	72	3					
																								M1	172	40	3					

1. Orientation is given in terms of dip direction (DDN) and dip of the peak or average orientation of the discontinuity set.
2. Percent refers to the percent concentration in a one percent area of the lower hemisphere for the peak or average orientation of the population.

6.1 Comparison of Vein Orientation Data

To test the integrity of the Piteau (1982) data, stereoplots of vein orientations were scanned from Piteau (1982) and Golder (1984) for comparison with a plot created in the program Dips of orientation data determined by EQR from more recent boreholes.

The results are shown in Figure 8. The Piteau (1982) plot is for the Domain 5C veins. Visually these are similar to all of the other domains determined by Piteau (1982) and shown on their Fig 6. Each of the stereoplots in Figure 8 is similar, indicating a consistency of measurements and that the veins are predominantly subvertical dipping to the north and to the south. The global orientations of the joint sets in the EQR database, as shown in Figure 8, are dip/dip direction 84/177 and 85/355.

The vein orientations shown in Figure 8 are, based on visual inspection and interpretation, consistent with the data shown in Table 1.

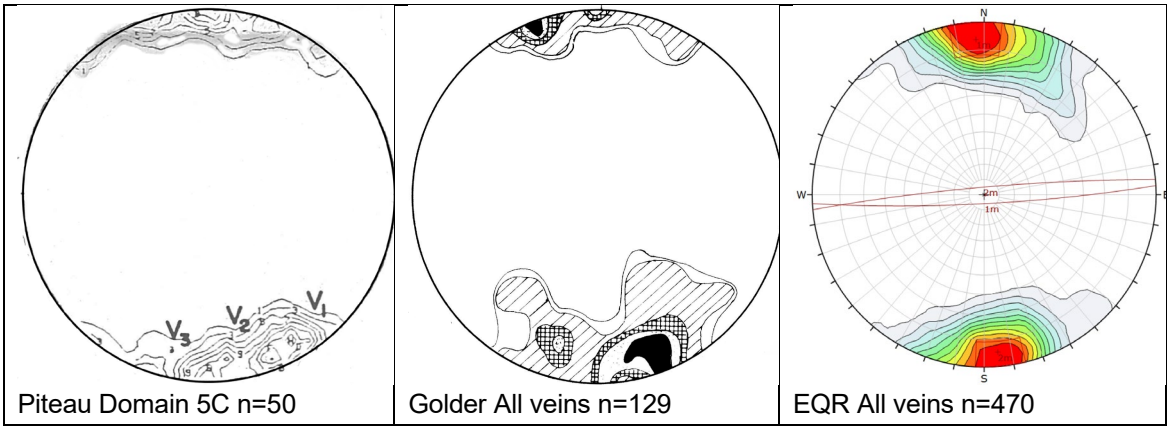


Figure 8. Stereoplots of vein orientation data.

The similarity of the plots provides confidence in the consistency of the data from three separate data sets and hence the validity of the data on which design recommendations have been made in the past and endorsement of them for the future development of the pit.

7. GROUNDWATER

Piteau (1982) indicates “that a detailed assessment of hydrogeological conditions in the open pit is beyond the scope of this report.” Nevertheless Piteau (1982) Chapter 7 provides some useful information regarding groundwater conditions.

In undisturbed ground ,the water table was recorded at depths of 20 to 30 m. Water levels were observed to rise quickly in response to rainfall and then to drain, moderately quickly, back to an equilibrium level. This reflects the moderate permeabilities that were measured in field falling-head tests. The rock mass, overall, is moderately fractured thereby facilitating groundwater flows.

Piteau (1982) notes that there was little evidence of instability due to groundwater and in many areas no effect was expected. However, they inferred that the SWF and other faults may act as

water barriers and recommended that drainage holes be installed to control water pressures behind the SWF.

8. MINING PLAN

The latest pit shells (Version 3 as of writing this report) are shown in plan view in Figure 9. They were derived from the supplied file “Pit Shells V3.dxf” and expanded to :

- PIT_DESIGNS_STAGE_1_SURFACE.00t
- TEMP_STAGE_3_PIT_DESIGNS_V2_STAGE_4_SURFACE_3_DXF_STAGE_3_PIT_DESIGNS_V2_STAGE_4_.00t
- TEMP_STAGE_2_V3_-_PIT_DESIGNS_V3_STAGE_2_SURFACE_DXF_STAGE_2_V3_-_PIT_DESIGNS_V3_STA.00t

Cross sections through the pit shells are shown in Figures 10 and 11.

One consequence of the Version 3 pitshell is that the proposed pit will dig through and remove an increased extent of the South Wall Fault compared with earlier plans. This will likely expose green schist and siliceous greywacke in the southern wall (See Piteau, 1982 Figure 1) The green schist is a low strength rock and requires support and the siliceous greywacke is a much stronger rock with a field estimated UCS of around 60 MPa or more. The relative proportions of each rock type likely to be exposed is currently not known.

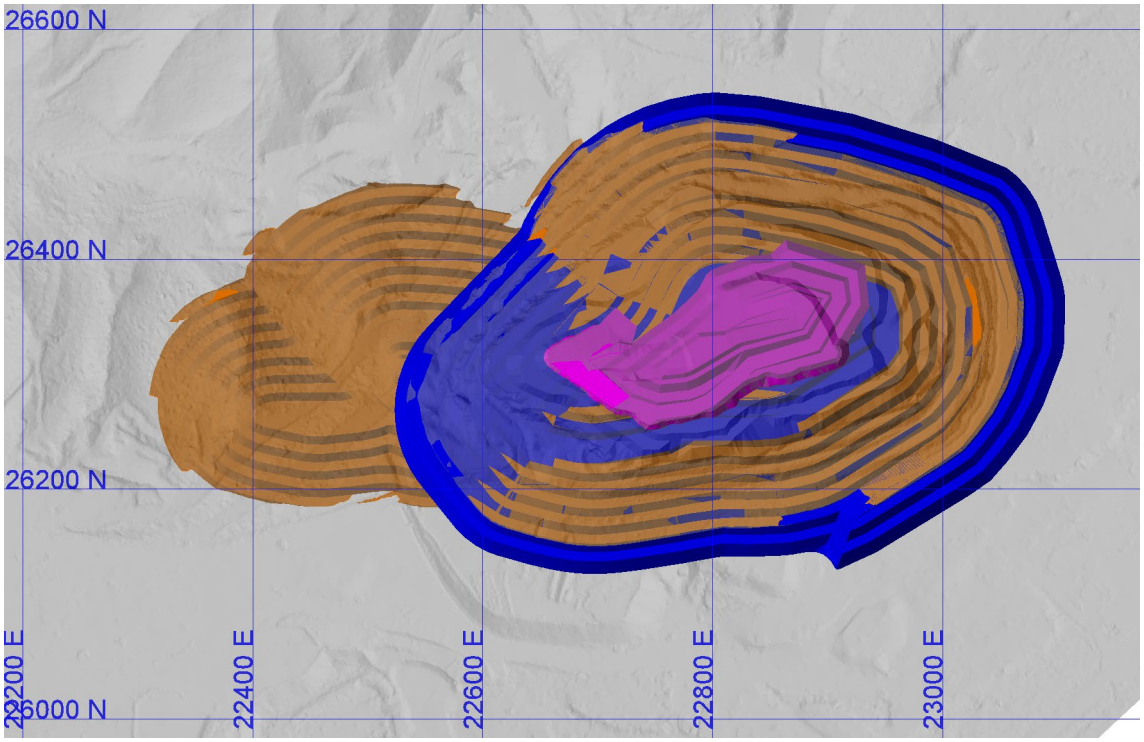


Figure 9. Proposed Mt Carbine open cut pit; Stage 1 - Magenta, Stage 2 – Blue Stage 3 - Orange.

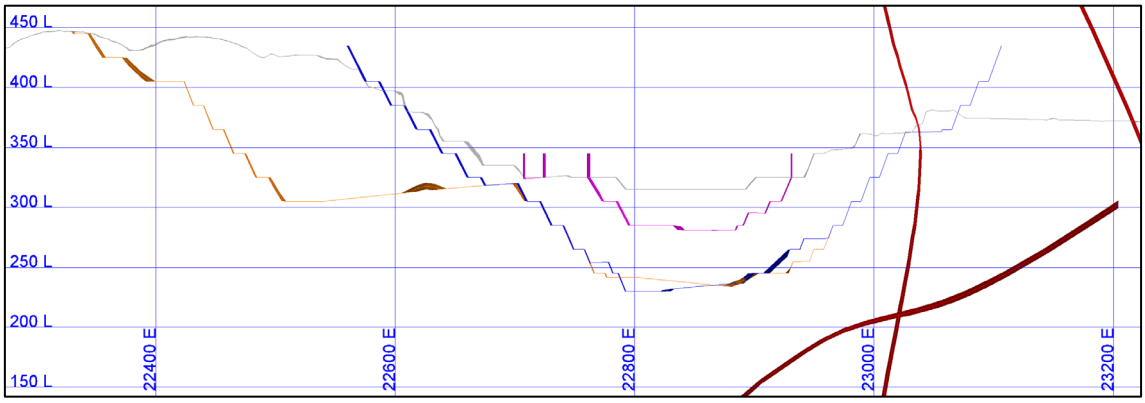


Figure 10. W-E cross section along 26,300 mN.

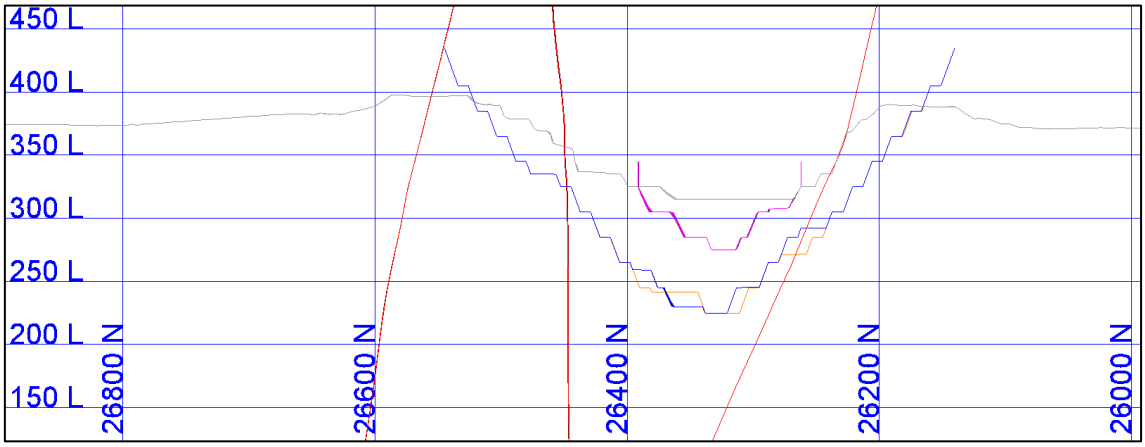


Figure 11. N-S cross section along 22,800E.

Perimeter strings of the Version 3 pushbacks are shown in Figure 12 overlain on Piteau (1982) Figure 14 to show the relationship between the Version 3 pitshell and the Piteau (1982) structural domains. Figure 12 was developed by taking a scanned image from Piteau (1982) scaling and georeferencing it and then overlaying pit perimeter strings that were exported from Vulcan. An annotated version of Figure 12, formatted for A3 size paper, is appended.

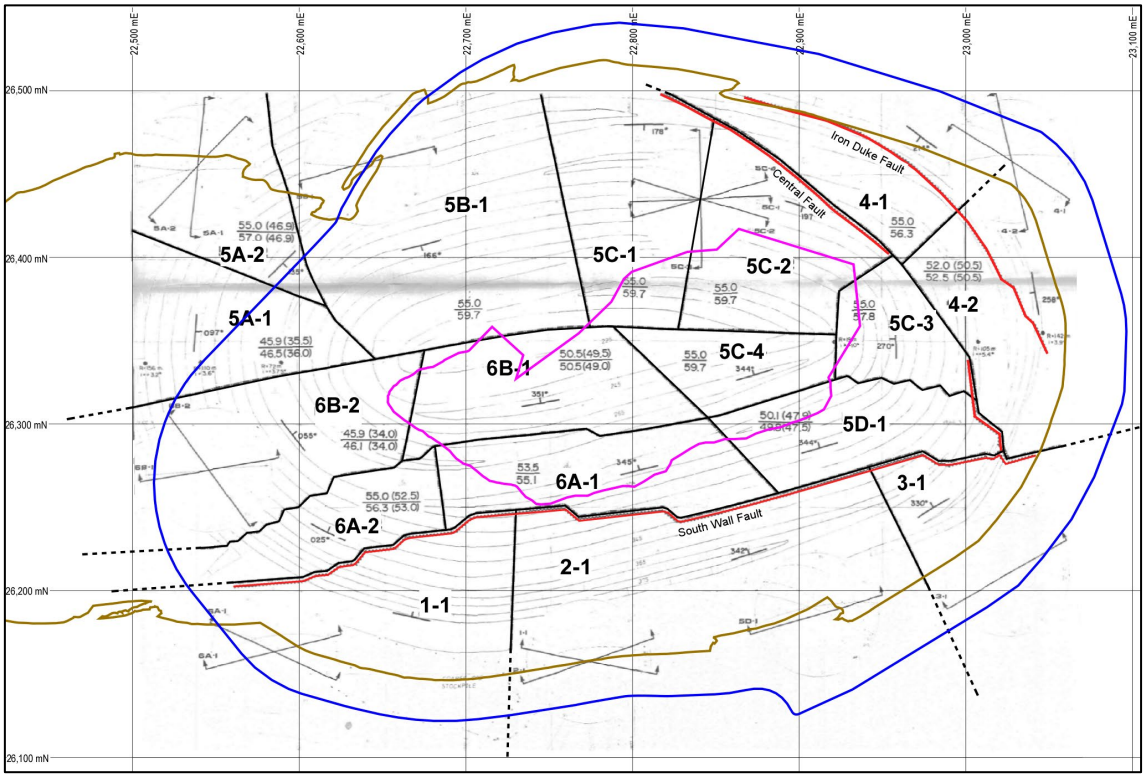


Figure 12. Piteau (1982) Fig 14 overlaid with pit perimeters for Version 3 stages 1-3. An annotated A3 version is appended.

9. SLOPE ANGLES

Terminology used for the components to describe the pit slope geometry are shown in Figure 13. Some writers, including Piteau (1982) set the inter-ramp slope from bench-crest-to-crest rather than bench-toe-to-toe, as shown. The inter-ramp angle is the same regardless of which line is used but following the publication of Read and Stacey (2009) “Guidelines for Open Pit Slope Design”, bench-toe-to-toe seems the preferred protocol.

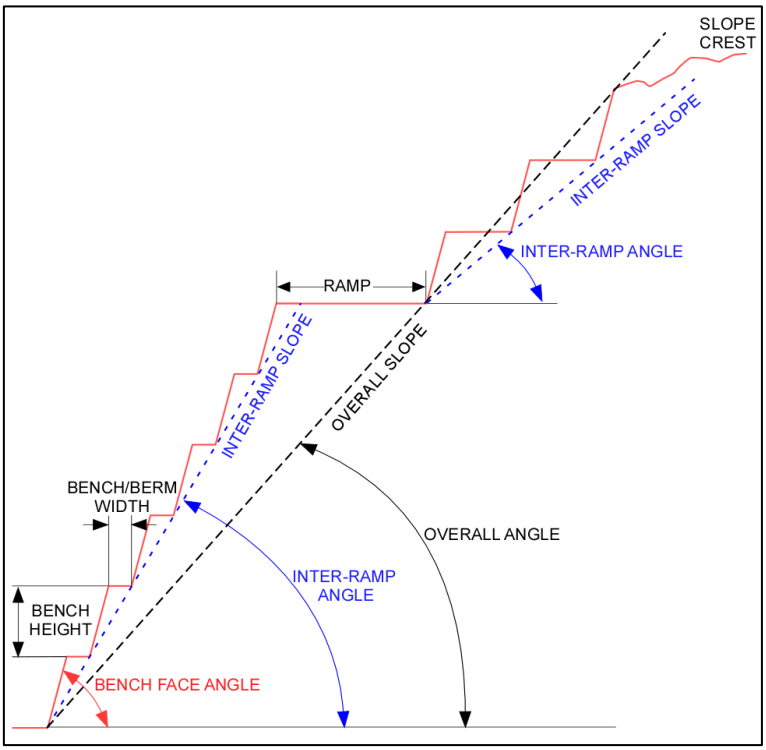


Figure 13. Terminology to describe excavated slope geometry.

Piteau (1982) divided the pit into 17 design sectors and variously analysed each sector for FOS 1.2 and 2, for bench heights of 20 m and 30 m and where slope did and did not have high groundwater pressures. The results are summarised in Piteau (1982) Table IX which has been reproduced below as Table 2.

Golder (1984) had the benefit of observing the pit when it had reached RL325 m and was dry They reported that “Although the additional exposure has not been analysed in detail, there is no new data that contradicts the Piteau report”. A similar conclusion is reached in the current review.

Table 2. Piteau (1982) Table IX Summary of slope information, stability analysis results and slope design recommendations for design sectors.

DESCRIPTION OF DESIGN SECTORS					MAIN MODES OF SLOPE FAILURE WHICH CONTROL SLOPE STABILITY	STABILITY ANALYSIS RESULTS FOR KINEMATICALLY POSSIBLE FAILURE MODES [1,2]								OPTIMUM INTERRAMP SLOPE DESIGN FOR DRY SLOPES BASED ON KINEMATIC ANALYSES RESULTS (SLOPE DESIGN FOR SLOPES WITH HIGH GROUNDWATER PRESSURES ARE GIVEN IN BRACKETS WHERE DIFFERENT)						POSSIBLE INCREASE IN SLOPE ANGLE DUE TO PLAN RADIUS OF CURVATURE (°)	RECOMMENDED INTERRAMP SLOPE DESIGN FOR DRY OR DRAINED SLOPES OR SLOPES WITH ADEQUATE GROUNDWATER DEPRESSURISATION [4]						REMEDIAL MEASURES AND COMMENTS [5,6,7]	DESIGN SECTOR
						AVERAGE DIP OR APPARENT PLUNGE OF FAILURE FOR WORST CASE WHERE STATISTICAL ANALYSIS NOT USED		APPARENT PLUNGE OF WEDGES CORRESPONDING TO A CUMULATIVE PERCENTAGE OF 20±%		APPARENT PLUNGE OF WEDGES CORRESPONDING TO THE BREAK IN THE CUMULATIVE FREQUENCY PLOT				BENCH HEIGHT = 20m			BENCH HEIGHT = 30m				BENCH HEIGHT = 20m BETWEEN 305m AND 345m ELEVATION			BENCH HEIGHT = 30 m ABOVE 345m AND BELOW 305m ELEVATION				
GN SECTOR	STRUCT. DOMAIN	SLOPE DIP DIREC-TION (°)	MAXIMUM SLOPE HEIGHT (m)	No. OF HAUL ROADS						F < 20		F < 1.2		OPTIMUM BENCH FACE ANGLE (°)	TOTAL BERM WIDTH[3] (m)	INTER RAMP SLOPE ANGLE (°)	OPTIMUM BENCH FACE ANGLE (°)	TOTAL BERM WIDTH[3] (m)	INTER RAMP SLOPE ANGLE (°)		BENCH FACE ANGLE (°)	BERM WIDTH (m)	INTER RAMP SLOPE ANGLE (°)	BENCH FACE ANGLE (°)	BERM WIDTH (m)	INTER RAMP SLOPE ANGLE (°)		
						F < 2.0	F < 1.2	F < 2.0	F < 1.2	CUM PERCENT	APPARENT PLUNGE	CUM PERCENT	APPARENT PLUNGE															
1-1	1 and 2	012	85	-	Rotational failure in weathered rocks at pit crest. Wedge failures formed by combination of joints of Joint Set A and Joint Set D.	40	[44]	58	54°	15	53˚	10	56˚	-	-	-	-	-	-	-	-	-	.	-	-		**1-1**
2-1	1 and 2	342	85	-	Rotational failure in weathered rocks at pit crest. Plane failures along joints of Joint Set A and Joint Set G.	47	[47]	50	50	-	-	-	-	-	-		-			-	-	-	-	-	-	Statistical analysis and design techniques were not used in Design Sectors 1-1, 2-1 and 3-1 because slope stability is controlled by rotational failure in weathered rocks as well as kinematically possible failure modes. Slope design and remedial measures in this area are discusser, in section 8.7.	**2-1**
3-1	3	330	30	1	Rotational failure in weathered rock at pit crest. Plane failure along joints of Joint Set B.	44	[44]	44	44	6	44	6	44	-			-			-	-	-	-	-	-		**3-1**
4 -1	4	214	60	1	Plane failure along joints of Joint Set A. Wedge failures formed by combination o joints of Joint Set A and Joint Set D.	[69]	[69]	69	69	-	-	-	-	80	10.5	55.0	80	14.7	56.3	+4°	80	10.5	55	80	14.7	56		**4-1**
4-2	4	258	60	[1]	Wedge failure formed by combination of joints of Joint Set A and Joint Set B.	52	56	[52]	[58]	-	-	-	-	80 (70)	12.1 (16.5)	52.1 (50.5)	70 (70)	23.0 (24.7)	52.5° (50.5)	-	80	10.5	55	80	14.4	56.5	Slope angle of 55° is recommended for 20m high benches to provide access to the south wall. Drainholes may be required to control groundwater pressures.	**4-2**
5A-1	5A	097	170	2	Wedge failures formed by combination of joints, faults, shears and veins.	27	42	[36]	[46]	-	-	22	66	70 (70)	19.1 (28.0)	45.9 (35.5)	70 (70)	28.9 (41.4)	46.1 (36.0)	+3°	70	17.4	49	70	26.1	49	Slopes below 305m elevation could be increased to 50° based on increased effects of plan radius of curvature. Horizontal drainholes may be required.	**5A-1**
5A-2	5A	135	170	1	Wedge failures formed by combination of joints, faults, shears and veins.	34	70	[47]	[70]	-	-	-	-	80 (70)	10.5 (18.7)	55.0 (46.9)	80 (70)	14.2 (28.1)	57.0 (46.9)	-	80	10.5	55	80	19.5	57	Horizontal drainholes may be required in specific areas on benches to control groundwater pressures in the slope.	**5A 2**
5B-1	58	166	260	2	Wedge failures formed by combination of joints, faults, shears and veins.	59	76	[75]	76	12	[74]	-	-	80	10.5	55.0	80	12.2	59.7	-	BO	10.5	55	80	12.0	60		**5B-1**
5C-1	5C	178	260	2	Wedge failures formed by combination of joints, faults, shears and veins.	57	80	[79]	[80]	23	79	-	-	80	10.5	55.0	80	12.2	59.7	-	80	10.5	55	80	12.0	60		**5C-1**
5C-2	5C	197	120	2	Wedge failures formed by combination of joints, faults, shears and veins.	77	77	[84]	[84]	-	-	-	-	80	10.5	55.0	80	12.2	59.7	-	80	10.5	55	80	12.0	60		**5C-2**
5C-3	5C	270	100	1	Wedge failure formed by combination of joints, faults, shears and veins.	68	68	[71]	[71]	-	-	-	-	80	10.5	55.0	80	13.6	57.8	+5°	80	10.5	55	80	12.0	60	Maximum slope angles of 55° are recommended for 20m high benches in the design sector to ensure reliable access to the south wall.	**5C-3**
5C-4	5C	344	50	1	Wedge failures formed by combination of joints, faults, shears and veins.	43	43	[74]	[74]	18	74	11	74	8O	10.5	55.0	BO	12.2	59.7	-	70	16.7	50	70	25.3	50	Maximum interramp slopes of 50° are recommended below 305m elevation due to sensitive nature of slope in this area and possible requirements for remedial measures.	**5C-4**
5D-1	5D	344	100	2	Wedge failures formed by combination of joints, faults, shears and veins.	26	40	[48]	[51]	-	-	.	.	70 (70)	16.7 (18.1)	50.1 (47.9)	70 (70)	25.4 (27.5)	49.8 (47.5)	-	70	18.7	47	N/A	N/A	N/A	20 m high benches and maximum inter-ramp slope angles of 47° are recommended above the haul road (300 m elevation) in Design Sectors 5D-1 and 6A-1 due to the sensitive nature of the slope and possible requirements for remedial measures. Horizontal drainholes may be required.	**5D-1**
6A-1	6A	345	60	1	Wedge failures formed by combination of joints, faults, shears and veins.	47	53	[64]	[64]	20	65	20	66	so	11.3	53.5	70	20.9	55.1	-	70	18.7	47	70	25.3	50		**6A-1**
6A-2	6A	025	120	1	Wedge failures formed by combination of joints. faults, shears and veins.	34	36	[59]	[69]	25	70	16	68	80 (80)	10.5 (12.0)	55.0 (52.2)	80 (70)	14.7 (22.6)	56.3 (53.0)	-	70	17.4	49	70	26.1	49	Interramp slope angles of 49° are recommended in this design sector for blending of slope designs between adjacent design sectors. Horizontal drainholes may be required.	**6A-2**
6B-1	6B	351	50	1	Plane failure along joints of Joint Set GI. Wedge failures formed by combination of joints, faults shears and veins.	47	49	[50]	[52]	-	-	.	-	70 (70)	16.5 (17.1)	511.5 (49.5)	70 (70)	24.7 (26.1)	50.5 (49.0)	-	N/A	N/A	N/A	70	25.3	50	Same as comments for Design Sector 5C-4. Horizontal drainholes may be required.	**6B-1**
6B-2	6B	055	170	2	Wedge failures formed by combination of joints, faults, shears and veins.	27	40	[34]	[36]	-	-	-	-	70 (70)	19.1 (30.7)	45.9 (34.0)	70 (70)	28.9 (44.4)	46.1 (34.0)	+3°	70	17.4	49	70	26.1	49	Slopes below 305m elevation could be increased to 50° based on increased effects of plan radius of curvature. Horizontal drainholes may be required.	**6B-2**

NOTES

3. Analyses results are presented for F < 2.0 and F < 1.2 which relate to un-dewatered and dry, drained or dewatered slopes respectively.
4. The dip or apparent plunge which is considered to control slope stability is in squared brackets for both un-dewatered (F < 2.0) and drained (F < 1.2) conditions in each design sector.
5. Total berm width is calculated based on berm width required to catch failed material with consideration of anticipated breakback of bench crests.
6. Feasibility of using 30m high benches should be verified by assessment of trial slopes.
7. Control blasting is recommended in all areas of the final slope to ensure minimal disturbance to the rock and maintain cohesion in the slope.
8. If control blasting Is not adequate or undue failures occur-in certain areas, grouted dowels may be required to ensure the integrity of haul roads or other critical installation.
9. Remedial measures are recommended to control groundwater and surface water. Sealed drainage ditches graded berms and horizontal drainholes are recommended in critical areas as required. If adequate groundwater control is not obtained using drainholes additional hydrogeological studies may be required.

10. PIT WALL ANGLE RECOMMENDATIONS

Tables 3 and 4 essentially summarise the data shown in Table 2 and are similar to Table 10 in the BFS. The tables present previous and, currently endorsed, recommendations for pit wall angles north of the SWF (Table 3) and south of the SWF (Table 4).

Table 3 Recommended geotechnical design parameters for open pit design north of SWF.

Parameter	Value	Comment
Bench height	20 m	Suitable in hornfels material north of the South Wall Fault.
HW Bench batter angle	45°	
MW- FR Bench batter angle	70°	
Bench width	8 m	
Ramp angle	10%	
Inter-ramp slope angle	53°	

HW Highly weathered
MW-FR Moderately weathered to Fresh

Table 4. Recommended geotechnical design parameters for open pit design south of SWF.

Parameter	Value	Comment
Bench height	20 m	Adopt Piteau (1982) Section 8.7 designs subject to inspection for stronger greywacke in walls Provide drainage relief holes at 1 row per bench, 50 m spacing; adjust spacing if high flows are encountered.
HW Bench batter angle	45°	
MW-FR Bench batter angle	70°	
Bench width	8 m	
Ramp angle	10%	
Inter-ramp slope angle	53°	

It is recommended that as mining proceeds and the Stage 3 pushback towards the west begins, that the design angles are re-evaluated. The ground within the stage 3 pushback has not been geotechnically evaluated in detail. While Golder (1984) shows a N-S cross section at 2250mE indicating favourable ground conditions no geotechnical cross sections have been developed further to the west.

The pit slope angles are based on the assumption that smooth wall blasting techniques will be adopted. Excessive blast damage will result in unstable walls.

11. REINFORCEMENT

Extensive reinforcement was recommended in Piteau (1982) for the south wall south of the SWF. The extent of reinforcement was based on three assumptions:

- The rock type immediately behind the SWF is a weak schist
- The depth of weathering is greater close to fault than away from the fault
- At depth the footwall of the fault would form at least one of the benches.

However, the current mine plan, “Version 3”, excavates more of the wall beyond the SWF than envisaged by Piteau (1982) and may transition out of the schist and into stronger, less deeply weathered greywacke. If that is the case then it may be possible to reduce the amount of reinforcement above RL320 m.

The SWF has minimal cover from RL290 to RL265 m and in this zone the Piteau (1982) reinforcement, as shown in their Figure 19, should be implemented.

From RL265 to RL225 m the degree of reinforcement should be progressively evaluated. Piteau (1982) notes that with depth the rock gets stronger and that there was little evidence of continuous adverse structures.

An alternative pit development is being considered in which an initial Stage 1 (lower pit guts grab) would be stepped further to the north leaving the SWF substantially buried beneath stronger hornfels rock. Under these circumstances, provided there are no continuous adverse structures it may be possible to substantially reduce the need for reinforcement of the south wall and provide only for spot reinforcement. It is recommended that additional inspections are undertaken progressively as mining takes place.

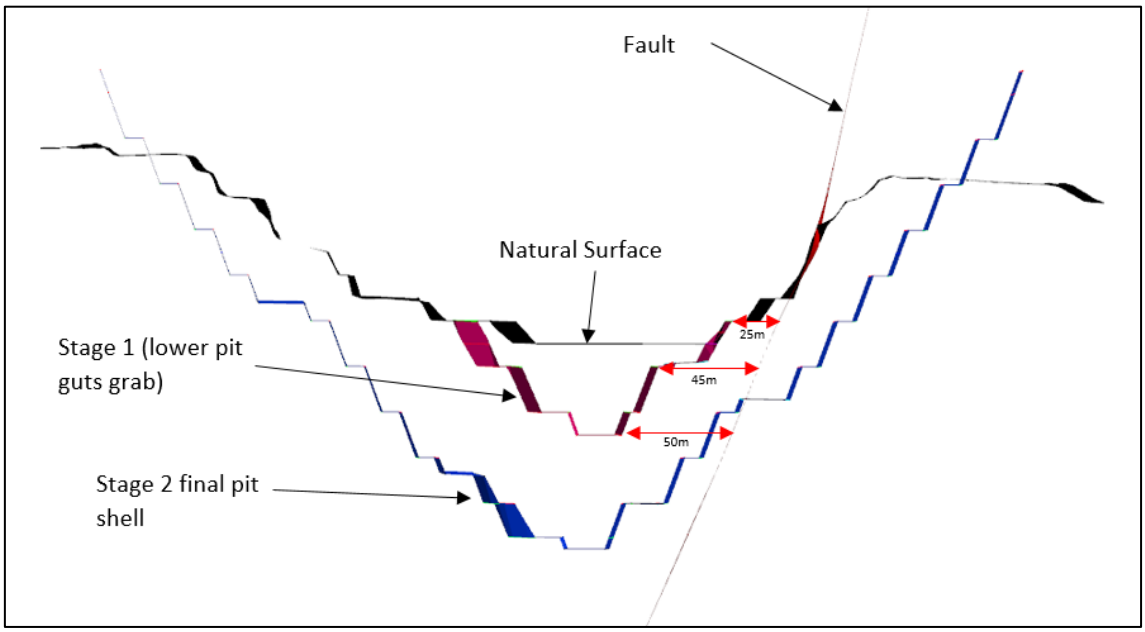


Figure 14. Cross section of alternative pit development.

12. DRAINAGE

As noted above in Section 7, Piteau (1982) considered the main groundwater concern to be the possibility of hydraulic pressure developing behind the SWF. Faults often form low permeability barriers because the fault gouge is clay rich and trap water behind them.

Where the pit is excavated to behind the SWF and into rock that is stronger than the green schist, further drainage is unlikely to be required.

Where the SWF comes within 20 m of the pit wall drainage is recommended. A single row of holes per bench at 50 m spacing drilled horizontally to penetrate 10 m beyond the fault is

recommended. If high flows are encountered then a localised reduction in spacing may help to accelerate the rate of depressurisation.

Subsurface drainage should be complemented by attention to surface drainage ensuring that water is shed and does not pond and any cracks in the ground are sealed, all with the aim of minimising water soaking into the ground.

13. OUT OF PIT DUMPS

Geotechnically, out of pits dumps can be constructed in 40 m lifts with 10 m catch benches. Founded on flat stable ground the dumps could be constructed to a height of 100 m and the factor of safety against overall failure would be greater than 1.3.

14. CLOSURE

The purpose of this review is to assess the existing geotechnical data and recommendations and relate them to site observations and current mine plans.

The Piteau (1982) recommendations, in general remain appropriate with the exception of:

- Those areas where the pit mines through the SWF and green schist to expose stronger hornfels in the south wall. This will likely reduce the need for wall reinforcement and in-pit drainage. Similarly where the SWF remains buried by more than 20 m of intact rock the extent of wall reinforcement can be reduced.
- In the extension of the pit west of the original Piteau (1982) design. Progressive re-evaluation will be required as mining takes place.

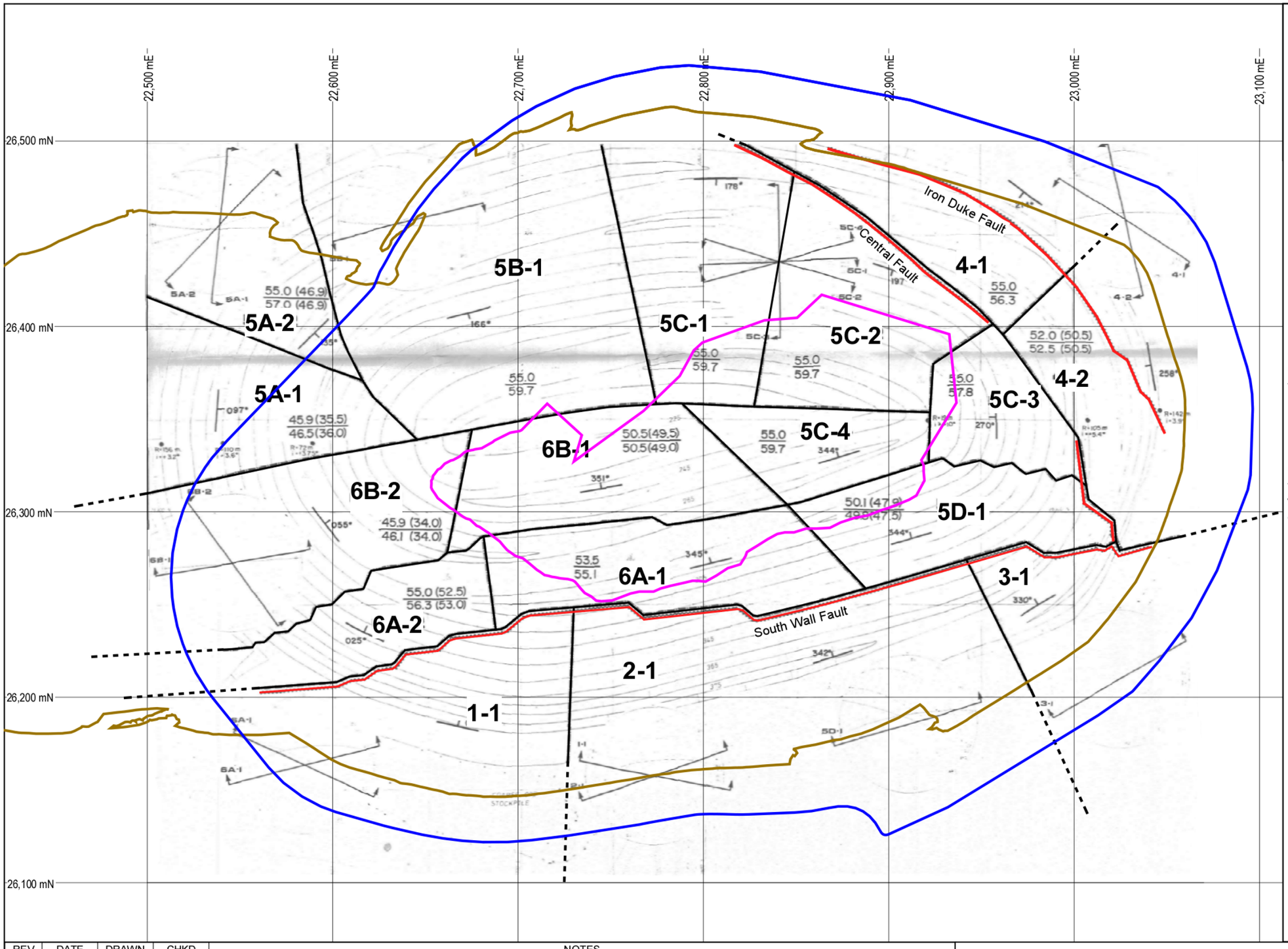
A further geotechnical inspection of the pit walls, once the pit has been fully drained, is recommended.



A Paul Maconochie RPEQ 5828
Principal Geotechnical Engineer

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SYMBOLS

Pit Design V3 Stage 1 Perimeter

Pit Design V3 Stage 2 Perimeter

Pit Design V3 Stage 3 Perimeter

Design Sector Boundary

Extrapolated Design Sector Boundary

5C-1

Design Sector Number

258°

Orientation and dip direction of final pit wall

Bench H = 20m 55.0 (46.9)
Bench H = 30m 57.0 (47.2)

Optimum interramp slope angle for Design Sectors with and ( ) without adequate groundwater depressurisation.

Fault

NOTES

1. Design sector boundaries are based on structural domain boundaries and boundaries of straight slope segments.
2. Results of kinematic statistical analyses were not used for design of slopes in Design Sectors 1-1, 2-1 and 3-1. Separate design of slopes and remedial measures for individual benches south of the South Wall Fault are discussed in Piteau (1982) Section 8.7.

REV	DATE	DRAWN	CHKD	NOTES
1	30/10/22	P. Maconochie		Plan created from scanned image in Piteau (1982) and pit design V3 triangulation

MOUNT CARBINE MINE

EQ RESOURCES

GOLDING CONTRACTORS

Piteau (1982) Fig 14
DISTRIBUTION OF DESIGN SECTORS AND KINEMATICALLY POSSIBLE FAILURE MODES

Job No.: 22-138 | Datum: Local Grid | Scale: as shown

Fig A1

Figure A1. Piteau (1982) Fig 14 overlaid with pit perimeters for Version 3 stages 1-3.

Appendix E:
Mt Carbine Mine Stage 3 Waste and Water Management Design Report *(*ATCW 2022b*)*

REPORT

Mt Carbine Quarries Pty Ltd
ABN: 52065645650

Mt Carbine Mine
Stage 3 Waste and Water Management Design Report

119190-05-R01
November 2022

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Document Control

Project Name:	Mt Carbine Mine
Document Title:	Stage 3 development design report
File Location:	N:\Synergy\Projects\119\119190 SMI Mt Carbine\05 TSF4 Scoping Rpt\Documents\R01
Document Number:	119190-05-R01.docx

Revision History

Revision	Issue	Issue Date	Prepared by	Reviewed by
A	For review	24/11/2022	Kathy Tehrani	Ralph Holding
0	Final	30/11/2022	Kathy Tehrani	Ralph Holding

Issue Register

Distribution List	Date
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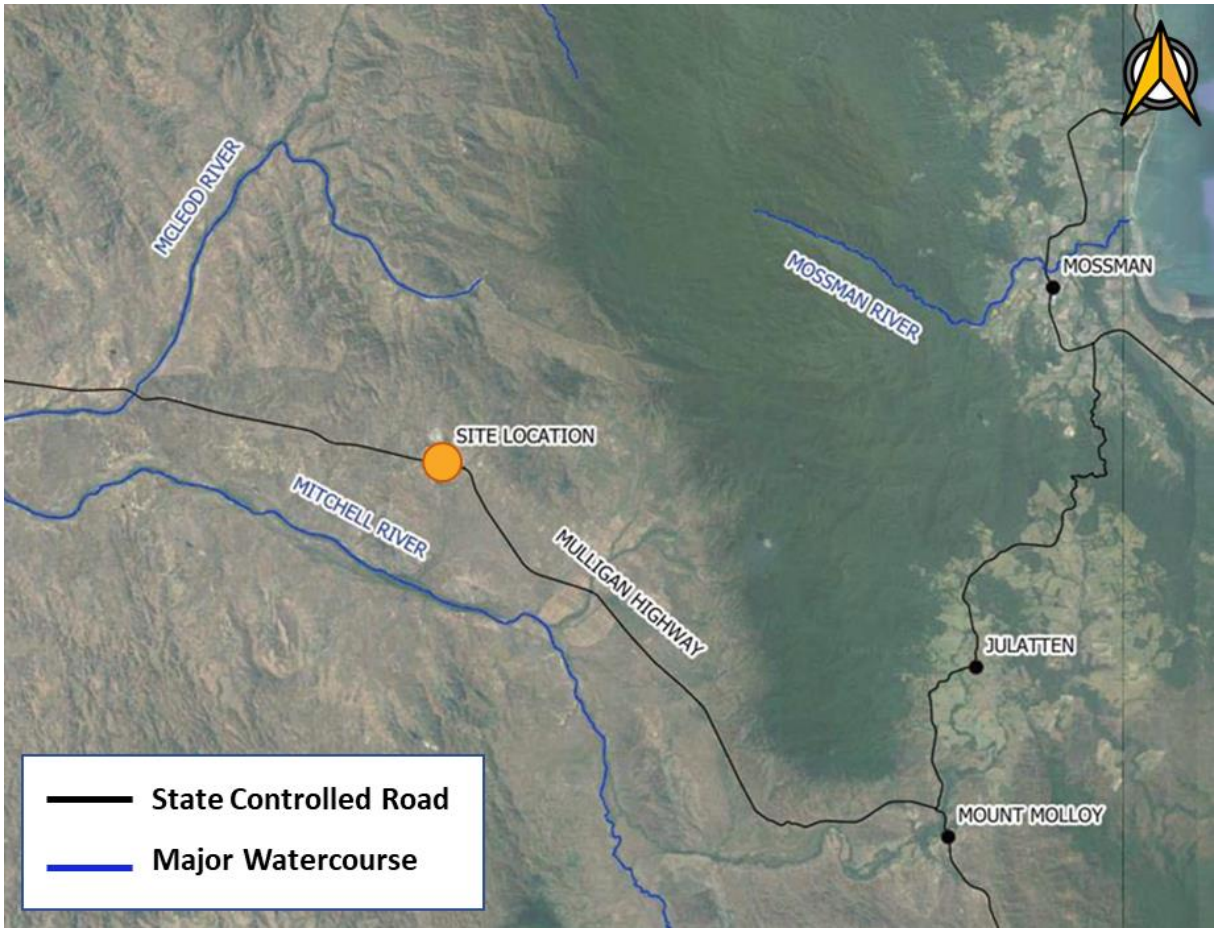
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1 INTRODUCTION

1.1 Project Background

The Mount Carbine Tungsten Project is adjacent to the township of Mount Carbine (approximately 80 km northwest of Cairns, Queensland). The Project is owned by Mt Carbine Quarries Pty Ltd (MCQ) and is referred to as the Mount Carbine Tungsten Project. It is on the site of an open-cut and underground tungsten mine, which operated in the 1970s and 1980s. Mining of various intensities occurred on the site and the surroundings since the 1890s. The Project is adjacent to the township of Mount Carbine and is in the Mareeba Shire Council area. The site is accessed from the Mulligan Highway. The Project's location is shown in **DIAGRAM 1**.

DIAGRAM 1: THE SITE LOCATION



The mining project operates under EA EPML00956913, dated 14 April 2022. The Mount Carbine Project comprises the repurposing of mine waste for beneficial reuse and is described and named as Quarry Product. Quarry Product is derived from the site waste emplacements, which were formed as part of previous mining activities on the ML 4867 and ML4919. This activity is a licensed extractive activity (i.e., quarry operation) that occurs under an approval (i.e., Environmental Authority (EA) Permit No. EPPR00438313, dated 16 March 2021) separate from the mining activity.

1.2 Project Proposal and Scope of Work

As part of the ongoing project development, MCQ propose to re-establish a mining operation at the site, comprising a cut-back to the existing open-cut Pit, following which an underground operation with a portal extending from the open-cut Pit. The cut-back works are described as Stage 3 Mount Carbine Development (Stage 3). In support of Stage 3, an enhanced site water management system is proposed

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to support both the Quarry Operation and Mine Development and includes the formalising and enhancement of the existing structures as well as water management of waste rock from the Mine Development.

To facilitate the water management works, MCQ engaged ATC Williams Pty Ltd (ATCW) to undertake the detailed design for the proposed Stage 3 water and waste management system and prepare the relevant design and construction documentation. This report presents the detailed design for the TSF3, and TSF4 embankment enhancement, Waste Rock Dump and Noise bund construction.

1.3 Report Structure

The structure of this report, to address the above purpose and scope, is as follows:

Section 2: Provides a description of the existing Project.

Section 3: Outlines the proposed Stage 3 Water Management configuration and description of associated infrastructure.

Section 4: Outlines the Consequence Category Assessment (CCA) and key design criteria

Section 5: Summarises geotechnical design analyses completed in relation to the TSF 3 and TSF 4 embankments, including details of stability and seepage analyses and design criteria.

Section 6: Describes the hydraulic analyses undertaken to size the spillway and for the design of associated hydraulic works.

Section 7: Details of the proposed Waste Rock Management and Noise Bund

Section 8: Outlines the characteristics of the proposed construction materials and associated construction methods and an overview of the Quality Assurance/Quality Control requirements of construction.

Section 9: Describes the operational requirements for the Water Management System.

Section 10: Outlines the closure for the structures.

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2 BACKGROUND DATA

2.1 Project Description

2.1.1 Site History and General Layout

Wolframite was first discovered on the slopes of Carbine Hill in the 1890s, and several small-scale mines operated in the vicinity before 1920. No further mining occurred until the 1970s when Queensland Wolfram Pty Ltd commenced mining utilising an open-cut pit mine. In 1973 Roche Brothers Mining commenced the development of the existing mine on the project site for the production of tungsten. Mining continued until 1986 when declining prices forced the closure of the operation. The mine was placed on a care and maintenance basis until 1991, when the plant and equipment were sold. Since 1987 the mine site has been operated as a quarry by Mt Carbine Quarries Pty Ltd, with the sale of gravels, rock and bases produced from the mine waste rock and fines.

The site is located on ML 4867 and ML 4919.

DIAGRAM 2 provides a general layout of the Mt Carbine Project, showing the below locations:

1. Low-grade stockpile
2. Quarry operational area
3. (a) Old mine workings
    a. (b) Overburden stockpile
    b. (c) Old stockpile area
4. Reject stockpile
5. TSF3
6. Process water pond
7. Open Pit
8. (a) Previous mill and RoM
    a. (b) Sulfide disposal dump
    b. (c) Core yard and laydown area
    c. (d) Office and laboratory
9. Processing plant and workshop, Tailings near processing plant, and Tailings SE of workshop
10. Tailings stockpile in TSF4
11. Water storage in TSF4 and a clean water dam
12. TSF4 dam wall and Roads.

Relevant elements are described in more detail below.

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DIAGRAM 2: GENERAL LAYOUT OF THE MOUNT CARBINE PROJECT



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2.1.2 Open-Cut Pit

The Open-Cut Pit is situated north of the Mulligan Highway. The pit comprises slopes of the order 1H:3.6V, with benches formed at 8 m vertical and 20 m width. Access to the pit is via a ramp from the south. The Open-Cut Pit is approximately 64 m deep and has a spill elevation of RL 380.4 m AHD. It has a surface area of some 9.7 ha, with an estimated capacity of 2,385 ML [1]. The Open Cut Pit has upstream catchment areas reporting from quarry disturbance areas on the site. These upstream catchment areas include the Quarry Operational Area and the Reject Stockpile Area.

2.1.3 TSF 3

TSF3 is an existing structure north of the Mulligan Highway, which was decommissioned and currently has no function at the site. It is understood that the tailings have been largely removed as the product in the Quarry operations. Storage appears to be formed by a low earthen embankment on the eastern and southern sides. The maximum height of the embankment is some 6.8 m with crest level varying and no formal spillway observed. Limited ponding of water has been noted. The Stage 3 upgrade will raise embankments around TSF3 for use as a water storage facility.

2.1.4 TSF 4

TSF4 was first constructed 30 to 40 years ago to contain tailings that have historically been generated from the mine process plant and comprise an above-ground storage facility formed by earthen embankments. In the northern portion of TSF4, tailings have been stockpiled above the crest level of the perimeter embankment, while the southern portion of the TSF consists of a tailings lagoon bounded by perimeter embankments to the west, south and southeast. At the southern corner of TSF4, a concrete-lined open channel spillway exists. Diversion drains are currently in place to divert water around TSF4 along the western, northern and north-eastern sides of the facility.

2.1.5 Quarry Operations Area

The crushing plant is in the Quarry Operational Area to the northwest of the Open Cut Pit. Quarry Operational Area drains to the Open Cut Pit. The crushing plant area comprises a Raw Water Tank and a dewatering system that recirculates water to the Raw Water Tank. The existing low-grade material stockpile is the northernmost feature of the existing mine infrastructure and is located between two ridgelines, with the northern toe of the stockpile in the headwaters of several streams flowing into Holmes Creek. The tailings area is located on the southern side of the Mulligan Highway, on flatter land than the low-grade rock stockpile. The reject crushed ore stockpile is located between the northern low-grade stockpile and the southern tailings area, with drainage flowing into the tailings dam.

2.1.6 Processing Plant and Workshop

The Processing Plant and Workshop area is located on the southern portion of the project site adjacent to the TSF4. The Processing Plant and Workshop area have a total disturbance area of some 3.1 ha (NRA, 2019), with runoff from this area reporting to the TSF4. The process water for processing is sourced from the Clean Water Dam at a rate of 65 l/sec. Under current EA conditions, tailings re-processing is limited to 100,000 tonnes/annum.

2.1.7 Clean Water Dam

The Clean Water Dam is located adjacent to TSF4, on the southern portion of the project site. The Clean Water Dam shares a common embankment with TSF4, with a spillway, is formed through the embankment wall, and any overflows from the Clean Water Dam will report to the TSF4. Runoff from the north and northeast of TSF4 is partially diverted to the Dam.

2.2 Site Topography

The Mount Carbine Mine Site is relatively rugged, with the topography described as varying between level alluvial plains rising to short, gently sloping pediments and foot-slopes to high hilly to mountainous lands with very steep slopes [2].

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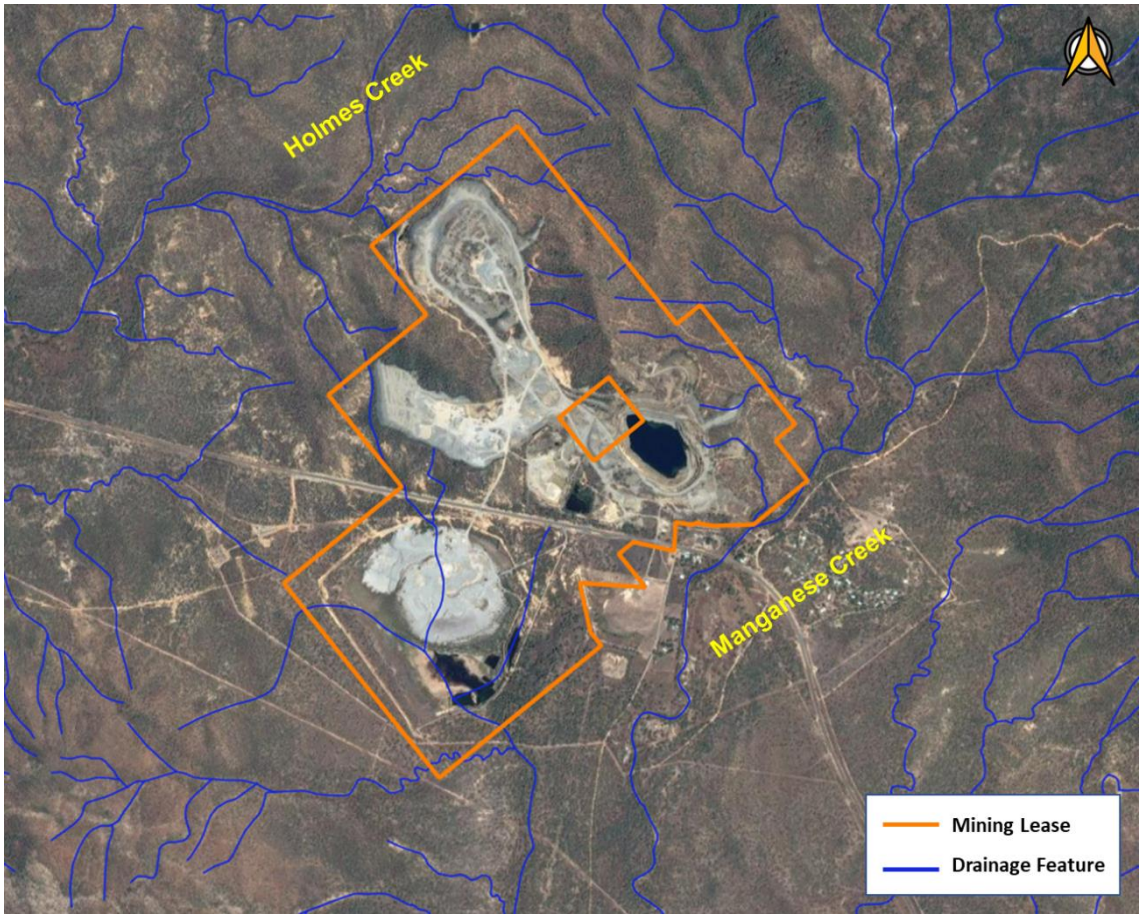
2.3 Hydrology

Regionally, the Project is located within the Mitchell River Basin, discharging to the Gulf of Carpentaria. The Mitchell River catchment covers an approximate area of 71,800 km2. The headwaters of the Mitchell River are located on the Atherton Tableland, some 50 km to the northwest of Cairns, at an approximate elevation of RL 376 m AHD. At the closest point, the Mitchell River flows in a north-westerly direction some 5 km south of the Mount Carbine project site.

Drainage within the project area reports to the Mitchell River via the Manganese Creek and Holmes Creek catchments. Holmes Creek is located northeast of the site, with its closest point some 300 m to the northeast of the LGMS area. Manganese Creek is located east of the site, with its closest point some 300 m to the southeast of the Pit.

The topography and drainage systems, relative to the project location, are depicted in **DIAGRAM 3.**

DIAGRAM 3: LOCAL DRAINAGE FEATURES

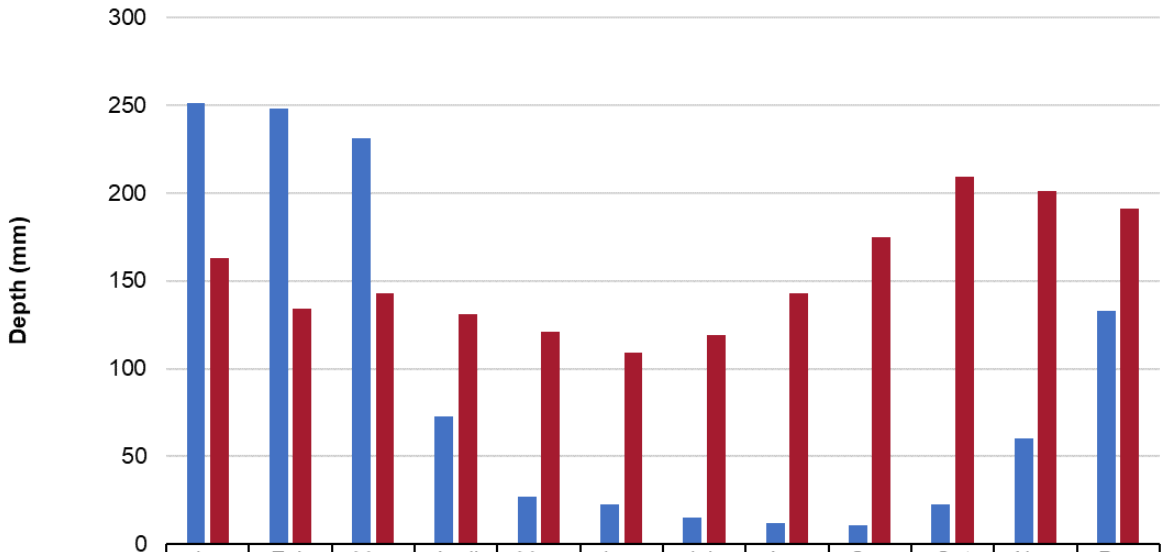


2.4 Climate

The Mount Carbine Project site is situated in the tropical monsoon belt of North Queensland and is subject to a tropical climate associated with highly variable rainfall conditions. For this assessment, rainfall and evaporation data have been sourced from a Patched SILO Data Drill for the Mount Carbine Township Station. Source: SILO Data Drill for the site location [3].

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GRAPH 1: AVERAGE MONTHLY RAINFALL AND EVAPORATION



	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
Rainfall	251	248	231	73	27	23	15	12	11	23	60	133
Evaporation	163	134	143	131	121	109	119	143	175	209	201	191

The average annual rainfall in the region is 1107 mm. The average annual evaporation potential is some 1,839 mm. Mean monthly rainfall values shown in **GRAPH 1** indicate a distinct pattern, with lower rainfall conditions in the winter months and higher values during summer. The wet season occurs between December and March, with 78% of the mean annual rainfall occurring during these months. On average, evaporation exceeds mean monthly rainfall throughout the dry season; however, rainfall exceeds evaporation potential for most wet season months, from January to March.

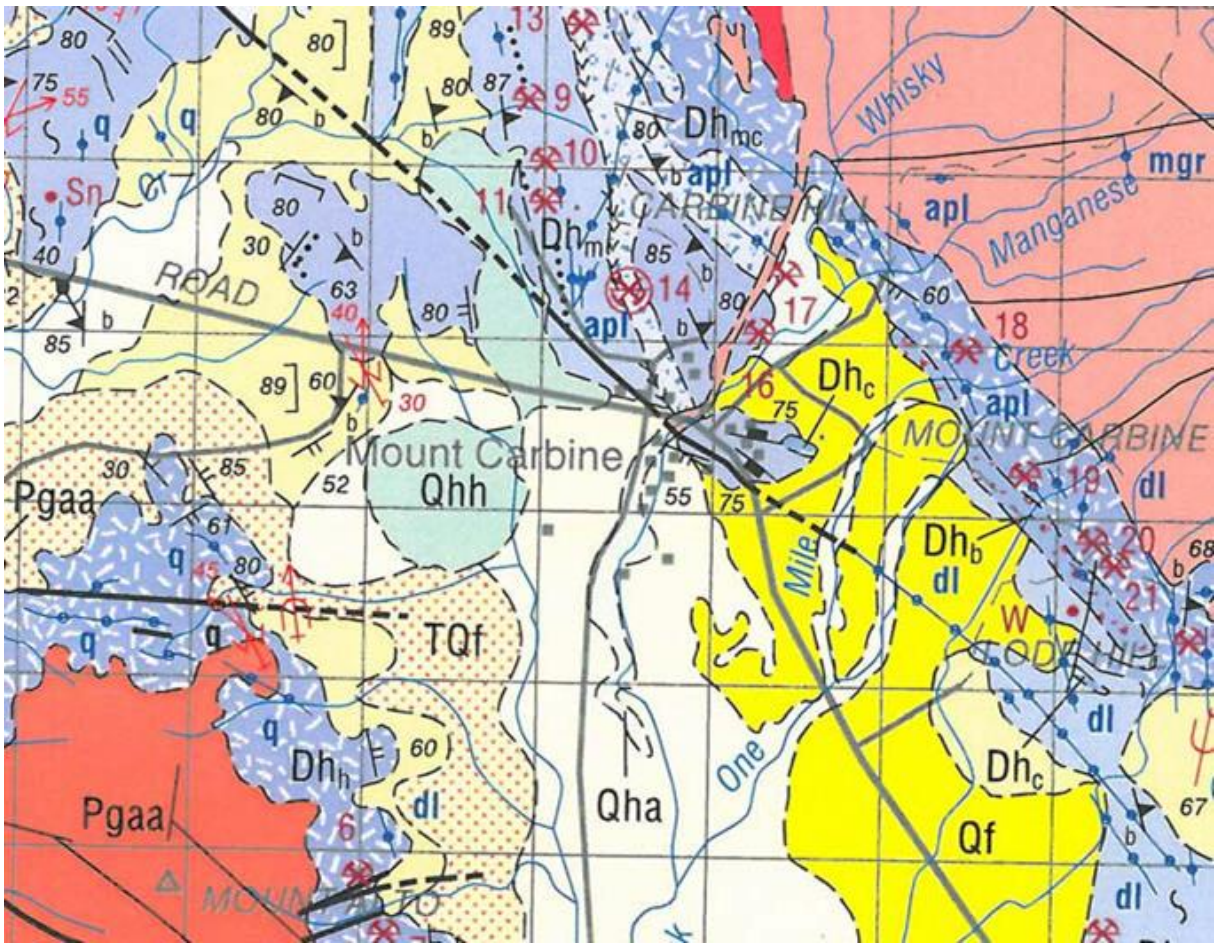
2.5 Regional Geology

The project site is in the Siluro-Devonian Hodgkinson sedimentary province of north-eastern Queensland. Based on the 1:100,000 scale Rumula geological map, the regional geology of the site is mapped as Hodgkinson Basin meta-greywackes and meta-argillites with local meta-basalts.

Mount Carbine is located in the Siluro-Devonian Hodgkinson sedimentary province of north-eastern Queensland. The sediments were complexly folded and regionally metamorphosed before and during extensive granitic intrusion in the Carboniferous and Permian periods. The area is underlain by the Hodgkinson Basin meta-greywackes and meta-argillites with local meta-basalts (greenschist facies). The geology, as described by the Rumula 1:100,000 scale geological map [4], is shown in **DIAGRAM 4,** and the main rock units are listed in Error! Reference source not found..

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DIAGRAM 4: SITE GEOLOGY



Adopted from Rumula sheet, scale 1:100,000, Bultitude et al. 1999

Tungsten deposits at Mount Carbine are typically associated with sheeted quartz vein systems related to hydrothermal activity from underlying intrusive granite formations (Blanchard & Brock 1984).

Table 1 summarises the geological units on the Rumula 1:100,000 geological map in the vicinity of the mount carbine mine site [4].

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TABLE 1: SITE GEOLOGICAL UNITS

Unit	Description
Dh_b	Dark green, fine coarse-grained, massive to locally amygdaloidal metabasalt; generally altered, poorly exposed; minor chert.
Dh_c	Pale to dark grey, black, reddish-brown or white, thin-bedded or massive chert (locally manganiferous); minor mudstone, siliceous mudstone, shale, jasper, metabasalt, iron stone.
Dh_h	Indurated arenite and 'spotted' mudstone, andalusite-cordierite (generally altered)-mica hornfels, minor schists, calc-silicate (skarn) rocks, metabasalt.
Dh_m	Brownish to dark grey, laminated to a thin-bedded mudstone and subordinate siltstone, claystone: minor fine to medium-grained arenite, chert, metabasalt.
DH_{mc}	Interbedded chert and mudstone.
Pgaa	Cream to white or pale grey, medium-grained, slightly to moderately porphyritic (biotite-) garnet-tourmaline-muscovite monzogranite miarolitic cavities common.
Pgwa	White, medium to coarse-grained, porphyritic (garnet-tourmaline-) muscovite-biotite monzogranite with pegmatitic lenses, quartz-tourmaline aggregates and sparse, small mafic inclusions; locally foliated; minor microgranite, pegmatite, Altered muscovite-biotite monzogranite.
Qa	Sand, gravel, clay, mud, silt; mainly older alluvial and minor colluvial deposits; some active stream bed deposits.
Qf	Rock debris, muddy sand, sandy and muddy gravel, and mainly alluvial fan (sheetwash) deposits developed on steeply to gently sloping surfaces.
Qha	Fine to coarse sand; minor gravel, mud, silt, clay; mainly active stream-channel deposits
Qhh	Mud, sand, gravel; mine tailings.
TQf	Rock debris, sandy and silty gravel, sand, silt, clay, mud: mainly older alluvial-fan (sheetwash) and talus deposits.

2.6 Site Geotechnical Data

In addition to the 2021-2022 hydrogeological work, which was undertaken by RLA and Hydrogeologist.com.au (Borehole locations are shown in **DIAGRAM 5** and borehole logs are attached in **Appendix E**), a site investigation was conducted by ATCW geotechnical engineer from 11 July 2022 to 14 July 2022 to assess foundation conditions and available construction material. The investigation comprised:

- Excavation of 12 test pits at locations shown in Error! Reference source not found. and summarised in **Table 2**.
- Classification of the soil profile
- Sample retrieval from 16 locations/depths

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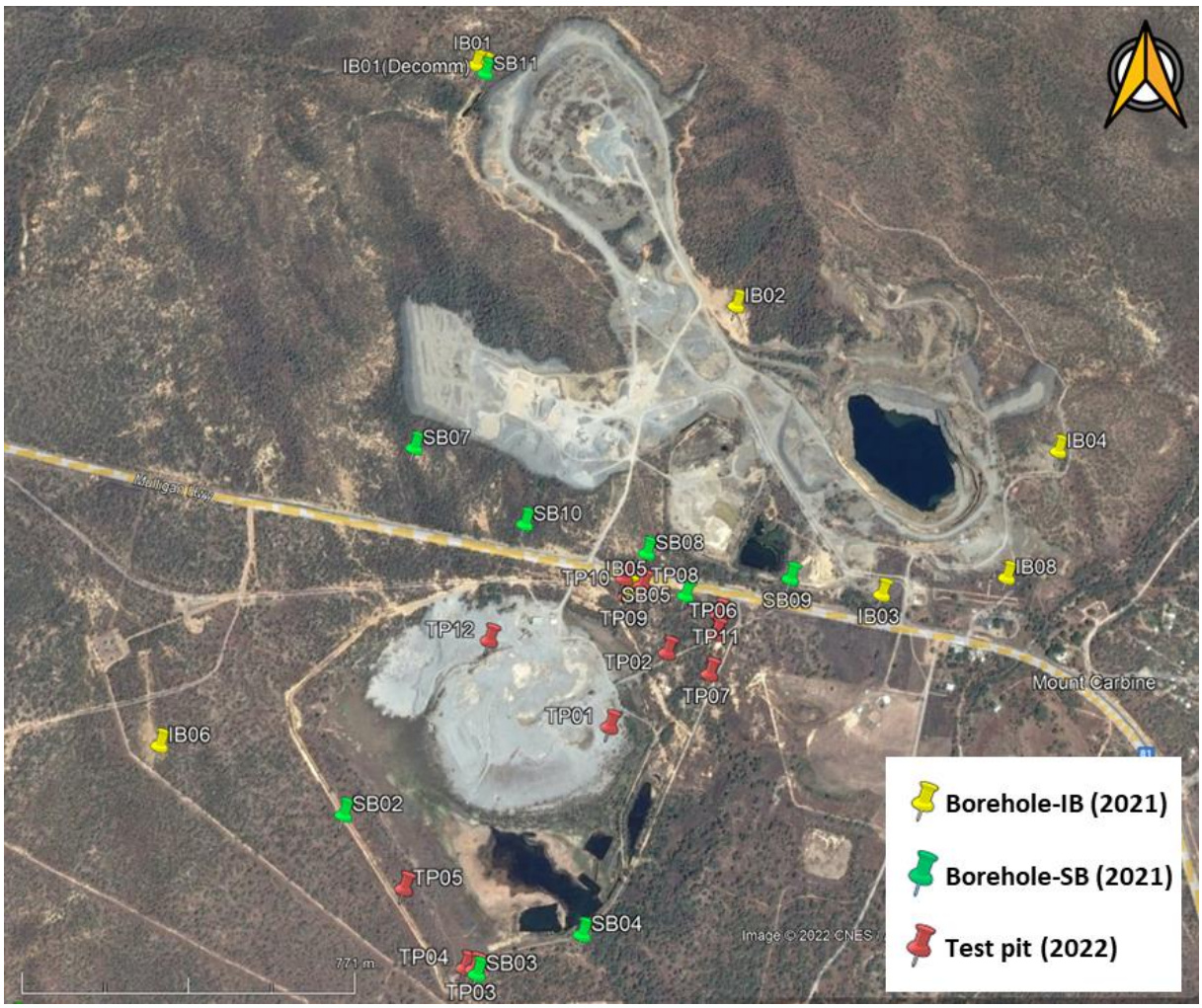
Test pits were excavated using a small excavator and a toothed bucket. Representative soil types encountered in the test pits were visually classified and logged, and laboratory testing was carried out on selected samples.

TABLE 2: TEST PITS LOCATIONS (SITE INVESTIGATION 2022)

TP ID	Zone	Northing	Easting	Final depth (m)
TP01	55k	8171405	299880	3.5
TP02	55k	8171593	300020	3.3
TP03	55k	8170815	299573	1.4
TP04	55k	8170817	299550	1.1
TP05	55k	8171003	299385	2.2
TP06	55k	8171644	300143	2.2
TP07	55k	8171541	300129	3.1
TP08	55k	8171764	299949	1.5
TP09	55k	8171737	299911	1.1
TP10	55k	8171782	299904	0.7
TP11	55k	8171691	300151	1.2
TP12	55k	8171620	299560	1

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DIAGRAM 5: TEST PIT AND BOREHOLE LOCATIONS



2.6.1 Subsurface Conditions

Table 3 summarises the inferred geotechnical units encountered at the site during the geotechnical investigation.

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TABLE 3: TEST PITS SUMMARY

TP No.	Depth (m)		Thickness (m)	Units encountered
	From	To		
TP01	0	1.4	1.4	Tailings
	1.4	2.1	0.7	Silt
	2.1	2.6	0.5	Organic Layer
	2.6	3.5	0.9	Clay
TP02	0	0.4	0.4	Sandy Silt
	0.4	1.8	1.4	Clayey Silt
	1.8	2.2	0.4	Clayey Silt with Gravel
	2.2	3.3	1.1	Silty Clay with Gravel
TP03	0	0.7	0.7	Sandy Silt
	0.7	1.4	0.7	Silty Sandy Clay with Gravel
TP04	0	1.1	1.1	Sandy Silt with Gravel
TP05	0	1.9	1.9	Sandy Silt with Gravel
	1.9	2.2	0.3	Clayey Sandy Silt with Gravel
TP06	0	2.2	2.2	Silty Sand with Gravel
TP07	0	0.7	0.7	Sandy Silt
	0.7	3.1	2.4	Clay
TP08	0	1	1	Gravelly Clay
	1	1.5	0.5	Weathered Shale
TP09	0	1	1	Clay
	1	1.1	0.1	Gravelly Clay
TP10	0	0.5	0.5	Clayey Silt
	0.6	0.7	0.1	Weathered Shale
TP11	0	1	1	Clayey Silt
	1	1.2	0.2	Weathered Shale
TP12	0	1	1	Tailings

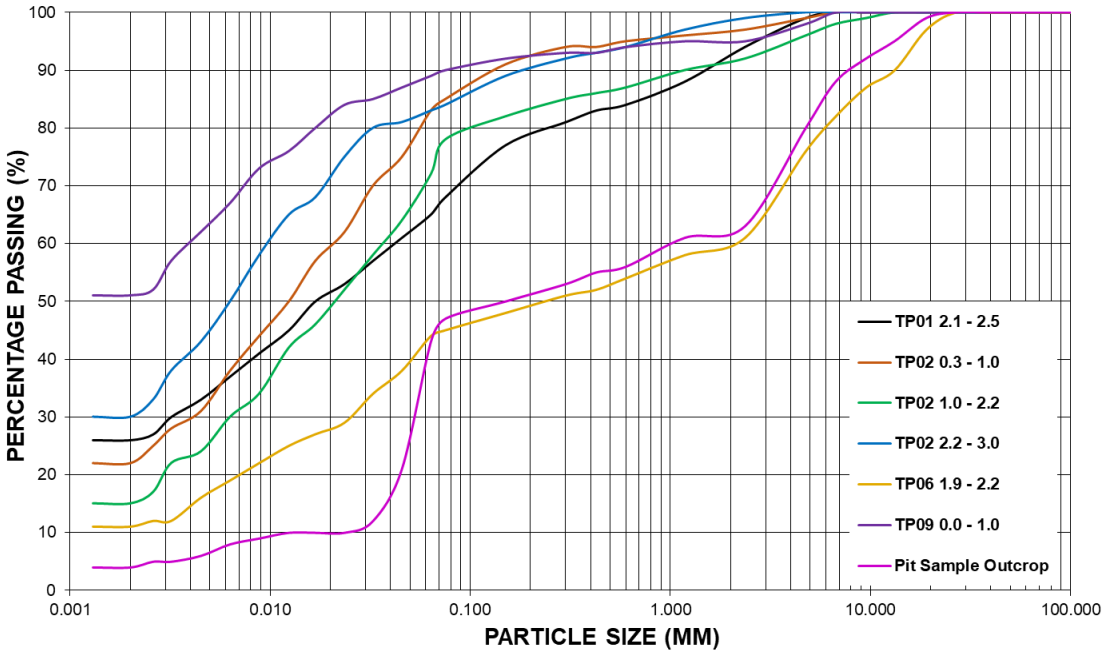
2.6.2

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2.6.3 Laboratory Testing

Particle size distribution and Hydrometer tests were carried out on the 7 samples collected during test pitting. A particle size distribution (PSD) defines the relative number, as a percentage, of particles present within a mass of material according to particle size. This can assist with classifying a material type in conjunction with correlations to estimate additional geotechnical parameters. A limited grading was undertaken for this assessment, comprising only passing 75um. The results from the PSD test are illustrated in **DIAGRAM 6**.

DIAGRAM 6 PARTICLE SIZE DISTRIBUTION CURVE



Based on the Passing 75um test results and logged laboratory material descriptions, materials are typically described as Silty CLAY material. A hydrometer test was undertaken to allow for finer material analysis (<0.075mm) to determine the SILT/CLAY content for the sample. Particle size distribution results are summarised and presented in **Table 4**.

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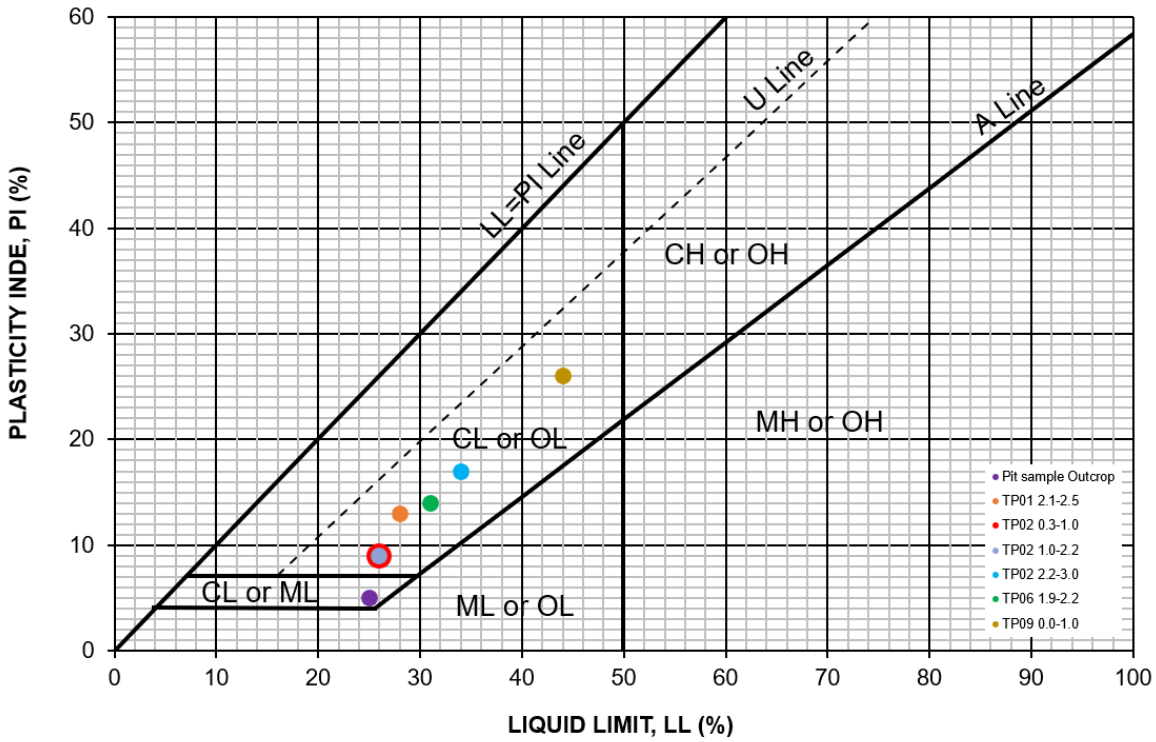
TABLE 4: PARTICLE SIZE DISTRIBUTION RESULTS SUMMARY

Parameter			Material Properties					
BH ID		PIT SAMPLE	TP01	TP02	TP02	TP02	TP06	TP09
Sample Depth (m)		Outcrop	2.1-2.5	0.3-1.0	1.0-2.2	2.2-3.0	1.9-2.2	0.0-1.0
Particle Size Distribution (%)	Cobbles	0	0	0	0	0	0	0
	Gravel	37	6	3	8	1	39	5
	Sand	16	26	12	14	15	16	5
	Silt	43	42	63	63	54	34	39
	Clay	4	26	22	15	30	11	51
Emerson Class Number		2	2	2	2	2	2	2
Liquid Limit (%)		25	28	26	26	34	31	44
Plastic Limit (%)		20	15	17	17	17	17	18
Plasticity Index (%)		5	13	9	9	17	14	26
Linear Shrinkage (%)		4.5	7.5	6.5	6.9	10	8.5	13
Classification		CL or ML*	CL	CL	CL	CL	CL	CL

*CL and ML refer to low-plasticity Clay and Silt, respectively, in the plasticity chart (shown below).

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DIAGRAM 7: PLASTICITY CHART



Geotechnical test certificates are attached in Appendix D.

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3 PROPOSED STAGE 3 WATER MANAGEMENT SYSTEM

3.1 General Description

Stage 3 water management is required to manage the site water system as detailed in ATCW Water Management Plan (2022) and comprises the following:

- Formalisation of TSF3
- Raising TSF4
- Associated hydraulic structures, including drains and spillways.

3.2 Water Management Sizing

The required upgraded capacity of the TSF 3 and TSF 4 has been assessed by ATCW (2022) to optimise practical development constraints whilst maintaining a Consequence Category Assessment (CCA) for the structures as Low. Based on the water balance model results and in discussion with site personnel, the following raises are proposed in **Table 5.**

3.3 Description of Stage 3 Embankment Raises

The Stage 3 embankment raises to TSF 3, and TSF 4 are proposed to increase capacity such that compliance with stipulated water storage and freeboard capacity is maintained. The raises will be formed by downstream construction methods using Rock Fill for the embankment with a Clay Fill core and a geotextile as a filtration layer.

The emergency spillways will be formed to the northwest for TSF 3 and Southwest for TSF 4, with the site release point as per the existing location, southwest of TSF 4, discharging into Manganese Creek. The spillways will be armoured with rock. The proposed layouts of the Stage 3 works and the typical embankment configurations are shown on drawings which attached as **APPENDIX F**. The general design configurations are summarised in **Table 5**.

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TABLE 5: DESIGN CONFIGURATION FOR STAGE 3

Interim Configuration Aspect	TSF 3	TSF 4
Construction Type	Downstream Raise	Downstream Raise
Construction Materials	Earth Fill	Earth Fill/Filter/Rock fill
Embankment Crest Level	376.5	358.5
Emergency Spillway / Full Supply Level	375.5	357.5
Embankment Crest Width	10	10
Embankment Batter Slopes - Upstream	1V:3H	1V:3H
- Downstream	1V:3H	1V:3H
Maximum Storage Capacity (m^3)	326,842	676,678
Designed Spillway Width	22	25
Designed Spillway Depth	1.0 m	1.0 m

3.4 Water Management Plan

A dynamic probabilistic simulation modelling approach, using GoldSim Pro Version 14.1, was adopted to model the proposed Stage 3 operations. An integrated catchment yield analysis for site catchments was also coupled with the water balance model. Using the available Silo Data Drill climatic record, 132 No. Monte Carlo sampling realisations were used to generate probabilistic distribution results.

The model was based on the conditions outlined in this report, with the duration from September 2022 to September 2027. The water balance model included the staged emptying of the Open Cut Pit from September 2022 through to 2027. The agreed dates for the different water balance operations until the completion of the Stage 3 upgrades are presented in **TABLE 6**.

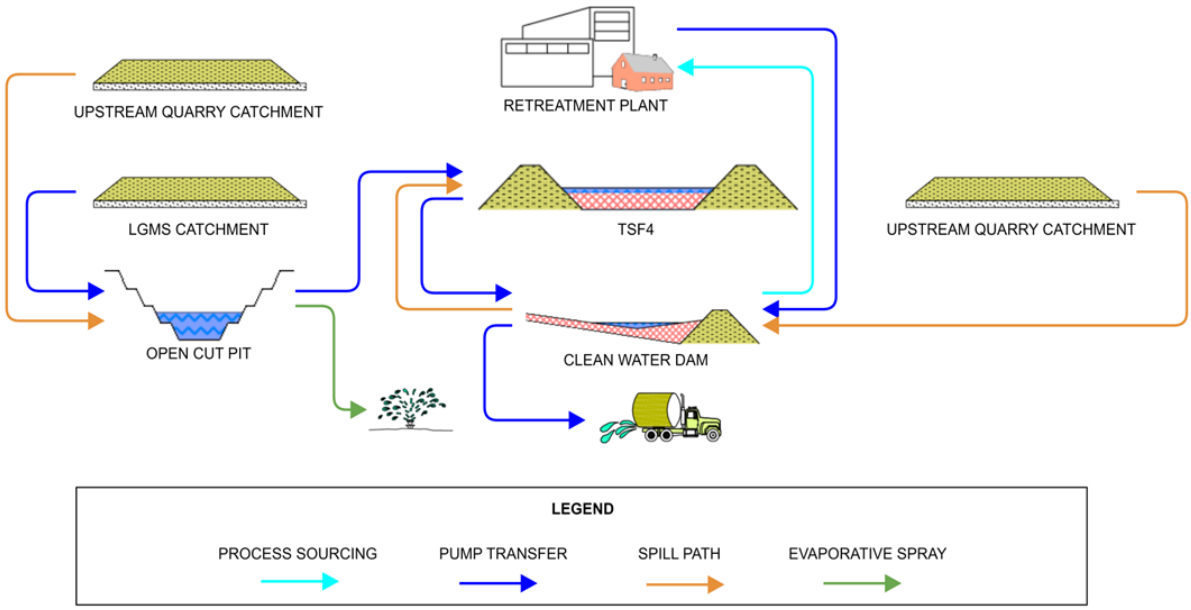
TABLE 6: TIMING OF STAGE 3 CONSTRUCTION

Phase	Date
Commence dewatering Open Cut Pit with evaporative sprayers and pumping to TSF4	01/09/2022
Completion of TSF3 and TSF4 construction	15/12/2022
Pumping from Open Cut Pit to TSF3	15/12/2022
Transfer half the evaporative sprayers from the Open Cut Pit to TSF3	01/02/2023
Commencement of mining from the Open Cut Pit (Dependent on dewatering of Open Cut Pit)	01/02/2023

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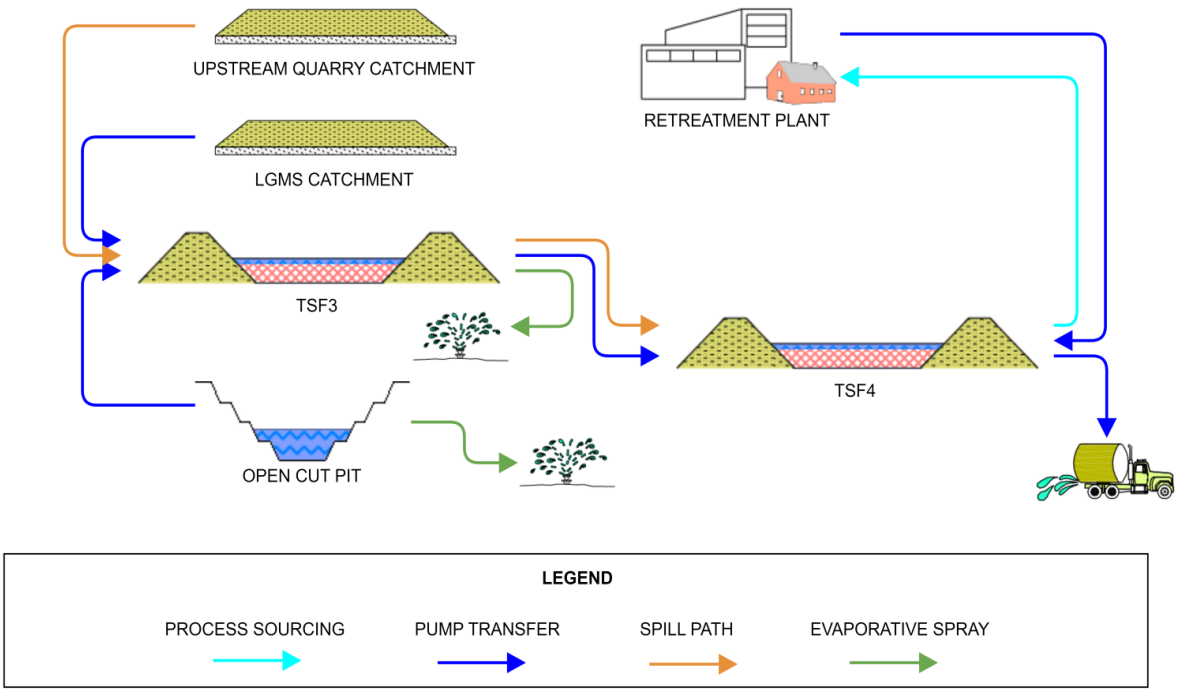
The key elements in this site water balance model are described below, with a process flow diagram representing the initial dewatering of the Open Cut Pit prior to construction of TSF3 shown in **DIAGRAM 8** and the post-TSF3 and TSF4 upgrade conditions shown in **DIAGRAM 9**.

DIAGRAM 8: PROCESS FLOW DIAGRAM (PRIOR TO CONSTRUCTION OF TSF3)



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DIAGRAM 9: PROCESS FLOW DIAGRAM POST CONSTRUCTION OF TSF3 AND TSF4 UPGRADE



4 CONSEQUENCE CATEGORY ASSESSMENT AND DESIGN CRITERIA

4.1 Consequence Category Assessment

The Consequence Category Assessment (CCA) for the proposed TSF3 and TSF4 embankment raises undertaken in accordance with DES (2016) [5]. In addition, the storage was also assessed in accordance with ANCOLD (2019) [6].

The storage/containment requirements shall be in accordance with the Manual for Assessing Consequence Categories and Hydraulic Performance of Structures DES (2016) [5], which defines the storage capacity required for a water containment dam. Assessed failure modes and determining consequence categories are summarised in **Table 7.**

TABLE 7: DES CONSEQUENCE CATEGORY ASSESSMENT SUMMARY

Failure Scenario	TSF 3 Raise	TSF 4 Raise
Failure to Contain – Seepage	N/A	N/A
Failure to Contain – Overtopping	Low	Low
Failure to Contain – Dam Break	Low	Low
Overall	**Low**	**Low**

Details of the Consequence Category Assessment are outlined in **Appendix A**.

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4.2 Design Criteria

4.2.1 Reference Documents

Criteria for the engineering of the Stage 3 development for Mount Carbine Mine are based on the following key references:

1. DES, 2016. *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures*, (March 2016).[5]**;**
2. ANCOLD, 2019. *Guidelines on Tailings Dams – Planning, Design, Construction, Operation, and Closure – Revision 1*, (July 2019) [7]**;**
3. ANCOLD, 2019. *Guidelines for Design of Dams and Appurtenant Structures for Earthquake,* (May 2019) [8]
4. ANCOLD, 2000. *Guidelines on Selection of Acceptable Flood Capacity for Dams, (*March 2020*)* [9]

Based on this list of references, the key aspects of the design include:

1. Structural stability.
2. Hydraulic Performance.
3. Construction materials.
4. Seepage management; and
5. Emergency Spillway.

4.2.2 Structural Stability

The design basis and criteria adopted for the Stage 3 development of Mount Carbine Mine design are in accordance with the Australian Committee on Large Dams (ANCOLD 2019) [10]. The project design criteria include the minimum Factor of Safety (FoS) requirements recommended by the ANCOLD and were used as targets in the analysis, which are presented in **Table 8.**

TABLE 8: ANCOLD RECOMMENDED MINIMUM SLOPE STABILITY FACTORS OF SAFETY

Loading Condition	Minimum FoS	Shear Strength Criteria
Long-term drained	1.50	Effective Strength
Short-term undrained (potential loss of containment)	1.50	Consolidated Undrained Strength
Short-term undrained (no potential loss of containment)	1.30	Consolidated Undrained Strength
Post-Seismic	1.00 – 1.20	Post-Seismic Shear Strength*

* Cyclically reduced undrained/drained shear strength and/or liquefied residual shear strength for potentially liquefiable materials.

The target for the post-seismic loading condition ranges between 1.00 and 1.20 based on the ANCOLD guidelines (ANCOLD 2019) [11]. Following ANCOLD, this range is related to the confidence that the selection of residual shear strength with 1.0 may be adequate for use with lower bound results. ATCW have adopted a value of 1.20 for this analysis based on the geotechnical data regarding the residual shear strength of existing materials. This should be reviewed in the later design stages following the completion of the ongoing site investigation.

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4.2.3 Spillway Design

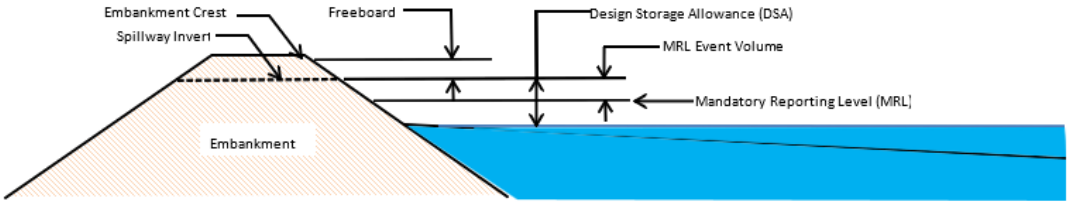
The minimum spillway capacity based on ANCOLD (2019) for a Low Consequence Category is summarised as follows:

Design Flood:	1:100 AEP
Wave Freeboard Allowance:	Wave runup for a 1:10 AEP wind

4.2.4 Design Storage Allowance (DSA) and Mandatory Reporting Level (MRL)

The storage/containment requirements are assigned based on the guidance provided in the Manual for Assessing Consequence Categories and Hydraulic Performance of Structures DES (2016) [5]. The Manual defines the Design Storage Allowance (DSA) and Extreme Storm Event (ESS) containment requirements, illustrated in **DIAGRAM 10.**

DIAGRAM 10: HYDRAULIC CONTAINMENT CRITERIA



As TSF3 and TSF 4 are not regulated structures (Low consequence category dams), DSA and MRL are not required. Notwithstanding, maintenance of freeboard within the storage is required to minimise the spill probability as detailed in ATCW (2022).

5 GEOTECHNICAL DESIGN

5.1.1 Slope Stability Analysis

The slope stability analysis was performed using the software developed by GeoSlope International Inc. SLOPE/W, a two-dimensional computer program that performs slope stability computations using limit-equilibrium methods. The Morgenstern-Price method (Morgenstern-Price, 1965) with a half sine function for interslice forces was selected for performing the computations in SLOPE/W. The method uses circular and non-circular shear surfaces and satisfies both moment and force equilibrium.

Stability evaluations were completed for potential downstream (DS) failures and were assessed for potential global failures (failures from embankment crest to embankment toe).

A summary of the failure surface definitions used in the stability assessment is as follows:

- The analyses performed the slope-stability analysis by defining slip surface entry/exit methods. It has been set to evaluate the impact of failures initiated along the slope or crest of the embankment and extending along the bedrock surface. This is also consistent with ANCOLD recommendations to select critical failure surfaces that would cause significant damage should failure occur.
- The pore water pressures utilised in the analyses were based on the results of the seepage analysis.

5.1.1.1 Material Properties

The material properties used in the slope stability analyses were based on experience from similar cases also well-known literature. The materials implemented for this slope stability investigation are shown in **Table 9.**

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The post-seismic loading conditions may be conservative, considering the site's relatively low seismic loading levels.

TABLE 9: MATERIAL STRENGTH PARAMETERS

Material	Unit Weight, γ (kN/m³)	Effective Parameters		Undrained Shear Strength Ratio	Post-Seismic	
		Cohesion, c (kPa)	Friction Angle, ϕ (º)		Effective Cohesion, c' (kPa)	Effective Friction Angle, ϕ' (º)
Embankment Rock Fill buttress	21	0	38	-	-	32
Embankment Rock Fill transition	20	0	35	-	-	29.3
Existing embankment Clay Fill	18	0	-	0.35	-	-
New embankment Clay Fill	18	0	-	0.35	-	-
Silty Clay	18	5	28	0.35	1	28
Weathered Shale	23	5	34	-	5	34

5.1.1.2 Analysis Cases

5.1.1.2.1 Short-Term – End of Construction

This case represents conditions immediately after the construction of the embankment raise. The phreatic surface has been taken from the seepage analysis, estimating the phreatic surface at the end of the construction phase of the raise with corresponding assumptions. The embankments were evaluated in terms of downstream (D/S) stability while considering the following cases:

1. In this case, all materials were characterised using drained and undrained counterparts. Consistent with ANCOLD Guidelines, all undrained strengths were capped at their respective drained strengths.
2. A minimum required factor of safety of 1.5 was adopted for this case, following ANCOLD Guidelines.
3. The slope-stability analysis also implemented the calculated B-bar value for the surface soil. The added weight is assumed to be the new Embankment Clay/Earth Fill and Embankment Rockfill. The other materials are not considered to be added weight because they exist.

5.1.1.2.2 Short-Term – Rapid Drawdown

This scenario evaluates the phreatic surface if the Dam requires a rapid water drawdown.

In this scenario, the analysis ensured that the influence of the water table and residing pore water pressures within embankment and insitu materials were insufficient to promote a failure to the upstream shoulder. This was modelled as a constant water head function with over a period of 30 days, as estimated by the pump-out rate of the TSFs.

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5.1.1.2.3 Long-term, Full Supply Level

This scenario evaluates the highest phreatic surface of the TSF, which assesses the dam at the full supply level of the storage. In this scenario, the upstream boundary condition was adopted as a constant head at RL 355.5m. It was used directly as an input to the stability analyses performed to evaluate the long-term condition of the TSF.

5.1.1.2.4 Post Seismic

In this scenario, the stability analyses were performed to evaluate the TSF condition post-seismic event using a 20% reduction in the material strength parameters keeping the phreatic surface at FSL (constant head at RL 355.5m).

5.1.1.3 Results of Geotechnical Analyses

The results of the slope stability analyses for the cross-section are presented in **Table 10.**

TABLE 10: SUMMARY OF CRITICAL SLOPE STABILITY FACTORS OF SAFETY

Scenario	Minimum FoS recommended by ANCOLD	Achieved FoS
End of Construction - Downstream	1.30*	1.30
End of Construction - Upstream	1.30*	1.64
Effective Drained - Downstream	1.50	2.02
Effective Drained - Upstream	1.50	3.38
Post-Seismic - Downstream	1.20	1.73
Post-Seismic - Upstream	1.20	1.84
Undrained - Downstream	1.50	1.54
Undrained - Upstream	1.50	2.77
Rapid Drawdown - Upstream (32days)	1.50	1.51

*Assumes stored water is not contaminated

The results demonstrate that the calculated factors of safety meet or exceed the minimum ANCOLD design criteria values for all analysed sections and loading conditions. Therefore, the proposed TSF embankments raise configuration is considered stable under both short- and long-term conditions and potential post-seismic events. The results are presented in **Appendix B.**

5.1.2 Seepage Modelling

A seepage analysis was performed to estimate the phreatic surface at the site during specific site conditions by implementing the SEEP/W software package developed by GeoSlope International Inc. The results produced by the seepage analysis were adopted as a parent analysis for providing the required pore pressure magnitudes used in slope stability analyses.

5.1.2.1 Permeability Parameters

The permeability parameters adopted for each material are presented in **Table 11.** The adopted parameters were quantified based on the review of available literature and experience with similar project settings.

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TABLE 11: SEEPAGE PERMEABILITY PARAMETERS

Material	Horizontal permeability, k (m/s)	Kh' / Kv' Ratio
Embankment Rockfill Buttress	1×10^{-4}	1
Embankment Rockfill Transition	1×10^{-5}	1
Existing embankment Clay fill	1×10^{-8}	0.2
Silty Clay	1×10^{-8}	0.2

5.1.2.2 Results of Seepage Analysis

The results of the seepage assessment are shown in **Appendix B**.

6 SPILLWAY HYDRAULIC DESIGN

The designed emergency spillway for the TSF3 is located on the eastern perimeter of the storage facility, formed through the Stage 3 raise embankment and discharging to TSF4 through existing culverts. The TSF4 emergency spillway is located on the southern perimeter close to the existing releasing point.

The approach to emergency spillway construction for TSF3 and 4 is to excavate into natural sequences or over the embankment (as directed on site) with armouring using coarse rock fill. Both TSFs have a consequence category of 'LOW' per DES requirements. However, the spillway was designed conservatively to accommodate runoff from a 1:1000 AEP. Summary results from the emergency spillway design analysis are provided in **Table 12.**

TABLE 12: TSF3 AND TSF4 EMERGENCY SPILLWAY DETAILS

Parameter	TSF3 Spillway Value	TSF4 Spillway Value
Base Width	22 m	25 m
Side Slopes	1:10	1:10
Longitudinal Grade	1%	1%
Spillway Depth	1 m	1 m
Flow Depth	0.49 m	0.50 m

7 STAGE 3 WASTE MANAGEMENT AND NOISE BUND

7.1 Waste Rock Dump

As part of Stage 3 development, a waste rock dump is required to be constructed to the south of the Pit. This location will contain waste rock derived from the Mt Carbine Mine operation based on the mining schedule. The WRD will be constructed on a low permeability founding layer/platform, which would preferentially drain toward the Pit via a seepage collection sump. During the WRD development and post-development as required, seepage will be monitored and recovered via the construction of the seepage collection sump. The WRD is proposed to be temporary storage of waste rock material, with the material ultimately being placed back into the Pit.

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- The key issues and risks concerning WRD development would be;
- General shedding of incident rainfall
- Availability of suitable construction materials
- Seepage management from the WRD and minimising infiltration/seepage
- Stability of WRD

The criteria for the final WRD landform are summarised below:

- Containment capacity 409,000m^3
- External batter configuration slopes 1.5 (H):1(V)
- WRD basal platform minimum surface grade 3%
- WRD basal platform minimum thickness 600mm

For seepage management, a basal platform comprising a low permeability graded zone and graded in a form to preferentially direct seepage to the Pit.

The basic development logistics and construction of the WRD in relation to the waste placement details would be as follows:

- A basal low permeability platform shall be formed using Earthfill (Clay) to provide a graded platform, draining towards the Pit.
- The maximum elevation of RL 416m, with a maximum landform height of 21m above the adjacent natural surface
- The minimum surface slope of some 3%
- External batters are to be formed at a maximum overall slope of 1 (H):1.5(V)
- A sump shall be designed and constructed to direct surface water runoff and seepage water towards the Pit.

The basal low permeability platform consists of a low hydraulic conductivity compacted clay layer which aids in minimising net percolation. The stored water from incident rainfall will either be removed through evapotranspiration or move through the Waste rock as Net Percolation and report to the WRD Sump and the Pit, should the capacity of the Sump be exceeded. While constructing, the air entry to the waste rock must be limited through shallow tip heads,paddock dumping and compaction. Waste rock will be dumped in layers not exceeding 1.5 m and will be compacted by haul truck or other means to achieve a thickness of at least 1.2 m. During high (and more intense) rainfall, an interim cover system over the waste rock shall be provided to limit the ponding of rainwater, net percolation and oxygen ingress rates, with water shedding towards the Sump. Cover system options could be a geomembrane, such as low-density polyethylene (LDPE) liner, geosynthetic clay liner (GCL) or earth fill.

7.2 Noise Bund

At peak production, a noise model has been developed for the Mt Carbine mine. The noise levels generally comply with the acoustic quality objectives; however, as mining progresses deeper into the Pit, the haul trucks increase significantly and potentially become the dominant noise source. Therefore, the SEG noise and vibration assessment [12] recommended constructing a 10m height noise bund adjacent to and south of the haul route, as shown in **DIAGRAM 11**.

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DIAGRAM 11: NOISE BUND MODEL [12]



7.2.1 Noise Bund Specification

The Noise Bund should be durable, erosion resistant and properly constructed to maintain the design intent. The Noise Bund foundation must be stripped of topsoil or other weathered unsuitable material. Fill for use in the Noise Bund formation can be dumped and trimmed using an excavator. The criteria for the final Noise Bund landform are summarised below:

- Batter angles are 1 (vertical) on 2.5 (horizontal).
- The height should be greater than 10 m
- Crest width of 17 m
- Safety bunds as required for trafficking.

The constructability component of the noise bund has been discussed with EQR and the proposed Mine Contractor. It is agreed to construct the Noise Bund as an elevated roadway, creating safety bunds on both sides of the bund. Ramps at either end of the bund shall be provided for truck access during construction and shall be formed with a maximum grade of 10%. The safety bunds shall generally comprise a 7 m wide base, 2 m crest width and 1 m minimum height, constructed using waste rock.

To utilise available mining equipment, the Noise Bund is to be constructed by paddock dumping mine waste rock and dozing to form a nominally 3 m lift.

7.2.2 Pit Wall Slope Stability Assessment

The noise bund will remain at mine closure serving as the pit bund. The bund incorporated the following design criteria, as contained within the safety bund wall guidelines for abandoned open pit mines, produced by the WA Department of Industry and Resources [13]:

- Abandonment bunds will be constructed at least 10 m outside the area designated as the potentially unstable pit edge zone.

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- The potentially unstable pit edge zone will be defined by the distance between the existing pit edge and the point where a plane has drawn at 25° (weathered rock), or 45° (unweathered rock) from the slope toe intersects the ground surface. Based on our visual inspection, we adopted 45° as the pit stability data was unavailable.
- Abandonment bunds will be constructed to a minimum height of 2 metres and a minimum base width of 5 metres.

A pit wall stability assessment was undertaken to determine a minimum setback from the final pit edge.

The stability assessment was conducted based on the recent IB03, 04 and 08 test pits and historical geotechnical report (Ref) for the drilled holes and discontinuities properties which shown in **DIAGRAM 12** to **DIAGRAM 14**.

DIAGRAM 12: PIT CONSTRUCTION STAGES AND CURRENT TEST PITS IN THE VICINITY OF THE SOUTH WALL

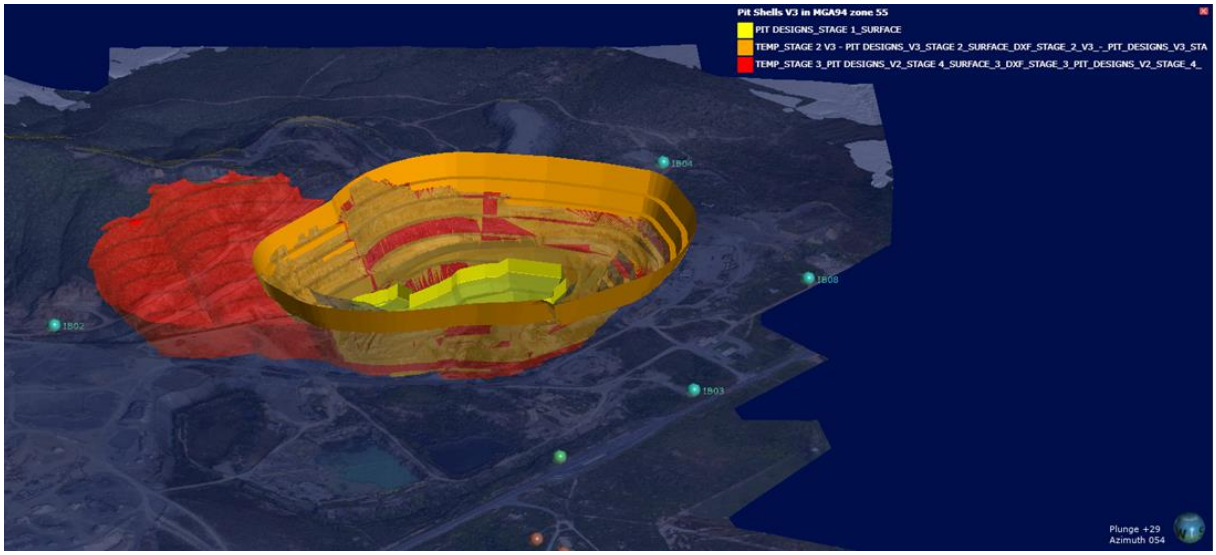
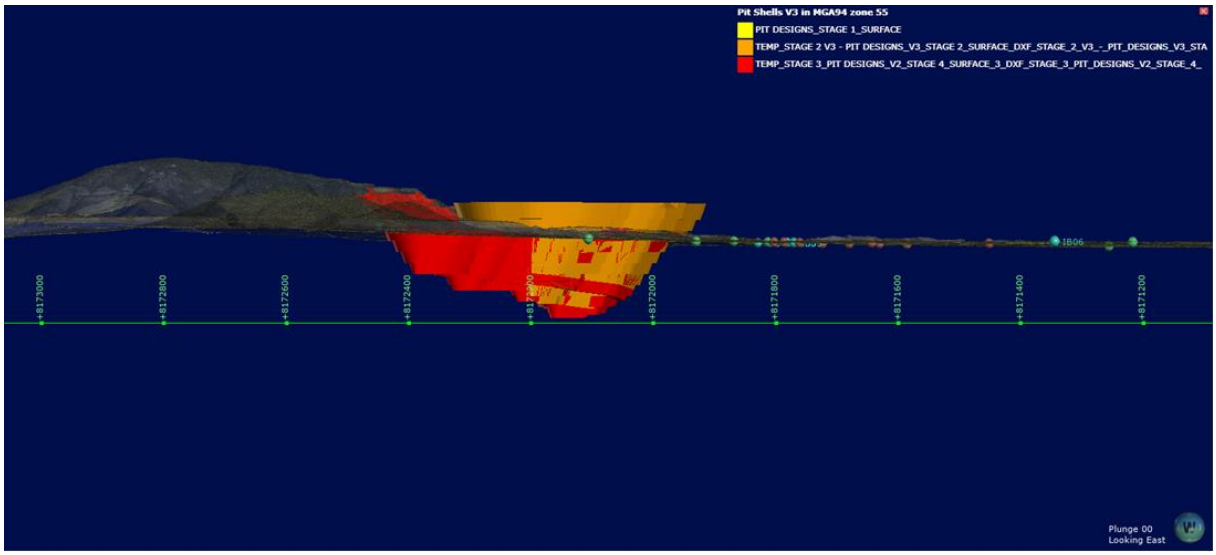
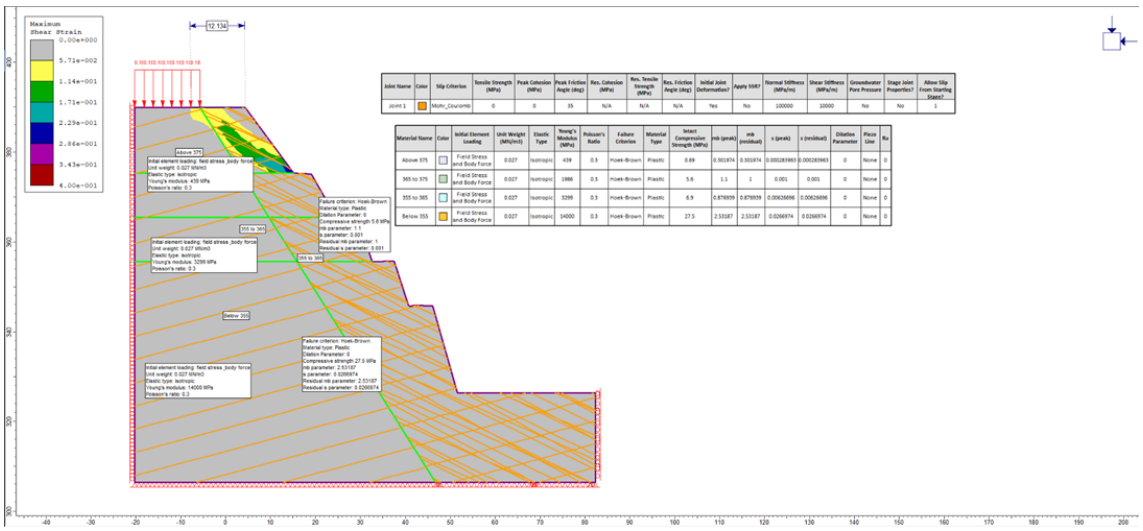


DIAGRAM 13: PIT CROSS-SECTION



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DIAGRAM 14: EAST-WEST CROSS SECTION



Initial Slope Assessment for determining the noise wall offset distance (random joints were applied up to the SW depth).

Based on the above assessment, it is concluded that the noise bund can be constructed at a minimum of 12.0 m offset from the Pit's edge. As part of the mine development, it is recommended that the wedge and block failures be further assessed subject to receipt of specific rock mapping of the Pit.

8 CONSTRUCTION ASPECTS

8.1 Construction (Earthworks Materials)

It is proposed the embankments forming the TSF3 and TSF4, WRD, and Noise Bund will be constructed using the following materials, also summarised in **Table 13**:

- Rock Fill Zone will comprise the downstream embankment shell for stability and as a cover layer on the upstream face to provide erosion protection for the clay embankment core. Also used to construct a basal platform for the WRD and the Noise Bund.
- Rock Fill Transition Zone (Filter) will be placed in between the clay core and rockfill buttress to provide erosion protection for the clay embankment core.
- Clay/Earth Fill Zone will comprise the upstream core of the embankment as a low permeability material to drawdown the phreatic surface through the embankment. Clay Fill will also be used for the WRD Clay Liner.

TABLE 13: SUMMARY OF EARTHWORK MATERIAL

Material	TSF3 Embankment Raise	TSF4 Embankment Raise	Waste Rock Dump	Noise Bund
Rock Fill	✓	✓	✓	✓
Filter	N/A	✓	N/A	N/A
Clay/Earth Fill	✓	✓	✓	N/A

Criteria adopted for earthworks materials to be used in raise construction have been developed based on relevant performance criteria (particularly embankment stability) to ensure that appropriate

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performance standards are achieved. The resulting criteria for construction material types proposed for use in the construction of the raise are outlined below.

8.1.1 Clay/Earthen Fill

Clay/Earthen fill for use in the TSF4 embankment upstream face, TSF3 raise, and WRD Liner key target properties are as outlined:

- Fine content (clay/silt fraction (<75µm) greater than 20% and Liquid Limits greater than 35%);
- Undrained shear strength over 50kPa after compaction.
- Achieved compaction permeability of less than 10-8m/s; and
- Engineerable to reduce potential “internal” erosion/piping.

Basic criteria for Clay/Earthen Fill materials would be to create a fill layer that can be engineered (i.e., achieves low voids, competent horizon when compacted) and is stable (i.e., not subject to significant vertical settlement under load or volume instability due to variation in moisture content). Additionally, the material should be non-dispersive when compacted to Specification requirements. The clay and earthen materials available on the site have been identified within the TSF 4 storage areas and generally meet the above requirements.

8.1.2 Rock Fill (Rock Armouring)

The purpose of Rock Fill within the embankment is to enhance structural stability. Rock Fill is also used as erosion protection on external portions of the embankment, and should possess the following general characteristics:

- High load-bearing capacity.
- Stable and durable (with respect to a potential settlement, volume instability, erosion potential and weathering);
- High permeability relative to adjacent clay/earthen fill core zones; and
- Geochemically stable (i.e., non-acid producing).

Details of the construction specification are outlined in **Appendix C**.

9 OPERATIONAL REQUIREMENTS

9.1 Regulatory Requirement

DES requires the dam owner to prepare and submit an operational plan consistent with the Environmental Authority’s requirements for all regulated structures. The consequence category for Mt Carbine mine, attached in **Appendix A**, categorises the dams as Low.

Periodic review and updating are required following any modifications to the conditions on which the document is based. The timing for such updates includes, but is not necessarily limited to, the following:

- Alteration (either increase or decrease) of the capacity by increased footprint or storage height.
- A significant incident with respect to the facility’s operation and/or performance is experienced.
- A significant change to the Environmental Authority, or conditions contained therein, is made.

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9.2 Inspection and Monitoring

Regular site surveillance and monitoring of the TSF3/TSF4 embankment shall be undertaken based on the following aspects:

- Settlement monitoring of the embankment – a minimum of 6 monuments is suggested, located on the downstream embankment crest. Monitoring should be undertaken at a frequency not greater than 6 months during high-water levels.
- Routine visual inspection, especially following significant rainfall events, to inspect the physical conditions of the embankment, spillway, and diversion system.

9.3 Emergency Action Plan

An emergency action plan for the TSF3/TSF4 is not required as no Population at Risk (PAR) is situated downstream, and the Low classification is assigned in the CCA under the Manual [5].

10 CLOUSURE AND RECLAIMATION

The final landforms will be subject to investigation works and detailed assessment in the years before closure. They would typically include an assessment of the water chemistry and the surrounding environment. The typical objectives to be adopted for rehabilitation of the Mt Carbine site would be to create a landform that is:

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

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REFERENCES

[1] GHD, 'Annual Hazardous Dam Inspection 2016 – Dam Inspection Report (prepared for on behalf of Carbon Tungsten Limited).', 2016.

[2] Northcote et al, 1968 1960. [Online]. Available: https://researchdata.edu.au/digital-atlas-australian-soils/1438223

[3] QLD Government DSITI, 2022. [Online]. Available: https://www.longpaddock.qld.gov.au/silo/point-data/

[4] Bultitude et al, 1999. [Online]. Available: https://catalogue.nla.gov.au/Record/2924815

[5] DES, 'Manual for Assessing Consequence Categories and Hydraulic Performance of Structures Ver. 5.01.', 2016.

[6] ANCOLD, 'Guidelines for Design of Dams and Appurtenant Structures for Earthquake', 2019.

[7] ANCOLD, 'Guidelines on Tailings Dams – Planning, Design, Construction, Operation, and Closure – Revision 1', 2019.

[8] ANCOLD, 'Guidelines for Design of Dams and Appurtenant Structures for Earthquake', 2019.

[9] ANCOLD, 'Guidelines on Selection of Acceptable Flood Capacity for Dams', 2000.

[10] ICOLD, 'Bulletin 74, Tailings Dam Safety.', 1989.

[11] ANCOLD, 'Guidelines on the Consequence Categories for Dams, October 2012', 2012b.

[12] SEG, 'Noise and vibration assessment', Nov. 2022.

[13] Department of industry and resources, 'Safety bund walls around abandoned open pit mines', Dec. 1997.

CONDITIONS OF REPORT

1. This report must be read in its entirety.
2. This report has been prepared by ATCW for the purposes stated herein and ATCW's experience, having regard to assumptions that can reasonably be expected to make in accordance with sound professional principles. ATCW does not accept responsibility for the consequences of extrapolation, extension or transference of the findings and recommendations of this report to different sites, cases, or conditions.
3. This document has been prepared based in part on information which was provided to ATCW by the client and/or others and which is not under our control. ATCW does not warrant or guarantee the accuracy of this information. The user of the document is cautioned that fundamental input assumptions upon which the document is based may change with time. It is the user's responsibility to ensure that these assumptions are valid.
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CONDITIONS OF GEOTECHNICAL INVESTIGATION

1. 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.
2. 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.
3. 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.

.

APPENDICES

APPENDIX A – CONSEQUENCE CATEGORY ASSESSMENT

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1 AVAILABLE SITE DATA AND REFERENCE GUIDELINES

This CCA was undertaken using the guidelines in the Manual **[3]**. The following data were available and considered in completing the CCA:

- Manual **[3]**.
- Queensland Globe Map Resource, retrieved 9 August 2022 **[17]**
- SILO Data Drill for Mt Carbine Mine, Lat, Long: -16.55 145.15 of evaporation data and patched rainfall for 01/01/2010 to 19/06/2022 **[6]**.
- 'Environmental Reports – Matters of State Environmental Significance', 9 August 2022, Department of Environment and Science **[29]**.
- 'Environmental Reports – Biodiversity and Conservation Values – Biodiversity Planning Assessments and Aquatic Conservation Assessments', 9 August 2022, Department of Environment and Science **[30]**.
- 'Environmental Reports – Regional Ecosystems – Biodiversity Status', 9 August 2022, Department of Environment and Science **[31]**.
- 'EPBC Act Protected Matters Report', 9 August 2022, Department of Agriculture. Water and the Environment and Energy Error! Reference source not found..

2 GENERAL ENVIRONMENTAL HARM ASSESSMENT

2.1 General

In assessing the consequence category for the failure of a structure in accordance with the Manual, the assessment is undertaken against the following "environmental harms":

- harm to humans,
- general environment harm, and;
- general economic loss or property damage.

When considering general environmental harm, the receiving environment for the failure of a structure includes but is not limited to ephemeral waterways, creeks and rivers. The main receiving environment for the site within a 10 km flow path includes:

- Holmes Creek,
- Manganese Creek; and
- Mitchell River.

The Mitchell River receives flows from Balfe Creek approximately 6 km downstream of the site.

In accordance with the Manual, the Consequence Category Assessment (General Environmental Harm) is concerned with effects on areas with 'Significant Values' and 'Moderate Values' within the receiving environment. The values are defined as follows.

- Significant Values
  - Matters of National Environmental Significance (MNES) **[15]**

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  - Matters of State Environmental Significance (MSES) **[16]**
  - High Ecological Value (HEV) waters as per the Queensland Environmental Protection (Water) Policy 2009 (EPP Water). **[16]**
  - Business Queensland Bore Reports (from Queensland Globe) **[17]**
- Moderate Values
  - Slightly or moderately disturbed waters as per the EPP Water
  - Wetland of general ecological significance (GES) as mapped on the Queensland Government referable wetland mapping **[18]**
  - Riverine areas, springs or lakes and associated flora and fauna.

The characteristics and exposure of these receiving environments are identified in the environmental assessment reports in **Appendix A**, **Appendix B**, **Appendix C** and **Appendix D**.

2.2 TSF Potential Surface Environment Impacts

The unnamed tributary of Manganese Creek and Holmes Creek, in the context of environmental values, were assessed from the following sources:

- Matters of National Environmental Significance
- Matters of State Environmental Significance
- High Ecological Value Wetlands and Waterways
- Aquatic Conservation Significance
- Registered Private Bores

The relevant information from these data sources is discussed in the following sub-sections.

2.2.1 Matters of National Environmental Significance

The Protected Matter Report (PMR) Error! Reference source not found. for the project, area is provided in **Appendix A.** The report lists the MNES that may occur within a 10 km radius of the TSF Raise location. It includes locations upstream and downstream of the project area, as well as locations in adjacent catchments.

There are some World Heritage Properties, National Heritage Places, Wetlands of International Importance, and Broad leaf tea-tree (Melaleuca viridiflora) woodlands in high rainfall coastal north Queensland Listed Threatened Ecological Communities (Endangered) in the PMR and summarised in **Table 1.**

TABLE 1: MNES LISTED HERITAGE PROPERTIES

Heritage Properties	Name	Legal Status	Buffer Status
World	Wet Tropics of Queensland	Declared property	In buffer areas, only

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Heritage Properties	Name	Legal Status	Buffer Status
National	Wet Tropics World Heritage Area (Indigenous Values)	Within listed place	In buffer areas, only
Natural	Wet Tropics of Queensland	Listed place	In buffer areas, only

The PMR **[28]**contains 15 Listed Threatened Species and 11 Migratory Species listed for the receiving environment in the PMR. The critically endangered and endangered animals listed in the PMR report is summarised in **TABLE 2.**

TABLE 2: MNES LISTED CRITICALLY ENDANGERED AND ENDANGERED ANIMALS

Name	Scientific Name	Status	Comments
Curlew Sandpiper	Calidris Ferruginea	Critically Endangered	Species or species habitat may occur within the area (Bird)
Southern Cassowary, Australian Cassowary, Double-wattled Cassowary [25986]	Casuarius casuarius johnsonii	Endangered	Species or species habitat likely to occur within the area
Gouldian Finch	Erythrura gouldiae	Endangered	Species or species habitat likely to occur within the area
Eastern Curlew, Far Eastern Curlew	Numenius madagascariensis	Critically Endangered	Species or species habitat may occur within the area
Australian Painted Snipe	Rostratula australis	Endangered	Species or species habitat is known to occur within the area
Buff-breasted Button-quail	Turnix olivii	Endangered	Species or species habitat likely to occur within the area
Tapping Nursery-frog	Cophixalus aenigma	Endangered	Species or species habitat likely to occur within the area
Armoured Mistfrog	Litoria lorica	Critically Endangered	Species or species habitat is known to occur within the area

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Name	Scientific Name	Status	Comments
Mountain Mistfrog, Nyakala Frog	Litoria nyakalensis	Critically Endangered	Species or species habitat likely to occur within the area
Northern Bettong	Bettongia tropica	Endangered	Species or species habitat likely to occur within the area
Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu]	Dasyurus hallucatus	Endangered	Species or species habitat is known to occur within the area
Yellow-bellied Glider (Wet Tropics), Fluffy Glider	Petaurus australis Wet Tropics subspecies	Endangered	Foraging, feeding or related behaviour is known to occur within the area
Koala (combined populations of Queensland, New South Wales and the Australian Capital Territory)	Phascolarctos cinereus (combined populations of Qld, NSW and the ACT)	Endangered	Species or species habitat likely to occur within the area
Spectacled Flying-fox	Pteropus conspicillatus	Endangered	Species or species habitat is known to occur within the area
Lesser Swamp-orchid	Phaius australis	Endangered	Species or species habitat may occur within the area
Prostanthera albohirta	Prostanthera albohirta	Critically Endangered	Species or species habitat may occur within the area
Dwarf Butterfly Orchid, Cooktown Orchid	Vappodes lithocola	Endangered	Species or species habitat is known to occur within the area
Curlew Sandpiper	Calidris ferruginea	Critically Endangered	Species or species habitat likely to occur within the area
Eastern Curlew, Far Eastern Curlew	Numenius madagascariensis	Critically Endangered	Species or species habitat may occur within the area
Curlew Sandpiper	Calidris ferruginea	Critically Endangered	Species or species habitat likely to occur within area overfly the marine area

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Name	Scientific Name	Status	Comments
Eastern Curlew, Far Eastern Curlew	Numenius madagascariensis	Critically Endangered	Species or species habitat may occur within the area
Australian Painted Snipe	Rostratula australis as Rostratula benghalensis (sensu lato)	Endangered	Species or species habitat known to occur within area overfly the marine area

2.2.2 Matters of State Environmental Significance

There are several areas of Matters of State Environmental Significance (MSES) **[29]** within ML4867 and the 10km buffer area pertaining to:

- Wildlife Habitat (special least concern and endangered or vulnerable),
- Regulated vegetation (essential habitat); and,
- Regulated vegetation (intersecting a watercourse) along the unnamed tributary of Mitchell River.

These areas are shown in the MSES documentation in **Appendix B – Map 3a and Map 4**.

2.2.3 High Ecological Value Wetlands and Waterways

Assessment of the available data MSES data **[29]** (**Appendix B**) showed that no High Ecological Value (HEV) wetlands or waterways were identified in the receiving environment within ML4867 and the 10 km buffer area.

2.2.4 Aquatic Conservation Significance

The unnamed tributary of Holmes Creek, Manganese Creek, and Mitchell River are located in the Einasleigh Uplands bioregion, the Hodgkinson Basin subregion, which falls within the Micthell River catchment. The unnamed tributary of Holmes Creek, Manganese Creek, was assessed against the characteristics of riverine areas, lakes and springs, as per the Queensland Government Wetland Maps **[32].** Review of the available wetland mapping, MNES**[28]**, MSES **[29]**, Biodiversity and Conservation Values **[30]** and Regional Ecosystems **[31]** did not identify any riverine waterbodies in the unnamed tributary of Holmes Creek, Manganese Creek.

The MSES documentation is in **Appendix B.**

3 ENVIRONMENTAL VALUES

3.1 General

The local environmental values have been designated by the Commonwealth and Queensland Governments. The data is available from the following sources.

- Matters of National Environmental Significance (MNES) Report
- Matters of State Environmental Significance (MSES) Report

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- High Ecological Value (HEV) waters set out by the Queensland Environmental Protection (Water) Policy 2009 (EPP Water)
- Wetlands of general ecological significance (GES), set out on the Queensland Government referable wetland mapping site
- Riverine areas, springs or lakes and associated flora and fauna.
- Business Queensland Bore Reports (from Queensland Globe) **[17]**

The environmental reports for the environmental factors are provided in **Appendices B and C**.

In addition to the Queensland Government assessments, Schedule 1 of the 'Environmental Protection (Water and Wetland Biodiversity) Policy 2019', which is subordinate legislation to the 'Environmental Protection Act 1994' (EP Act) . This documents the waters for which the legislation applies that are either enhanced or protected and specifies relevant environmental values (EV's) and Water Quality Objectives (WQO's). The MNES report in Appendix C provides details of the matters of environmental significance that may occur or relate to an area of 10 km around the Mount Carbine site that is protected by the Environmental Protection Biodiversity and Conservation (EPBC) Act.

3.2 Wetlands and Waterways

A review of Schedule 1 of the 'Environmental Protection (Water and Wetland Biodiversity) Policy 2019 indicates that the Mitchell River Basin does not currently have gazetted and mapped EV's or WQO's. Notwithstanding, generalised assessment under the Environmental Policy can be based on the nature of the receiving environment, as described in more detail below.

The MNES report in **Appendix C** states that there were no wetlands of international importance within 10 km of the site.

The MNES report Indicates that the site is located within a water resource planning area. A water resource plan is a scheme over a part of the State that advances the sustainable management of Queensland's water. This planning area indicates that there is a system in place to allocate the use of water in the area and to provide riverine protection to the watercourses and groundwater that may be used for water supply.

The receiving environment surrounding the project site is 'slightly to moderately disturbed as a result of the impacts of low-intensity cattle grazing and exploration activities in the area. The ANZECC guidelines define 'slightly to moderately disturbed' systems as:

Ecosystems in which aquatic biological diversity may have been adversely affected to a relatively small but measurable degree by human activity.

Based upon the hydrological domains downstream of the project site and potential downstream users, the classification of Environmental Values (EV's) for the downstream environment may include:

- Aquatic ecosystems;
- Primary industries, including irrigation, stock drinking water, aquaculture and human consumption of aquatic foods;
- Recreation and aesthetics;
- Drinking water;
- Industrial water; and
- Cultural and spiritual values.

The MSES Report **Appendix B** states that there are no wetlands or waterways in high ecological value (HEV) waters within Lot SP254833, which contains the Mount Carbine Mine site.

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3.3 Groundwater

The Environmental Management Plan Reported environmental values for the area in the absence of a definition in legislation, and these values remain applicable. The Environmental Management Plan presented information that showed that:

- Groundwater in the area is moderately alkaline.
- Shallower groundwater is generally of lower electrical conductivity than deeper groundwater. As electrical conductivity is one measure of water salinity, the deeper groundwater is more saline than the shallower groundwater. Higher salinity groundwater is generally an indication of longer residence time within the aquifer zone. Therefore it is likely that the hydraulic conductivity of the deeper aquifer zone is less than the hydraulic conductivity of the shallower aquifer zone, with consequent lower groundwater flow velocity in the deeper aquifer zone.
- The electrical conductivity of the groundwater indicates that the water is naturally brackish and not suitable for human consumption.

Therefore, the following values have been nominated for the Project:

- stock watering
- firefighting (industrial).

3.4 Protected Fauna

The MSES report (**Appendix B**) has not identified any protected special wildlife reserves, state marine parks or fish habitat areas within Lot SP254833.

The MSES did identify a number of threatened (endangered or vulnerable) wildlife within Lot SP254833. The Mount Carbine site is surrounded by an area identified as both Wildlife habitat – special least concern and endangered or vulnerable. The list of animals within each category is provided in the MSES report in **Appendix B**.

3.5 Protected Vegetation

The vegetation surrounding the Mount Carbine site is classified as Category B which is remnant vegetation shown on a regional ecosystem or remnant map as an endangered regional ecosystem, an of concern regional ecosystem or a least concern regional ecosystem. The MSES report in Appendix B has identified this vegetation as 'Protected Areas – nature refuges'. This protected area is named the Brooklyn Nature Refuge. Map 4 in the MSES report has subdivided this protected area into different types of regulated vegetation. The area surrounding the mine site is identified as essential habitat. Further areas of essential habitat and endangered or of concern vegetation exist between the Mount Carbine site and the Mitchell River.

3.6 Groundwater Aquifers

The DES Wetland Info Database Does not hold any aquifer data in the Mareeba Shire region. There are 36 sub-artesian groundwater bores within 20 km of the Mount Carbine site. A summary of the bore locations is provided in **Table 3** and in. The water quality data contained within the borehole records are either a decade old or do not exist. As an alternative to reviewing all the borehole water quality data, the groundwater records from the mine site have been reviewed. A figure showing the locations of the groundwater boreholes on the site is in **Appendix A**. More information on groundwater water quality is provided in **Section 4**.

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DIAGRAM 1: BOREHOLE LOCATIONS WITHIN 20 KM OF THE PROJECT

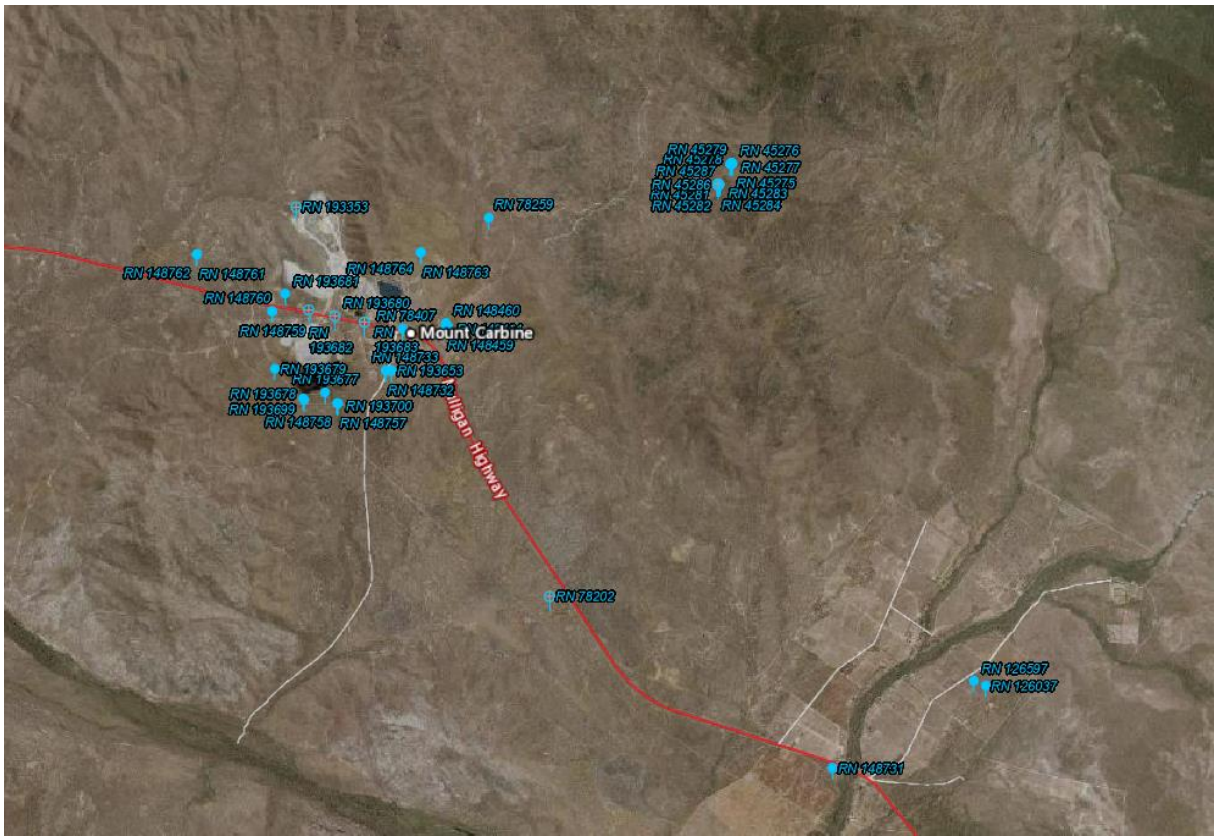


TABLE 3: GROUNDWATER BORES WITHIN 20 KM OF MOUNT CARBINE

Registered Number	Original Name	Latitude	Longitude	Drilled date
45276	FARM 1 BORE 5	-16.50982854	145.1719553	-
45277	FARM 1 BORE 2	-16.50995882	145.1719553	-
45279	FARM 1 BORE 3	-16.50982854	145.171825	-
45275	FARM 1 BORE 1	-16.50982854	145.171825	-
45280	FARM 1 BORE 6	-16.50995882	145.1717599	-
45278	FARM 1 BORE 4	-16.50995882	145.1716947	-
45287	FARM 2 BORE 7	-16.51217359	145.1704571	-
45285	FARM 2 BORE 3	-16.51217359	145.1704571	-
45283	FARM 2 BORE 5	-16.51217359	145.1704571	-
45284	FARM 2 BORE 2	-16.51230387	145.1704571	-
45286	FARM 2 BORE 4	-16.51217359	145.1703268	-
45281	FARM 2 BORE 6	-16.51230387	145.1701965	-

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Registered Number	Original Name	Latitude	Longitude	Drilled date
78259	VILLAGE BORE	-16.51595173	145.1435547	7-May-92
148764	MB 3	-16.51979169	145.1356174	27-Nov-11
148758		-16.53665636	145.1259379	17-Nov-11
148757	MB 4	-16.5366474	145.1259474	16-Nov-11
148732		-16.53299266	145.1315189	15-Nov-11
148733	MB 6	-16.53298371	145.1315283	15-Nov-11
148458		-16.5283333	145.0061111	8-Jul-10
78407		-16.52832723	145.1335146	12-Feb-92
148760		-16.52637676	145.1182623	20-Nov-11
148759	MB 1	-16.52636781	145.1182718	18-Nov-11
148762	MB 5	-16.52001744	145.1094722	24-Nov-11
148761	MB 5	-16.52000849	145.1094817	24-Nov-11
148763	MB 3	-16.51980064	145.135608	27-Nov-11
148457		-16.5180556	145.0066667	1-Jul-10
183803		-16.49194444	145.0008333	25-Oct-19
126037		-16.56814132	145.2015144	28-May-02
126597		-16.5676269	145.2001356	27-Feb-03
148731		-16.57732341	145.1836657	21-Nov-11
148461		-16.5280201	145.1387784	3-Jul-10
148459		-16.5279513	145.1384787	5-Jul-10
148460		-16.5276753	145.1385185	6-Jul-10
45641		-16.50087602	144.9890476	
45164		-16.49961587	144.9891621	1-Jan-70
45163		-16.49824116	144.9890476	1-Jan-66

4 CONTAMINANT SOURCE STUDY

4.1 Preamble

A contaminant source study identifies the origin and chemical composition of different types of water in the mining project. The objective of this is to maintain the biological integrity of the surface waters and groundwater at the project site and to ensure the quality of the water does not adversely affect any environmental values or the health, welfare and amenity of people, fauna and land users by meeting statutory requirements and acceptable standards.

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4.2 Receiving Environment

4.2.1 Catchment Conditions

The Mount Carbine mine site is in the upper reaches of the Mitchell River catchment in Far North Queensland. The site is located approximately 5 km from the Mitchell River, and any surface runoff or spills have the potential to contaminate the surface water network or the local groundwater system. The Mitchell River originates on the Atherton Tableland, in the Great Dividing Range, 48 km northwest of Cairns and flows approximately 750 km northwest across the Cape York Peninsula from Mareeba Shire to the Gulf of Carpentaria. The watershed of the Mitchell River is 41,315 km^2**.** The mine site is bounded by Holmes Creek to the northwest and Manganese Creek to the east. In this location, Homes Creek and Manganese Creek are ephemeral.

4.3 Origin and Chemical Composition of Contaminants

4.3.1 Origin of Contaminants

With reference to the NRA figure showing the EA mapped domains and quarry and mining disturbance areas. In **Appendix A**, the contaminant sources can be classified into mining disturbance and quarry disturbance areas. The areas of the site in the different classifications are provided in **Table 4**

TABLE 4: CONTAMINANT SOURCES

Contaminant Source	
Mining Disturbance	**Quarry Disturbance**
Open Pit	Low-Grade Material Stockpile
Processing Plant and Workshop	Quarry Operational Area
Clean Water Dam	Reject Stockpile
Old mine Workings	TSF3 (not operational)
Overburden Stockpile	Process Water Pond (not operational)
Old Stockpile Area	Tailings Stockpile in TSF4
Roads around the Open Pit	Water Storage in TSF4
Core Yard and Laydown Area	
Offices and Laboratory	
Sulphide Disposal Dump	
Previous Mill and ROM Pad	

4.3.2 Chemical Composition of Contaminants from Different Sources

4.3.2.1 Tailing Storage Facility 4

The tailings geochemistry was developed from water quality monitoring from TSF4 and elemental analysis from 2001 to 2013. The monitoring data indicated that the water in TSF4 was circum-neutral to slightly alkaline. This indicates that no significant acidification occurred in the tailings material, which reflects the composition of the non-acid-forming low-grade stockpile material. The chemical composition of the water in TSF4 is presented in **Table 5**.

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TABLE 5: WATER MONITORING DATA FOR TSF4 (2001-2013)

Element	Units	Median Quantity	EA Release Quality Objective
pH	-	7.15	6.0 – 7.5
Electrical Conductivity	µS/cm	230	5000
Sulphate	mg/L	31	20 x 80th percentile of reference site concentration
Fluoride	mg/L	2.4	Default value or 20 x 80th percentile of reference site concentration
Aluminium (total)	mg/L	0.12	1.1 or 20 x 80th percentile of reference site concentration, whichever is higher
Antimony (total)	mg/L	<0.003	20 or 20 x 80th percentile of reference site concentration, whichever is higher
Arsenic (total)	mg/L	0.038	0.26 or 20 x 80th percentile of reference site concentration, whichever is higher
Cadmium (total)	mg/L	0.0001	0.004 or 20 x 80th percentile of reference site concentration, whichever is higher
Chromium (total)	mg/L	<0.001	0.02 or 20 x 80th percentile of reference site concentration, whichever is higher
Cobalt (total)l	mg/L	0.001	0.028 or 20 x 80th percentile of reference site concentration, whichever is higher
Copper (total)	mg/L	0.002	0.028 or 20 x 80th percentile of reference site concentration, whichever is higher
Lead (total)	mg/L	0.0005	0.068 or 20 x 80th percentile of reference site concentration, whichever is higher
Manganese (total)	mg/L	0.11	38 or 20 x 80th percentile of reference site concentration, whichever is higher
Mercury (total)	mg/L	<0.0001	-
Molybdenum (total)	mg/L	0.097	0.68 or 20 x 80th percentile of reference site concentration, whichever is higher
Nickel (total)	mg/L	<0.001	0.22 or 20 x 80th percentile of reference site concentration, whichever is higher
Selenium (total)	mg/L	<0.003	0.02 or 20 x 80th percentile of reference site concentration, whichever is higher
Tin (total)	mg/L	0.008	-
Tungsten (total)	mg/L	0.034	20 x 80th percentile of reference site concentration
Zinc (total)	mg/L	0.009	0.16 or 20 x 80th percentile of reference site concentration, whichever is higher

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4.3.2.2 Low-Grade Material Stockpile

Testing of samples from the low-grade stockpile all indicated that the material was non-acid forming, and hence generation of strongly acidic drainage was not expected to occur**.** Testing of the sampled material from the low-grade stockpile indicated that arsenic, selenium, cadmium and antimony were significantly enriched. The 2013 Environmental Management Plan. Also indicated that the quality of the seepage from the toes of the low-grade stockpile was circum-neutral and not significantly acidified. The test results of the seepage indicated a range of elements were present in its chemical composition, as listed in **Table 6**.

TABLE 6: ELEMENTS IN SEEPAGE FROM THE LOW-GRADE STOCKPILE (2011-2013)

Element	Units	Median Value (mg/L)
pH (Lowest value reported was 6.4)	-	6.7
Electrical Conductivity	µS/cm	925
Sulphate	mg/L	435
Fluoride	mg/L	9.3
Aluminium	mg/L	1.75
Zinc	mg/L	0.18
Nickel	mg/L	0.031
Manganese	mg/L	0.018
Arsenic	mg/L	0.009
Tungsten	mg/L	0.006
Selenium	mg/L	0.004
Copper	mg/L	0.004
Cadmium	mg/L	0.0016
Cobalt	mg/L	0.0005
Chromium	mg/L	0.0005

The seepage and surface runoff from the low-grade stockpile area is currently pumped to the Open Pit.

4.3.2.3 Clean Water Dam

The Clean Water Dam receives recycled water from the processing plant and surface runoff from the upstream quarry catchment. As a result, it is expected to have similar chemical constituents to the low-

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grade stockpile and TSF4. The Clean Water Dam spills to TSF4, so it does not directly contribute to spills to the natural environment.

4.3.2.4 Open Cut Pit

Results from water quality sampling in the Open Pit on 26 August 2021 were provided by MCQ site staff. The results of the testing are presented in **Table 7**.

TABLE 7: WATER MONITORING DATA FOR THE OPEN PIT (26 AUGUST 2021)

Element	Units	Median Quantity
pH	-	7.5
Electrical Conductivity	µS/cm	670
Fluoride	mg/L	6.8
Aluminium (total)	mg/L	0.020
Antimony (total)	mg/L	<0.003
Arsenic (total)	mg/L	0.1
Boron (total)	mg/L	0.023
Cadmium (total)	mg/L	<0.0001
Chromium (total)	mg/L	<0.001
Cobalt (total)l	mg/L	<0.001
Copper (total)	mg/L	0.001
Lead (total)	mg/L	<0.001
Manganese (total)	mg/L	0.029
Mercury (total)	mg/L	<0.00005
Molybdenum (total)	mg/L	0.1
Nickel (total)	mg/L	0.001
Selenium (total)	mg/L	<0.003
Tungsten (total)	mg/L	0.024
Uranium	Mg/L	0.0006
Zinc (total)	mg/L	<0.005

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The results indicated that at the time of sampling, the water stored in the Open Pit was circum-neutral. Fluoride levels are elevated, but no metals were detected at enriched levels in the water samples. The water quality within the Open Pit is suitable for use within the retreatment processes on site.

4.4 Reuse of Contaminated Water

The site does not have any external water supply, so all water used in the retreatment processes is from surface runoff collected from the quarry catchments, TSF4 and the Open Pit. The water balance provides details of spill frequencies from the different storages under the proposed water management regime.

5 SIMPLIFIED DAM BREAK ASSESSMENT

5.1 General

To approximate the impact of a dam break failure on the TSF3 and TSF4, a simplified assessment was undertaken using empirical methods to determine the potential for impact on the Pit. As a dam break failure of the Pit was not a credible failure scenario, a dam break assessment was not undertaken.

5.2 Methodology and Location

5.2.1 Methodology

The simplified dam break assessment utilises the methodology described in Rico et al.. This approach incorporates the following parameters:

- Height of embankment failure
- The volume of outflow (water)

5.2.2 Locations

As part of this assessment, the simplified dam break was undertaken at the TSF3 and TSF4 that are shown on DIAGRAM 2.

5.3 Scenarios

Two (2) scenarios were identified for assessment, namely the Sunny Day Failure (SDF) and Flood Day Failure (FDF). The SDF is a scenario where a sudden failure occurs during normal operating conditions such as failure modes induced by internal erosion, piping or earthquakes. The FDF is a scenario where the failure is triggered by excessive rainfall above the capacity of the spillway, causing an overtopping of and subsequent failure of the embankment. Failure input assumptions are detailed in **TABLE 8**. The assumptions made in assessing an SDF and FDF are detailed in the following sub-sections.

TABLE 8: SDF AND FDF FAILURE INPUTS

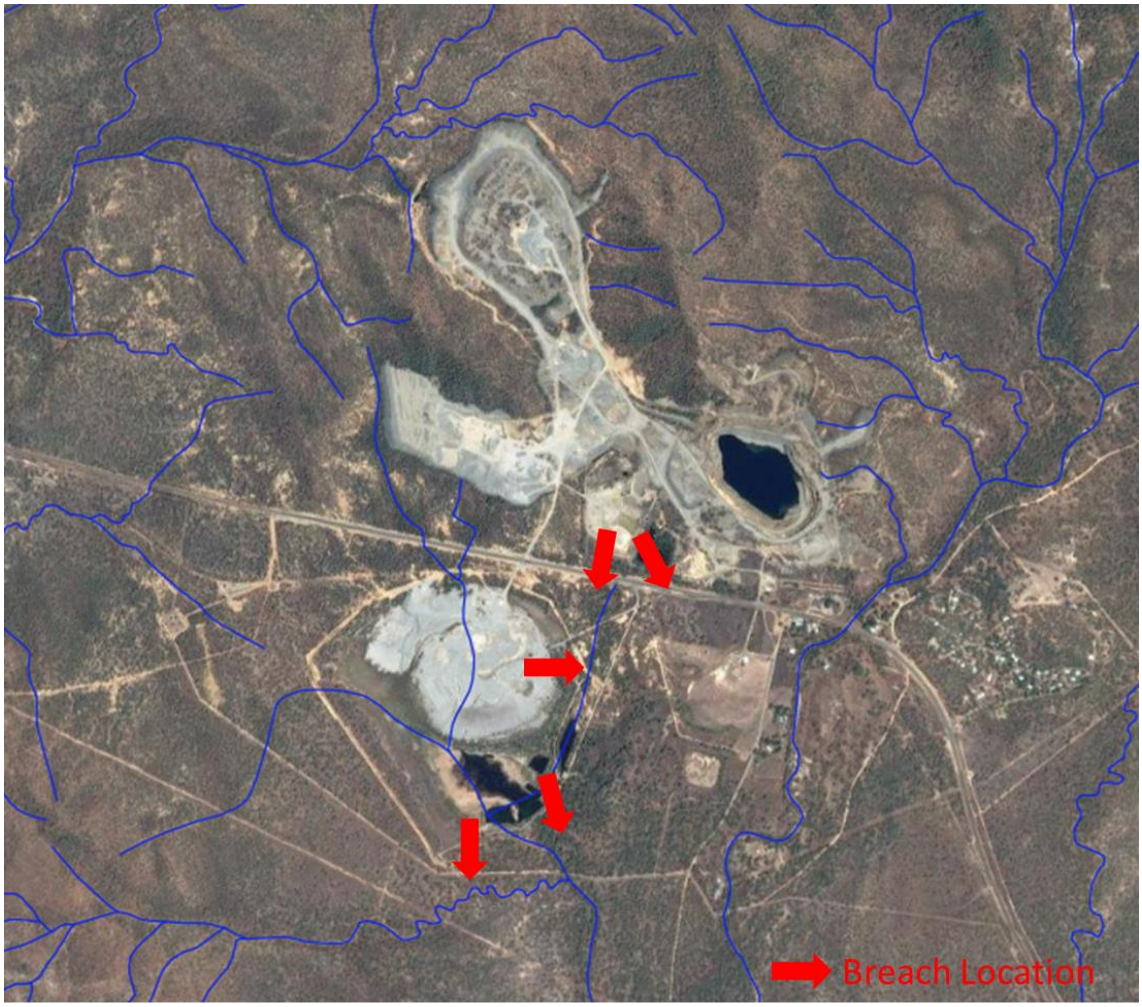
Parameter	TSF3	TSF4
Embankment Crest Level (m AHD)	376.5	358.5
Full Supply Level (FSL) (m AHD)	375.5	357.5

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Parameter	TSF3	TSF4
Natural Ground Level (m AHD)	366	352
Failure Height (m)	9.5	5.5
The volume of water above failure elevation (ML) (V_w)	326	680

The scenarios were selected based on the worst-case impacts on the downstream area in both the SDF and FDF scenarios. Both the adopted SDF and FDF are considered conservative in their failure impacts. Under both scenarios, it has been assumed the TSF's are at full spillway level. It was also assumed that the breach would develop to a total depth of 9.5 m for TSF3 and 5.5m for TSF4 from the embankment crest to natural ground, thus allowing for the total 326 ML and 680 ML of impounded waters to exit the Structures respectively. These assumptions align with the Manual, which suggests using conservative assumptions. Thus the adopted scenarios represent the' worst case' conditions. In the unlikely event of a failure, the volume of impounded waters and failure height are not expected to meet the assumed values, and as such, the impacts to the downstream impact area would be less than presented below.

DIAGRAM 2: DAM BREAK FAILURE LOCATION



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5.3.1 Sunny Day Failure

The SDF assumes no rainfall trigger mechanism. The failure is assumed to occur in the natural ground downstream of the TSF.

5.3.2 Flood Day Failure

The assumed SDF occurs when the Dam contains water to FLS. An FDF is assumed to occur immediately in conjunction with rainfall equivalent to a Probable Maximum Precipitation (PMP) event. The failure is assumed to occur in the natural downstream ground.

5.4 Flow Estimates and Downstream Impacts Scenarios

5.4.1 Peak Outflow Estimate

The peak flow estimate under an SDF/FDF failure scenario can be estimated based on **Equation 1** from Rico et al., and is summarised in **Table 9**.

EQUATION 1: PEAK OUTFLOW ESTIMATE

$$Q_p = 0.607\ x\ (V_w^{0.295} x\ h_w^{1.24})$$

Where: Q_p = Peak Outflow (m³/s)

V_w = volume of water above breach (m³)

h_w = height of water above breach bottom (m)

TABLE 9: SDF AND FDF PEAK OUTFLOW ESTIMATE

Parameter	TSF4 (SDF/FDF)	TSF3 (SDF/FDF)
The volume of water above failure elevation (ML) - V_w	680	326
Failure Height (m) - h_w	5.5	9.5
Peak Outflow (m³/s) - Q_p	34	55

5.4.2 Downstream Site Impacts

Both the TSF3 and TSF4 are water storage dams containing mine-impacted waters. Within the 'Guideline for failure impact assessment of water dams' **[17],** Section 2.2.3 provides for a preliminary assessment of an indicative runout distance of up to 20 km for storage containing 200 ML. When at full supply level, the TSF3 contains approximately 326 ML, and the TSF4 contains approximately 680 ML. As such, an isolated failure of the TSF3 would have a maximum runout distance of 20 km. The Mulligan Highway is located approximately 100m downstream of the TSF3, so it is possible that in the case of a complete dam break failure, the Mulligan Highway and vehicles may be impacted.

The population at Risk (PAR) is a key indicator in characterising off-property impacts. PAR is defined as people other than site personnel or people engaged in on-site work. The PAR is comprised of the general public in the failure impact zone. The most likely locations of impact to non-site personnel are the general public travelling on the Mulligan Highway.

Traffic data for the Barkly Highway was extracted from the 'Traffic census of the Queensland state-declared road network – 2019' [16]. The Annual Average Daily Traffic (AADT) was stated as 521 on the

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Mulligan Highway. The PAR can be calculated based on AADT by **Equation 2 [17].** The parameters used to calculate the PAR on the Barkly Highway is detailed in Table 6.

EQUATION 2: POPULATION AT RISK FROM AADT

$$PAR = \frac{(AADT\ x\ Nv)}{24\ x\ (\frac{60}{Thaz})}$$

TABLE 10: POPULATION AT RISK

Parameter	Value
AADT	529
Nv (Number of persons per vehicle)	1.5
Length of Road Impacted (m)	1000*
Gazetted Speed Limit (km/hr)	60*
T_{hat} (Hazard Exposure Time) (minute)	1 (60 sec)
Population at Risk	0.55

*Based on assessment via Google Earth

6 CONSEQUENCE CATEGORY ASSESSMENT

6.1 Basis of the Consequence Category Assessment

The TSF LoM Raise was assessed against the requirements of the Manual Error! Reference source not f ound. for operational site conditions. This involved a desktop review of potential harm associated with failure-to-contain scenarios and the dam break scenario.

6.2 Consequence Category Assessment Regulatory Requirements

The Manual sets out the requirements of the administering authority for a consequence category assessment and certification of the design of regulated structures constructed as part of environmentally relevant activities under the Environmental Protection Act (1994) Error! Reference source not found..

The purpose of the Manual is to:

- guide the assessment of the Consequence Category of all structures constructed as part of activities that require an EA or development approval;
- guide the determination of the Structure (s) that require formal documentation; and
- provide approved methods for specifying the design performance and monitoring requirements for those structures.

Assessment criteria for CCA are based on the following failure event scenarios.

- Failure to Contain – Seepage

  Spills or release to ground/groundwater via seepage from the floor and/or sides of the Structure. This is only relevant to a new structure and does not apply to structures approved prior to the development of the current version of the Manual

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- Failure to Contain – Overtopping

  Spills or releases from the Structure that result from loss of containment due to overtopping of the Structure.

- Failure to Contain – Dam Break

  The collapse of the Structure is due to any possible cause.

Under these scenarios, several modes of failure are possible, as described below:

- A failure to contain scenario means a release from the Structure that results from loss of containment due to excessive seepage, overtopping of the Structure and/or other deficiencies in water management aspects of the storage. Although such a failure mechanism is typically non-flood producing, failure to contain events may involve the release of contaminants, which could endanger environmental values or human life/wellbeing.
- A dam break scenario involves the partial or complete collapse of a structure due to any possible cause. For the purposes of CCA, a simplified empirical dam break assessment was undertaken for the proposed TSF LoM Raise north towards Dingo Gully and east towards the unnamed tributary of Balfe Creek, assuming the following:
  - The pond was full to the embankment crest level (i.e. FDF scenario); and,
  - Full failure of above-ground embankments to natural ground level

The basis for assessment of the Consequence Category reproduced from the Manual is reproduced in **TABLE 11**.

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TABLE 11: CONSEQUENCE CATEGORY ASSESSMENT CRITERIA (DES 2016) ERROR! REFERENCE SOURCE NOT FOUND.

Environmental Harm	Consequence Category		
	High	**Significant**	**Low**
Harm to Humans	A location such that people are routinely present in the failure path and if present loss of life to greater than 10 people is expected[8]. Note: The requirement to consider the location of people in the failure path is only relevant to the 'dam break' scenario.	A location such that people are routinely present in the failure path and if present loss of life to 1 person or greater but less than 10 people is expected[7]. Note: The requirement to consider the location of people in the failure path is only relevant to the 'dam break' scenario.	A location such that people are not routinely present in the failure path and loss of life is not expected[7]. Note: The requirement to consider the location of people in the failure path is only relevant to the 'dam break' scenario.
	A location such that contamination of waters (surface and/or groundwater[9]) used for human consumption could result in the health of 20 or more people being affected[10].	A location such that contamination of waters (surface and/or groundwater[8]) used for human consumption could result in the health of 10 or more people but less than 20 people being affected[9].	A location such that contamination of waters (surface and/or groundwater[8]) used for human consumption could result in the health of fewer than 10 people being affected[9].
General environmental harm	A location such that: a) Contaminants may be released to areas of MNES, MSES or HEV waters that are not already authorised to be disturbed to at least the same extent under other conditions of this authority subject to any applicable offset commitment (Significant Values); and b) Adverse effects[11] on Significant Values are likely; and c) The adverse effects[10] are likely to cause at least one of the following: i) loss or damage or remedial costs greater than $50,000,000; or ii) remediation of damage is likely to take 3 years or more; or iii) permanent alteration to existing ecosystems; or iv) the area of damage (including downstream effects) is likely to be at least 5 km².	A location such that contaminants may be released so that adverse effects[10] (that are not already authorised to be disturbed to at least the same extent under other conditions of the authority subject to any applicable offset commitment) either: a) Would be likely to be caused to Significant Values, but that adverse effects[10] would not be likely to meet the thresholds for the High Consequence Category and instead would be likely to cause at least one of the following: i) loss or damage or remedial costs greater than $10,000,000 but less than $50,000,000; or ii) remediation of damage is likely to take more than 6 months but less than 3 years; or iii) significant alteration to existing ecosystems; or iv) the area of damage (including downstream effects) is likely to be at least 1km2 but less than 5 km². or b) Would be likely to be caused to environmental values classed as slightly or moderately disturbed waters[12], the wetland of general ecological significance[13], riverine areas, springs or lakes and associated flora and fauna (Moderate Values), and the adverse effects[10] are likely to cause at least one of the following: i) loss or damage or remedial costs greater than $20,000,000; or ii) remediation of damage is likely to take more than 1 year; or iii) significant alteration to existing ecosystems; or the area of damage (including downstream effects) is likely to be at least 2 km².	A location such that either: a) Contaminants are unlikely to be released to areas of Significant Values or Moderate Values; or b) Contaminants are likely to be released to those areas but would be unlikely to meet any of the minimum thresholds specified for the Significant Consequence Category for adverse effects[10]
General economic loss or property damage	A location such that harm (other than a different category of harm as specified above) to third-party assets in the failure path would be expected to require $10 million or greater in rehabilitation, compensation, repair or rectification costs[14].	A location such that harm (other than a different category of harm as specified above) to third-party assets in the failure path would be expected to require $1 million and greater but less than $10 million in rehabilitation, compensation, repair or rectification costs[13].	A location such that harm (other than a different category of harm as specified above) to third-party assets in the failure path would be expected to require less than $1 million in rehabilitation, compensation, repair or rectification costs[13].

7 To be used for all failure event scenarios

8.'People routinely present in the failure path' could be considered to be people who occupy buildings or other places of occupation that lie within the failure impact zone. For the purposes of this Manual, this should refer to people other than site personnel engaged by the resource operation and located on the tenements and tenure associated with the resource operation; for other ERAs, it would be the 'premises referred to in authority. It should be noted that while this is appropriate for the assessment of consequence categories in accordance with this Manual, adherence to the requirements of this Manual does not limit, amend or change in any way any other requirements to be complied with under relevant health and safety acts or legislation that requires the safety of site personnel to be considered.

9 When considering potential impacts on groundwater, it is not envisaged that a full hydrogeological assessment will be required in all cases. Any consideration of potential impacts on groundwater systems should consider the water quality of the potential receiving aquifer as well as the quality of fluid stored in the regulated Dam. Existing groundwater drawdown in areas surrounding resource operations (e.g. drawdown as a result of mine pit or underground mine dewatering) can also be considered when assessing the consequence of dam seepage on groundwater systems.

10 'An adverse effect on human health means a physiological effect on human health and does not include an impact on the quality of downstream water that merely negatively affects the taste and which is unlikely to cause persons to become physically ill.

11 Adverse effects include chronic and acute effects where an acute effect is on living organism/s which results in severe symptoms that develop rapidly, and a chronic effect is an adverse effect on a living organism/s which develops slowly. In some instances, it may be necessary to carry out or reference existing ecological/toxicological studies to assess the impacts of contaminants on living organisms.

12 See Water EPP for definitions

13 Wetland of general ecological significance' means a wetland shown on a map of referable wetland as a 'general ecologically significant wetland' or 'wetland of other environmental value'.

14 This does not include the holder's own mine or gas production, on-site industrial or commercial assets, the holder's workers' accommodation, agricultural facilities on the holder's land such as a farm shed or farm dam or infrastructure solely for servicing the holder.

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7 DES CONSEQUENCE CATEGORY ASSESSMENT

Assessments against the failure scenarios following the Manual for the proposed TSF LoM configuration conditions were undertaken. This assessment is contained in **TABLE 12**.

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TABLE 12: CONSEQUENCE CATEGORY ASSESSMENT FOR TSF3

Environmental Harm	Consequence Category		
	Failure to Contain - Seepage	**Failure to Contain - Overtopping**	**Failure to Contain - Dam Break**
Harm to Humans	Under Section 2.1.2.1.a of the Manual Error! Reference source not found., t he assessment against the 'Failure to contain – seepage' scenario is applicable for new structures and does not apply to structures approved prior to the development of Version 5.02 of the Manual. As the TSF Raise is the formalisation/raise of the existing structure, an assessment of 'Failure to contain – seepage' has not been undertaken. **The consequence Category is assessed as N/A.**	The TSF3 is filled via pumped transfer from the Pit or rainfall over its catchment area. The primary method of filling is via pumped transfer. In the event of an overtopping failure, the release of contaminants may flow either south or southeast, which would impact Mulligan Highway. There are no bores used for human consumption in the failure path. **The consequence Category is assessed as Low.**	Due to the natural surface elevation of the TSF3, it was assessed that overtopping flows would reach the Mulligan Highway. However, the Population at Risk (PAR) was assessed to be < 1 such that any dam break scenario would not result in potential loss of life. **The consequence Category is assessed as Low.**
General environmental harm	Under Section 2.1.2.1.a of the Manual Error! Reference source not found., t he assessment against the 'Failure to contain – seepage' scenario is applicable for new structures and does not apply to structures approved prior to the development of Version 5.02 of the Manual. As the TSF Raise is the raise of the existing structure, an assessment of 'Failure to contain – seepage' has not been undertaken. **The consequence Category is assessed as N/A.**	In the event of an overtopping failure, the release of contaminants may flow either south or southeast, which would be directed towards the site operational area, where no MNES or MSES are located. **The consequence Category is assessed as Low.**	In the event of a dam break, failure of the TSF3 impacted waters would be directed towards the unnamed tributary of Mitchell River. These watercourses both contain MSES (regulated vegetation - intersecting a watercourse and regulated vegetation – essential habitat). There are also areas of state biodiversity significance that may be impacted. Impact on these areas is expected to impact areas of significant environmental values, with impacts likely to include: ii) remediation of damage is likely to take 6 months or less; or the area of damage (including downstream effects) is likely to be less than 5 km². **The consequence Category is assessed as Low.**
General economic loss or property damage	Under Section 2.1.2.1.a of the Manual Error! Reference source not found., t he assessment against the 'Failure to contain – seepage' scenario is applicable for new structures and does not apply to structures approved prior to the development of Version 5.02 of the Manual. As the TSF Raise is the raise of the existing structure, an assessment of 'Failure to contain – seepage' has not been undertaken.	In the event of an overtopping failure of the TSF 3, where third-party assets (Mulligan Highway) exist in the failure path, is it expected that rehabilitation, repair or compensation would be expected to be less than $1 million. In the event of an overtopping failure to the southeast, only site infrastructure would be impacted.	In the event of a dam break failure of the TSF3 where the third party assets exist in the failure path (Mulligan Highway), is it expected that rehabilitation, repair or compensation would be expected to be less than $1 million.

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Environmental Harm	Consequence Category		
	Failure to Contain - Seepage	Failure to Contain - Overtopping	Failure to Contain - Dam Break
	The consequence Category is assessed as N/A.	**The Consequence Category assessed as Low.**	**The consequence Category is assessed as Low.**
Overall Consequence Category	**N/A**	**Low**	**Low**

TABLE 13: CONSEQUENCE CATEGORY ASSESSMENT FOR TSF4

Environmental Harm	Consequence Category		
	Failure to Contain - Seepage	Failure to Contain - Overtopping	Failure to Contain - Dam Break
Harm to Humans	Under Section 2.1.2.1.a of the Manual **Error! Reference source not found.**, t he assessment against the 'Failure to contain – seepage' scenario is applicable for new structures and does not apply to structures approved prior to the development of Version 5.02 of the Manual. As the TSF Raise is the raise of the existing structure, an assessment of 'Failure to contain – seepage' has not been undertaken. **The consequence Category is assessed as N/A.**	In the event of an overtopping failure, the release of contaminants may flow either south or southeast. Flows to both sides would enter the unnamed tributary of Mitchell river. Overtopping flows would not impact public roads or impacted areas where non-site personnel would be expected to be routinely present. It is considered that harm to humans is unlikely. It is assessed that the location of the TSF4 is such that contamination of groundwater used for human consumption would not result in the health of people being affected. This is due to the large distances between the storage and any potential user resulting in low impact. Groundwater bores located surrounding the project area are not used as a source of drinking water. **Consequence Category assessed as Low.**	In the event of a dam break, failure of the TSF4 flows to the south or southeast would not impact non-site personnel as there are no residences or public roads where people would be routinely present (the Population at Risk (PAR) was assessed to be < 1). In the event of a breach to the north, flows would enter the unnamed tributary of Mitchell River. **Consequence Category assessed as Low.**
General environmental harm	Under Section 2.1.2.1.a of the Manual Error! Reference source not found., t he assessment against the 'Failure to contain – seepage' scenario is applicable for new structures and does not apply to structures approved prior to the development of Version 5.02 of the Manual. As the TSF Raise is the raise of the existing structure, an assessment of 'Failure to contain – seepage' has not been undertaken. **The consequence Category is assessed as N/A.**	Overtopping flows to the south or southeast would direct mine impacted waters to the unnamed tributary of Mitchell River. These watercourses contain MSES (regulated vegetation - intersecting a watercourse and regulated vegetation – essential habitat). There are also areas of state biodiversity habitat for EVNT taxa significance that may be impacted. However, the mine impacted waters quality doesn't meet any of the minimum thresholds specified for the Significant Consequence Category for adverse effects. Impacts would likely include: i) remediation of damage is likely to take less than 6 months; or ii) the area of damage (including downstream effects) is likely to be less than 1 km^2. **The consequence Category is assessed as Low.**	In the event of a dam break, failure of the TSF4 impacted waters would be directed towards the unnamed tributary of Mitchell River. These watercourses both contain MSES (regulated vegetation - intersecting a watercourse and regulated vegetation – essential habitat). There are also areas of state biodiversity significance that may be impacted. Impact on these areas is expected to impact areas of significant environmental values, with impacts likely to include: ii) remediation of damage is likely to take 6 months or less; or the area of damage (including downstream effects) is likely to be less than 5 km^2. **The consequence Category is assessed as Low.**
General economic loss or property damage	Under Section 2.1.2.1.a of the Manual Error! Reference source not found., t he assessment against the 'Failure to contain – seepage' scenario is applicable for new structures and does not apply to structures approved prior to the development of Version 5.02 of the Manual. As the TSF Raise is the raise of the existing structure, an assessment of 'Failure to contain – seepage' has not been undertaken.	No identifiable developments or third-party infrastructure are present immediately downstream of the TSF4, which would be impacted by an overtopping failure.	No identifiable developments or third-party infrastructure are present immediately downstream of the TSF4, which would be impacted by a dam break failure.

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Environmental Harm	Consequence Category		
	Failure to Contain - Seepage	Failure to Contain - Overtopping	Failure to Contain - Dam Break
	The consequence Category is assessed as N/A.	**Consequence Category assessed as Low.**	**Consequence Category assessed as Low.**
Overall Consequence Category	**N/A**	**Low**	**Low**

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8 ANCOLD CONSEQUENCE CATEGORY ASSESSMENT

An assessment under the criteria outlined within the ANCOLD guidelines Error! Reference source not f ound. is based on considerations given to four distinct factors:

- Business (corporate risk)
- Social (amenity and health risk);
- Natural Environment (environmental risk); and
- The population at Risk (PAR) or Potential loss of life (PLL).

The impact assessment and associated consequence category for the TSF LoM Raise based on these factors are summarised in **TABLE 14** and **TABLE 15,** respectively.

TABLE 14: ANCOLD CONSEQUENCE CATEGORY ASSESSMENT

DAMAGE TYPE	CATEGORY AND IMPACT	COMMENTARY
Infrastructure (Dam, houses, commerce, farms, community)	**MINOR** <$10m	The only identified third-party assets in the failure path are bores. Expected repair, rehabilitation or compensation costs are expected to be less than $10 million.
Business Importance	**MAJOR** Severe to crippling	A dam break failure would likely result in the cessation of operations
Public health	**MINOR** <100 People affected	The offsite PAR has been calculated to be less than 1.
Social dislocation	**MINOR** <100 persons or <20 business months	Social dislocation is not expected to impact more than 100 people, with local businesses not impacted for greater than 20 business months.
Impact Area	**MAJOR** < 20 km²	The impact area is not expected to exceed 5 km² in the downstream impact area
Impact Duration	**MINOR** <1 year	The time required to repair the TSF Raise and restore full site operations and remediate the downstream environment would be expected to be less than 1 year.
Impact on the natural environment	**MEDIUM** Significant effects on rural land and local flora and fauna. Limited effects on: A. Item(s) of local and State natural heritage. B. Native flora and fauna within forestry, aquatic and conservation reserves, or recognised habitat corridors, wetlands or fish breeding areas.	Due to the presence of MSES in the failure impact area, there is the potential for significant effects on these areas. Areas of national and State concern are located within 10 km of the site and on the ML, respectively, and would likely be impacted in the event of a failure.
OVERALL	**MAJOR**	-

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Based on **TABLE 14,** the highest category for damage and losses severity level is Minor. Additional information regarding the business is required to adequately assess the impact. For the purpose of this review, the severity level has been kept as "Minor".

The population at Risk (PAR) has been assessed as less than 1, as discussed in **TABLE 12**; this, together with a Severity level of "Minor", results in a consequence category of "Very Low", as per **TABLE 15**.

TABLE 15: RECOMMENDED CONSEQUENCE CATEGORY (REPRODUCED FROM TABLE 2, ANCOLD 2019 Error! Reference source not found.**)**

POPULATION AT RISK	SEVERITY OF DAMAGE AND LOSS			
	MINOR	MEDIUM	MAJOR	CATASTROPHIC
<1	Very Low	Low	Significant	High C
≥ 1 to < 10	Significant (Note 2)	Significant (Note 2)	High C	High B
≥ 10 to < 100	High C	High C	High B	High A
≥ 100 to < 1000	Note 1	High B	High A	Extreme
> 1000	Note 1	Note 1	Extreme	Extreme
For Note 1 and Note 2 details, refer to Error! Reference source not found.				

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9 SUMMARY AND DESIGN

The consequence category assessment outcomes in accordance with DES Error! Reference source not found. from **TABLE 12** are summarised in **TABLE 16**.

TABLE 16: DES CONSEQUENCE CATEGORY ASSESSMENT SUMMARY

Failure Scenario	TSF Raise
Failure to Contain – Seepage	N/A.
Failure to Contain – Overtopping	Low
Failure to Contain – Dam Break	Low
Overall	Low
Regulated Structure, as defined in the Manual (Y/N)	Y

As shown in **TABLE 16**, the TSF LoM has an overall consequence category of "**Low**" and is therefore considered to be regulated stricture.

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CONDITIONS OF REPORT

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APPENDICES

APPENDIX A – EPBC ACT PROTECTED MATTER REPORT

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Australian Government
Department of Agriculture, Water and the Environment

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected. Please see the caveat for interpretation of information provided here.

Report created: 04-Aug-2022

Summary
Details
- Matters of NES
- Other Matters Protected by the EPBC Act
- Extra Information

Caveat
Acknowledgements

Summary

Matters of National Environment Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	1
National Heritage Places:	2
Wetlands of International Importance (Ramsar	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	None
Listed Threatened Ecological Communities:	1
Listed Threatened Species:	41
Listed Migratory Species:	21

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Lands:	None
Commonwealth Heritage Places:	None
Listed Marine Species:	26
Whales and Other Cetaceans:	None
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	None
Habitat Critical to the Survival of Marine Turtles:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have

State and Territory Reserves:	3
Regional Forest Agreements:	None
Nationally Important Wetlands:	None
EPBC Act Referrals:	1
Key Ecological Features (Marine):	None
Biologically Important Areas:	None
Bioregional Assessments:	None
Geological and Bioregional Assessments:	None

Details

Matters of National Environmental Significance

World Heritage Properties [Resource Information]

Name	State	Legal Status	Buffer Status
Wet Tropics of Queensland	QLD	Declared property	In buffer area only

National Heritage Places [Resource Information]

Name	State	Legal Status	Buffer Status
Indigenous			
Wet Tropics World Heritage Area (Indigenous Values)	QLD	Within listed place	In buffer area only
Natural			
Wet Tropics of Queensland	QLD	Listed place	In buffer area only

Listed Threatened Ecological Communities [Resource Information]

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.
Status of Vulnerable, Disallowed and Ineligible are not MNES under the EPBC Act.

Community Name	Threatened Category	Presence Text	Buffer Status
Broad leaf tea-tree (Melaleuca viridiflora) woodlands in high rainfall coastal north Queensland	Endangered	Community may occur within area	In buffer area only

Listed Threatened Species [Resource Information]

Status of Conservation Dependent and Extinct are not MNES under the EPBC Act.
Number is the current name ID.

Scientific Name	Threatened Category	Presence Text	Buffer Status
BIRD			
Calidris ferruginea			
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat likely to occur within area	In feature area
Casuarius casuarius johnsonii			
Southern Cassowary, Australian Cassowary, Double-wattled Cassowary [25986]	Endangered	Species or species habitat likely to occur within area	In buffer area only
Erythrotriorchis radiatus			
Red Goshawk [942]	Vulnerable	Species or species habitat likely to occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Erythrura gouldiae Gouldian Finch [413]	Endangered	Species or species habitat likely to occur within area	In feature area
Falco hypoleucos Grey Falcon [929]	Vulnerable	Species or species habitat known to occur within area	In feature area
Hirundapus caudacutus White-throated Needletail [682]	Vulnerable	Species or species habitat known to occur within area	In feature area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area	In feature area
Rostratula australis Australian Painted Snipe [77037]	Endangered	Species or species habitat known to occur within area	In feature area
Turnix olivii Buff-breasted Button-quail [59293]	Endangered	Species or species habitat likely to occur within area	In feature area
Tyto novaehollandiae kimberli Masked Owl (northern) [26048]	Vulnerable	Species or species habitat likely to occur within area	In feature area
FROG			
Cophixalus aenigma Tapping Nursery-frog [79086]	Endangered	Species or species habitat likely to occur within area	In buffer area only
Litoria dayi Australian Lace-lid, Lace-eyed Tree Frog, Day's Big-eyed Treefrog [86707]	Vulnerable	Species or species habitat likely to occur within area	In feature area
Litoria lorica Armoured Mistfrog [1841]	Critically Endangered	Species or species habitat known to occur within area	In feature area
Litoria nyakalensis Mountain Mistfrog, Nyakala Frog [1820]	Critically Endangered	Species or species habitat likely to occur within area	In buffer area only
MAMMAL			

Scientific Name	Threatened Category	Presence Text	Buffer Status
Bettongia tropica Northern Bettong [214]	Endangered	Species or species habitat likely to occur within area	In feature area
Dasyurus hallucatus Northern Quoll, Digul [Gogo-Yimidir], Wijingadda [Dambimangari], Wiminji [Martu] [331]	Endangered	Species or species habitat known to occur within area	In feature area
Hipposideros semoni Semon's Leaf-nosed Bat, Greater Wart-nosed Horseshoe-bat [180]	Vulnerable	Species or species habitat may occur within area	In feature area
Macroderma gigas Ghost Bat [174]	Vulnerable	Species or species habitat likely to occur within area	In feature area
Mesembriomys gouldii rattoides Black-footed Tree-rat (north Queensland), Shaggy Rabbit-rat [87620]	Vulnerable	Species or species habitat likely to occur within area	In feature area
Petauroides minor Greater Glider (northern), Greater Glider (north-eastern Queensland) [92008]	Vulnerable	Species or species habitat known to occur within area	In feature area
Petaurus australis Wet Tropics subspecies Yellow-bellied Glider (Wet Tropics), Fluffy Glider [88022]	Endangered	Foraging, feeding or related behaviour known to occur within area	In feature area
Phascolarctos cinereus (combined populations of Qld, NSW and the ACT) Koala (combined populations of Queensland, New South Wales and the Australian Capital Territory) [85104]	Endangered	Species or species habitat likely to occur within area	In feature area
Pteropus conspicillatus Spectacled Flying-fox [185]	Endangered	Species or species habitat known to occur within area	In feature area
Rhinolophus robertsi Large-eared Horseshoe Bat, Greater Large-eared Horseshoe Bat [87639]	Vulnerable	Species or species habitat likely to occur within area	In feature area
Saccolaimus saccolaimus nudicluniatus Bare-rumped Sheath-tailed Bat, Bare-rumped Sheathtail Bat [66889]	Vulnerable	Species or species habitat likely to occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
PLANT			
Acriopsis emarginata Pale Chandelier Orchid [83928]	Vulnerable	Species or species habitat may occur within area	In buffer area only
Arthraxon hispidus Hairy-joint Grass [9338]	Vulnerable	Species or species habitat may occur within area	In feature area
Cepobaculum carronii an orchid [78700]	Vulnerable	Species or species habitat likely to occur within area	In feature area
Cyclophyllum costatum a shrub [82770]	Vulnerable	Species or species habitat may occur within area	In buffer area only
Dichanthium setosum bluegrass [14159]	Vulnerable	Species or species habitat likely to occur within area	In feature area
Macropteranthes montana [9003]	Vulnerable	Species or species habitat likely to occur within area	In buffer area only
Phaius australis Lesser Swamp-orchid [5872]	Endangered	Species or species habitat may occur within area	In feature area
Phaleria biflora [82049]	Vulnerable	Species or species habitat likely to occur within area	In buffer area only
Prostanthera albohirta [82052]	Critically Endangered	Species or species habitat may occur within area	In buffer area only
Tomophyllum walleri [83507]	Vulnerable	Species or species habitat likely to occur within area	In buffer area only
Tropilis callitrophilis Thin Feather Orchid [82771]	Vulnerable	Species or species habitat may occur within area	In buffer area only

Scientific Name	Threatened Category	Presence Text	Buffer Status
Vappodes lithocola			
Dwarf Butterfly Orchid, Cooktown Orchid [78893]	Endangered	Species or species habitat known to occur within area	In feature area
Vappodes phalaenopsis			
Cooktown Orchid [78894]	Vulnerable	Species or species habitat may occur within area	In feature area
Zeuxine polygonoides			
Velvet Jewel Orchid [46794]	Vulnerable	Species or species habitat may occur within area	In buffer area only
REPTILE			
Egernia rugosa			
Yakka Skink [1420]	Vulnerable	Species or species habitat may occur within area	In feature area
SHARK			
Pristis pristis			
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat may occur within area	In feature area

Listed Migratory Species [Resource Information]

Scientific Name	Threatened Category	Presence Text	Buffer Status
Migratory Marine Birds			
Apus pacificus			
Fork-tailed Swift [678]		Species or species habitat likely to occur within area	In feature area
Migratory Marine Species			
Pristis pristis			
Freshwater Sawfish, Largetooth Sawfish, River Sawfish, Leichhardt's Sawfish, Northern Sawfish [60756]	Vulnerable	Species or species habitat may occur within area	In feature area
Migratory Terrestrial Species			
Cecropis daurica			
Red-rumped Swallow [80610]		Species or species habitat may occur within area	In feature area
Cuculus optatus			
Oriental Cuckoo, Horsfield's Cuckoo [86651]		Species or species habitat known to occur within area	In feature area
Hirundapus caudacutus			
White-throated Needletail [682]	Vulnerable	Species or species habitat known to occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Hirundo rustica Barn Swallow [662]		Species or species habitat may occur within area	In feature area
Monarcha frater Black-winged Monarch [607]		Species or species habitat may occur within area	In feature area
Monarcha melanopsis Black-faced Monarch [609]		Species or species habitat known to occur within area	In feature area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat known to occur within area	In feature area
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area	In feature area
Myiagra cyanoleuca Satin Flycatcher [612]		Species or species habitat likely to occur within area	In feature area
Rhipidura rufifrons Rufous Fantail [592]		Species or species habitat known to occur within area	In feature area
Symposiachrus trivirgatus as Monarcha trivirgatus Spectacled Monarch [83946]		Species or species habitat likely to occur within area	In feature area
Migratory Wetlands Species			
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area	In feature area
Calidris acuminata Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area	In feature area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat likely to occur within area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
[Calidris melanotos](#) Pectoral Sandpiper [858]		Species or species habitat may occur within area	In feature area
[Gallinago hardwickii](#) Latham's Snipe, Japanese Snipe [863]		Species or species habitat known to occur within area	In feature area
[Numenius madagascariensis](#) Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area	In feature area
[Pandion haliaetus](#) Osprey [952]		Species or species habitat known to occur within area	In feature area
[Tringa nebularia](#) Common Greenshank, Greenshank [832]		Species or species habitat likely to occur within area	In feature area

Other Matters Protected by the EPBC Act

Listed Marine Species			[Resource Information]
Scientific Name	Threatened Category	Presence Text	Buffer Status
Bird			
[Actitis hypoleucos](#) Common Sandpiper [59309]		Species or species habitat known to occur within area	In feature area
[Anseranas semipalmata](#) Magpie Goose [978]		Species or species habitat may occur within area overfly marine area	In feature area
[Apus pacificus](#) Fork-tailed Swift [678]		Species or species habitat likely to occur within area overfly marine area	In feature area
[Bubulcus ibis as Ardea ibis](#) Cattle Egret [66521]		Species or species habitat may occur within area overfly marine area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
[Calidris acuminata](#) Sharp-tailed Sandpiper [874]		Species or species habitat known to occur within area	In feature area
[Calidris ferruginea](#) Curlew Sandpiper [856]	Critically Endangered	Species or species habitat likely to occur within area overfly marine area	In feature area
[Calidris melanotos](#) Pectoral Sandpiper [858]		Species or species habitat may occur within area overfly marine area	In feature area
[Cecropis daurica as Hirundo daurica](#) Red-rumped Swallow [80610]		Species or species habitat may occur within area overfly marine area	In feature area
[Chalcites osculans as Chrysococcyx osculans](#) Black-eared Cuckoo [83425]		Species or species habitat may occur within area overfly marine area	In feature area
[Gallinago hardwickii](#) Latham's Snipe, Japanese Snipe [863]		Species or species habitat known to occur within area overfly marine area	In feature area
[Haliaeetus leucogaster](#) White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area	In feature area
[Hirundapus caudacutus](#) White-throated Needletail [682]	Vulnerable	Species or species habitat known to occur within area overfly marine area	In feature area
[Hirundo rustica](#) Barn Swallow [662]		Species or species habitat may occur within area overfly marine area	In feature area
[Merops ornatus](#) Rainbow Bee-eater [670]		Species or species habitat may occur within area overfly marine area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Monarcha frater Black-winged Monarch [607]		Species or species habitat may occur within area overfly marine area	In feature area
Monarcha melanopsis Black-faced Monarch [609]		Species or species habitat known to occur within area overfly marine area	In feature area
Motacilla cinerea Grey Wagtail [642]		Species or species habitat known to occur within area overfly marine area	In feature area
Motacilla flava Yellow Wagtail [644]		Species or species habitat may occur within area overfly marine area	In feature area
Myiagra cyanoleuca Satin Flycatcher [612]		Species or species habitat likely to occur within area overfly marine area	In feature area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat may occur within area	In feature area
Pandion haliaetus Osprey [952]		Species or species habitat known to occur within area	In feature area
Rhipidura rufifrons Rufous Fantail [592]		Species or species habitat known to occur within area overfly marine area	In feature area
Rostratula australis as Rostratula benghalensis (sensu lato) Australian Painted Snipe [77037]	Endangered	Species or species habitat known to occur within area overfly marine area	In feature area
Symposiachrus trivirgatus as Monarcha trivirgatus Spectacled Monarch [83946]		Species or species habitat likely to occur within area overfly marine area	In feature area

Scientific Name	Threatened Category	Presence Text	Buffer Status
Tringa nebularia			
Common Greenshank, Greenshank [832]		Species or species habitat likely to occur within area overfly marine area	In feature area
Reptile			
Crocodylus johnstoni			
Freshwater Crocodile, Johnston's Crocodile, Johnstone's Crocodile [1773]		Species or species habitat may occur within area	In feature area

Extra Information

State and Territory Reserves			[Resource Information]
Protected Area Name	Reserve Type	State	Buffer Status
Brooklyn	Private Nature Reserve	QLD	In feature area
Brooklyn	Nature Refuge	QLD	In feature area
Mount Lewis	National Park	QLD	In feature area

EPBC Act Referrals				[Resource Information]
Title of referral	Reference	Referral Outcome	Assessment Status	Buffer Status
Not controlled action				
Improving rabbit biocontrol: releasing another strain of RHDV, sthrn two thirds of Australia	2015/7522	Not Controlled Action	Completed	In feature area

Caveat

1 PURPOSE

This report is designed to assist in identifying the location of matters of national environmental significance (MNES) and other matters protected by the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) which may be relevant in determining obligations and requirements under the EPBC Act.

The report contains the mapped locations of:

- World and National Heritage properties;
- Wetlands of International and National Importance;
- Commonwealth and State/Territory reserves;
- distribution of listed threatened, migratory and marine species;
- listed threatened ecological communities; and
- other information that may be useful as an indicator of potential habitat value.

2 DISCLAIMER

This report is not intended to be exhaustive and should only be relied upon as a general guide as mapped data is not available for all species or ecological communities listed under the EPBC Act (see below). Persons seeking to use the information contained in this report to inform the referral of a proposed action under the EPBC Act should consider the limitations noted below and whether additional information is required to determine the existence and location of MNES and other protected matters.

Where data are available to inform the mapping of protected species, the presence type (e.g. known, likely or may occur) that can be determined from the data is indicated in general terms. It is the responsibility of any person using or relying on the information in this report to ensure that it is suitable for the circumstances of any proposed use. The Commonwealth cannot accept responsibility for the consequences of any use of the report or any part thereof. To the maximum extent allowed under governing law, the Commonwealth will not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance

3 DATA SOURCES

Threatened ecological communities

For threatened ecological communities where the distribution is well known, maps are generated based on information contained in recovery plans, State vegetation maps and remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species

Threatened, migratory and marine species distributions have been discerned through a variety of methods. Where distributions are well known and if time permits, distributions are inferred from either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc.) together with point locations and described habitat; or modelled (MAXENT or BIOCLIM habitat modelling) using

Where little information is available for a species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc.).

In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More detailed distribution mapping methods are used to update these distributions

4 LIMITATIONS

The following species and ecological communities have not been mapped and do not appear in this report:

- threatened species listed as extinct or considered vagrants;
- some recently listed species and ecological communities;
- some listed migratory and listed marine species, which are not listed as threatened species; and
- migratory species that are very widespread, vagrant, or only occur in Australia in small numbers.

The following groups have been mapped, but may not cover the complete distribution of the species:

- listed migratory and/or listed marine seabirds, which are not listed as threatened, have only been mapped for recorded
- seals which have only been mapped for breeding sites near the Australian continent

The breeding sites may be important for the protection of the Commonwealth Marine environment.

Refer to the metadata for the feature group (using the Resource Information link) for the currency of the information.

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Department of Land and Resource Management, Northern Territory
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Australian Tropical Herbarium, Cairns
-eBird Australia
-Australian Government – Australian Antarctic Data Centre
-Museum and Art Gallery of the Northern Territory
-Australian Government National Environmental Science Program
-Australian Institute of Marine Science
-Reef Life Survey Australia
-American Museum of Natural History
-Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
-Tasmanian Museum and Art Gallery, Hobart, Tasmania
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

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APPENDIX B – ENVIRONMENTAL REPORTS – MATTERS OF STATE ENVIRONMENTAL SIGNIFICANCE

TAILINGS.WATER.WASTE.

Queensland Government

Department of Environment and Science

Environmental Reports

Matters of State Environmental Significance

For the selected area of interest
ml: 4867

Environmental Reports - General Information

The Environmental Reports portal provides for the assessment of selected matters of interest relevant to a user specified location, or area of interest (AOI). All area and derivative figures are relevant to the extent of matters of interest contained within the AOI unless otherwise stated. Please note, if a user selects an AOI via the "central coordinates" option, the resulting assessment area encompasses an area extending for a 2km radius from the point of interest.

All area and area derived figures included in this report have been calculated via reprojecting relevant spatial features to Albers equal-area conic projection (central meridian = 146, datum Geocentric Datum of Australia 1994). As a result, area figures may differ slightly if calculated for the same features using a different co-ordinate system.

Figures in tables may be affected by rounding.

The matters of interest reported on in this document are based upon available state mapped datasets. Where the report indicates that a matter of interest is not present within the AOI (e.g. where area related calculations are equal to zero, or no values are listed), this may be due either to the fact that state mapping has not been undertaken for the AOI, that state mapping is incomplete for the AOI, or that no values have been identified within the site.

The information presented in this report should be considered as a guide only and field survey may be required to validate values on the ground.

Please direct queries about these reports to: Planning.Support@des.qld.gov.au

Disclaimer

Whilst every care is taken to ensure the accuracy of the information provided in this report, the Queensland Government makes no representations or warranties about its accuracy, reliability, completeness, or suitability, for any particular purpose and disclaims all responsibility and all liability (including without limitation, liability in negligence) for all expenses, losses, damages (including indirect or consequential damage) and costs which the user may incur as a consequence of the information being inaccurate or incomplete in any way and for any reason.



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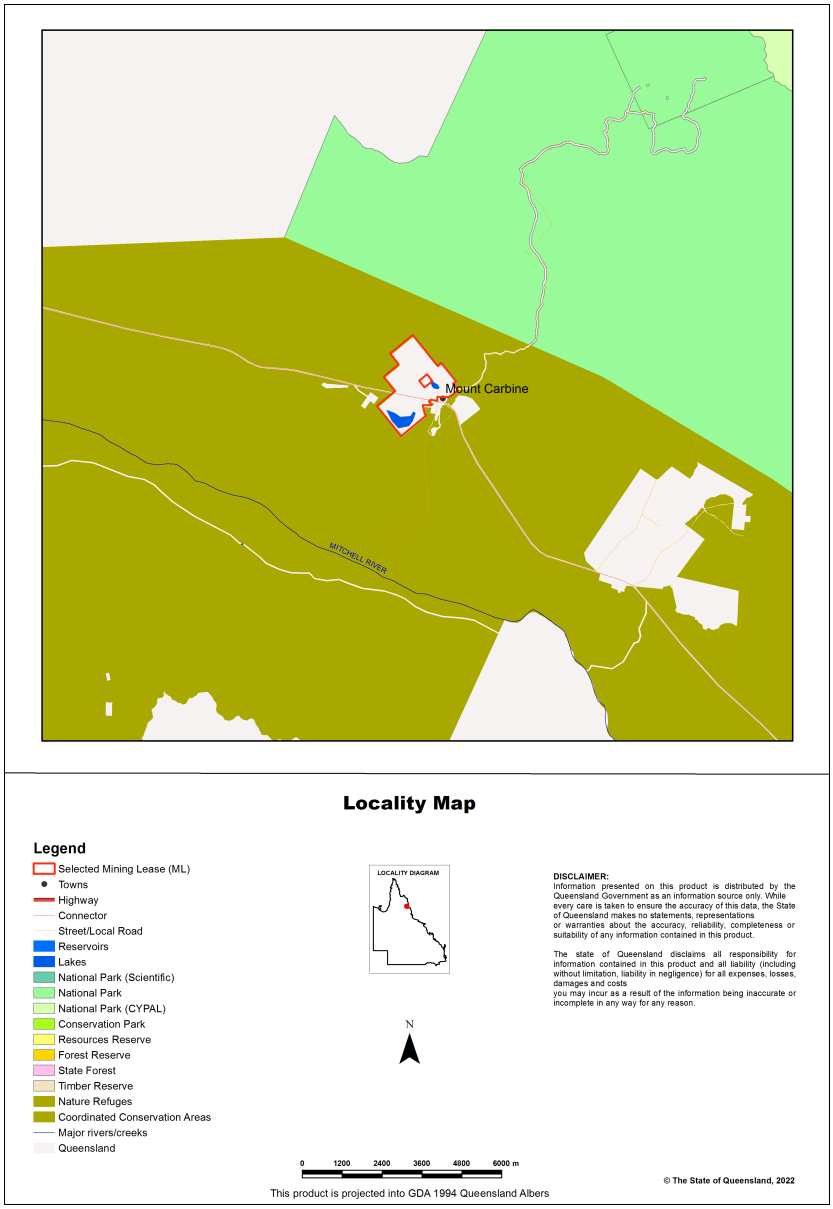
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Assessment Area Details

The following table provides an overview of the area of interest (AOI) with respect to selected topographic and environmental values.

Table 1: Summary table, details for AOI ml: 4867

Size (ha)	358.48
Local Government(s)	Mareeba Shire
Bioregion(s)	Einasleigh Uplands
Subregion(s)	Hodgkinson Basin
Catchment(s)	Mitchell



Matters of State Environmental Significance (MSES)

MSES Categories

Queensland's State Planning Policy (SPP) includes a biodiversity State interest that states:

'The sustainable, long-term conservation of biodiversity is supported. Significant impacts on matters of national or state environmental significance are avoided, or where this cannot be reasonably achieved; impacts are minimised and residual impacts offset.'

The MSES mapping product is a guide to assist planning and development assessment decision-making. Its primary purpose is to support implementation of the SPP biodiversity policy. While it supports the SPP, the mapping does not replace the regulatory mapping or environmental values specifically called up under other laws or regulations. Similarly, the SPP biodiversity policy does not override or replace specific requirements of other Acts or regulations.

The SPP defines matters of state environmental significance as:

- Protected areas (including all classes of protected area except coordinated conservation areas) under the *Nature Conservation Act 1992* ;

- Marine parks and land within a 'marine national park', 'conservation park', 'scientific research', 'preservation' or 'buffer' zone under the *Marine Parks Act 2004* ;

- Areas within declared fish habitat areas that are management A areas or management B areas under the Fisheries Regulation 2008;

- Threatened wildlife under the *Nature Conservation Act 1992* and special least concern animals under the Nature Conservation (Wildlife) Regulation 2006;

- Regulated vegetation under the *Vegetation Management Act 1999* that is:

    • Category B areas on the regulated vegetation management map, that are 'endangered' or 'of concern' regional ecosystems;

    • Category C areas on the regulated vegetation management map that are 'endangered' or 'of concern' regional ecosystems;

    • Category R areas on the regulated vegetation management map;

    • Regional ecosystems that intersect with watercourses identified on the vegetation management watercourse and drainage feature map;

    • Regional ecosystems that intersect with wetlands identified on the vegetation management wetlands map;

- Strategic Environmental Areas under the *Regional Planning Interests Act 2014* ;

- Wetlands in a wetland protection area of wetlands of high ecological significance shown on the Map of Queensland Wetland Environmental Values under the Environment Protection Regulation 2019;

- Wetlands and watercourses in high ecological value waters defined in the Environmental Protection (Water) Policy 2009, schedule 2;

- Legally secured offset areas.

MSES Values Present

The MSES values that are present in the area of interest are summarised in the table below:

Table 2: Summary of MSES present within the AOI

1a Protected Areas- estates	0.0 ha	0.0 %
1b Protected Areas- nature refuges	12.4 ha	3.5%
1c Protected Areas- special wildlife reserves	0.0 ha	0.0 %
2 State Marine Parks- highly protected zones	0.0 ha	0.0 %
3 Fish habitat areas (A and B areas)	0.0 ha	0.0 %
4 Strategic Environmental Areas (SEA)	0.0 ha	0.0 %
5 High Ecological Significance wetlands on the map of Referable Wetlands	0.0 ha	0.0 %
6a High Ecological Value (HEV) wetlands	0.0 ha	0.0 %
6b High Ecological Value (HEV) waterways	0.0 km	Not applicable
7a Threatened (endangered or vulnerable) wildlife	133.32 ha	37.2%
7b Special least concern animals	134.35 ha	37.5%
7c i Koala habitat area - core (SEQ)	0.0 ha	0.0 %
7c ii Koala habitat area - locally refined (SEQ)	0.0 ha	0.0 %
7d Sea turtle nesting areas	0.0 km	Not applicable
8a Regulated Vegetation - Endangered/Of concern in Category B (remnant)	0.0 ha	0.0 %
8b Regulated Vegetation - Endangered/Of concern in Category C (regrowth)	0.0 ha	0.0 %
8c Regulated Vegetation - Category R (GBR riverine regrowth)	0.0 ha	0.0 %
8d Regulated Vegetation - Essential habitat	141.12 ha	39.4%
8e Regulated Vegetation - intersecting a watercourse	5.5 km	Not applicable
8f Regulated Vegetation - within 100m of a Vegetation Management Wetland	0.0 ha	0.0 %
9a Legally secured offset areas- offset register areas	0.0 ha	0.0 %
9b Legally secured offset areas- vegetation offsets through a Property Map of Assessable Vegetation	0.0 ha	0.0 %

Additional Information with Respect to MSES Values Present

MSES - State Conservation Areas

1a. Protected Areas - estates

(no results)

1b. Protected Areas - nature refuges

Name
Brooklyn Nature Refuge

1c. Protected Areas - special wildlife reserves

(no results)

2. State Marine Parks - highly protected zones

(no results)

3. Fish habitat areas (A and B areas)

(no results)

Refer to **Map 1 - MSES - State Conservation Areas** for an overview of the relevant MSES.

MSES - Wetlands and Waterways

4. Strategic Environmental Areas (SEA)

(no results)

5. High Ecological Significance wetlands on the Map of Queensland Wetland Environmental Values

(no results)

6a. Wetlands in High Ecological Value (HEV) waters

(no results)

6b. Waterways in High Ecological Value (HEV) waters

(no results)

Refer to **Map 2 - MSES - Wetlands and Waterways** for an overview of the relevant MSES.

MSES - Species

7a. Threatened (endangered or vulnerable) wildlife

Values are present

7b. Special least concern animals

Values are present

7c i. Koala habitat area - core (SEQ)

Not applicable

7c ii. Koala habitat area - locally refined (SEQ)

Not applicable

7d. Wildlife habitat (sea turtle nesting areas)

Not applicable

Threatened (endangered or vulnerable) wildlife habitat suitability models

Species	Common name	NCA status	Presence
Boronia keysii		V	None
Calyptorhynchus lathami	Glossy black cockatoo	V	None
Casuarius casuarius johnsonii	Sthn population cassowary	E	None
Crinia tinnula	Wallum froglet	V	None
Denisonia maculata	Ornamental snake	V	None
Litoria freycineti	Wallum rocketfrog	V	None
Litoria olongburensis	Wallum sedgefrog	V	None
Macadamia integrifolia		V	None
Macadamia ternifolia		V	None
Macadamia tetraphylla		V	None
Melaleuca irbyana		E	None
Petaurus gracilis	Mahogany Glider	E	None
Petrogale persephone	Proserpine rock-wallaby	E	None
Pezoporus wallicus wallicus	Eastern ground parrot	V	None
Phascolarctos cinereus	Koala - outside SEQ*	V	None
Taudactylus pleione	Kroombit tinkerfrog	E	None
Xeromys myoides	Water Mouse	V	None

**For koala model, this includes areas outside SEQ. Check 7c SEQ koala habitat for presence/absence.*

Threatened (endangered or vulnerable) wildlife species records

Scientific name	Common name	NCA status	EPBC status	Migratory status
Turnix olivii	buff-breasted button-quail	E	E	
Rostratula australis	Australian painted snipe	E	E	
Calidris ferruginea	curlew sandpiper	E	CE	M-C/J/R/B/E

Scientific name	Common name	NCA status	EPBC status	Migratory status
Macroderma gigas	ghost bat	E	V	
Grantiella picta	painted honeyeater	V	V	PM

Special least concern animal species records

Scientific name	Common name	Migratory status
Gallinago hardwickii	Latham's snipe	M-J/R/B/E
Actitis hypoleucos	common sandpiper	M-C/J/R/B/E
Calidris acuminata	sharp-tailed sandpiper	M-C/J/R/B/E
Calidris ruficollis	red-necked stint	M-C/J/R/B/E
Tringa nebularia	common greenshank	M-C/J/R/B/E
Pluvialis fulva	Pacific golden plover	M-C/J/R/B/E
Tringa stagnatilis	marsh sandpiper	M-C/J/R/B/E

Shorebird habitat (critically endangered/endangered/vulnerable)

Not applicable

Shorebird habitat (special least concern)

Not applicable

**Nature Conservation Act 1992 (NCA) Status- Endangered (E), Vulnerable (V) or Special Least Concern Animal (SL). Environment Protection and Biodiversity Conservation Act 1999 (EPBC) status: Critically Endangered (CE) Endangered (E), Vulnerable (V)*

Migratory status (M) - China and Australia Migratory Bird Agreement (C), Japan and Australia Migratory Bird Agreement (J), Republic of Korea and Australia Migratory Bird Agreement (R), Bonn Migratory Convention (B), Eastern Flyway (E)

To request a species list for an area, or search for a species profile, access Wildlife Online at:
https://www.qld.gov.au/environment/plants-animals/species-list/

Refer to **Map 3a - MSES - Species - Threatened (endangered or vulnerable) wildlife and special least concern animals, Map 3b - MSES - Species - Koala habitat area (SEQ)** and **Map 3c - MSES - Wildlife habitat (sea turtle nesting areas)** for an overview of the relevant MSES.

MSES - Regulated Vegetation

For further information relating to regional ecosystems in general, go to:
https://www.qld.gov.au/environment/plants-animals/plants/ecosystems/
For a more detailed description of a particular regional ecosystem, access the regional ecosystem search page at:
https://environment.ehp.qld.gov.au/regional-ecosystems/

8a. Regulated Vegetation - Endangered/Of concern in Category B (remnant)

Not applicable

8b. Regulated Vegetation - Endangered/Of concern in Category C (regrowth)

Not applicable

8c. Regulated Vegetation - Category R (GBR riverine regrowth)

Not applicable

8d. Regulated Vegetation - Essential habitat

Values are present

8e. Regulated Vegetation - intersecting a watercourse**

A vegetation management watercourse is mapped as present

8f. Regulated Vegetation - within 100m of a Vegetation Management wetland

Not applicable

Refer to **Map 4 - MSES - Regulated Vegetation** for an overview of the relevant MSES.

MSES - Offsets

9a. Legally secured offset areas - offset register areas

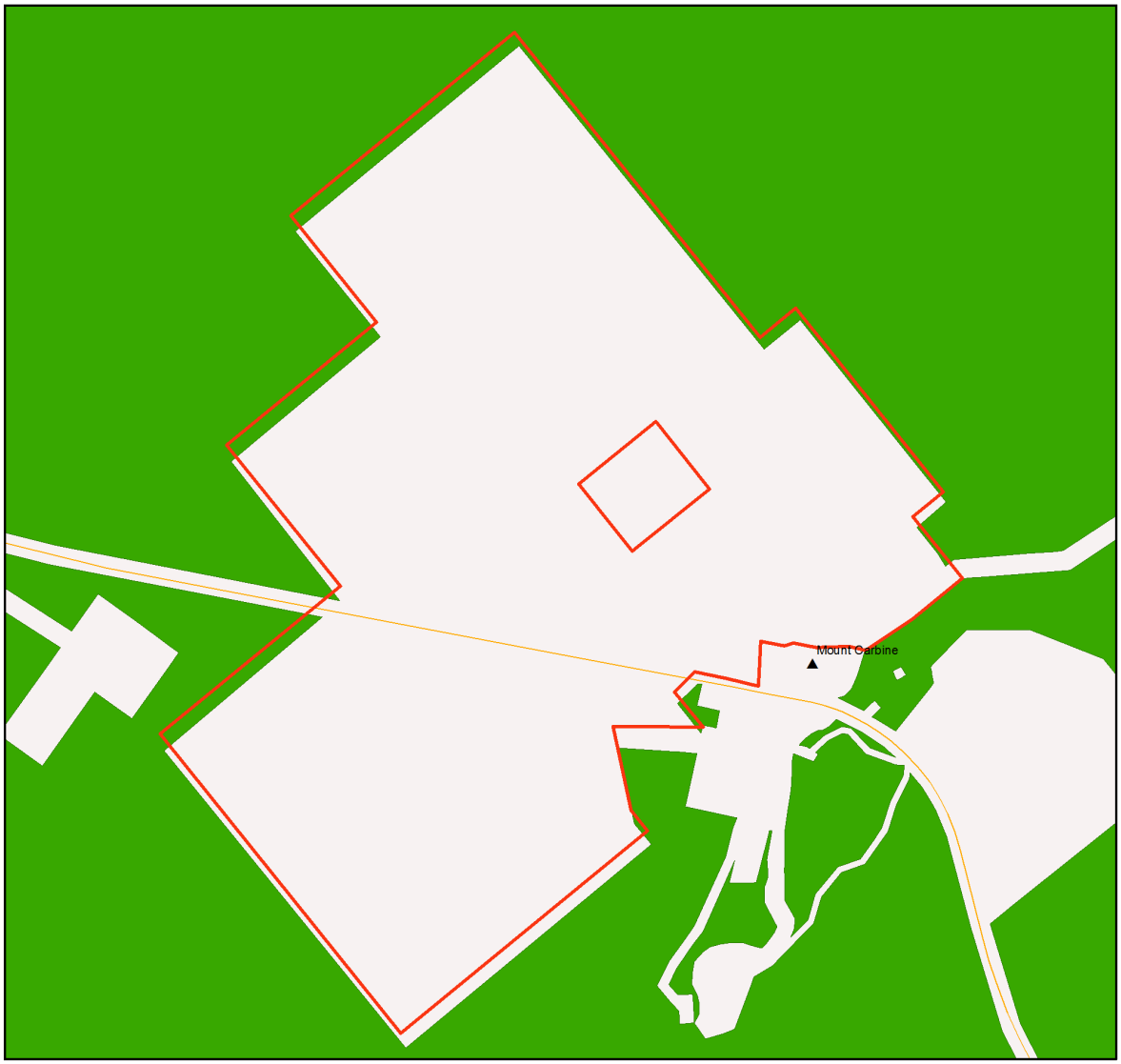
(no results)

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

(no results)

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

Map 1 - MSES - State Conservation Areas

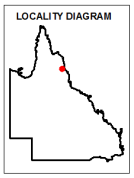


MSES - State Conservation Areas

Area of Interest

- Selected Mining Lease (ML)
- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Protected area (estates, nature refuges, special wildlife reserves)
- Declared fish habitat area (A and B areas)
- Marine park (highly protected)

LOCALITY DIAGRAM



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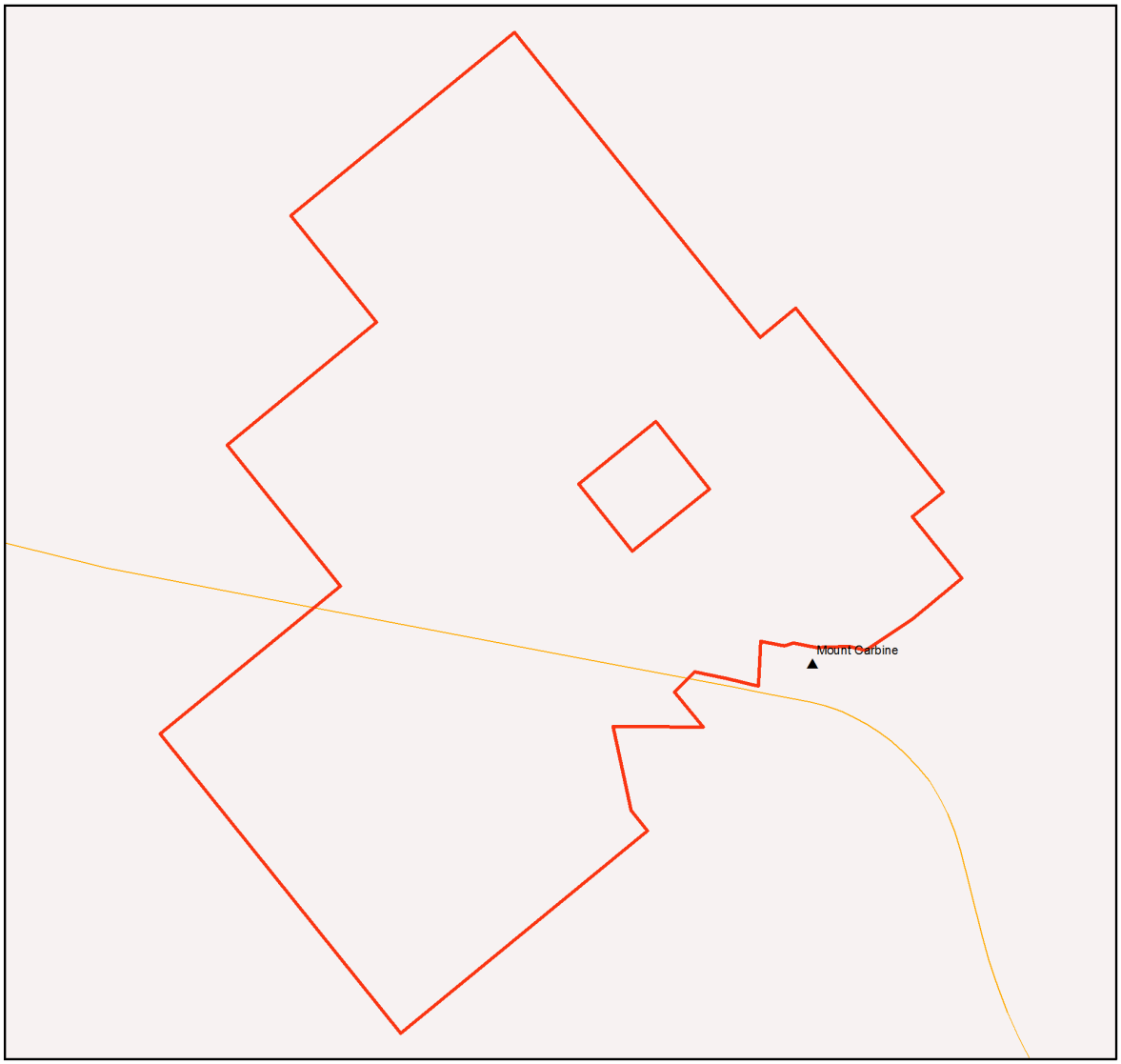
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Map 2 - MSES - Wetlands and Waterways

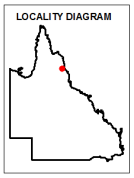


MSES - Wetlands and Waterways

Area of Interest

- Selected Mining Lease (ML)
- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Declared high ecological value waters (watercourse)
- Strategic environmental area (designated precinct)
- Declared high ecological value waters (wetland)
- High ecological significance wetlands

LOCALITY DIAGRAM



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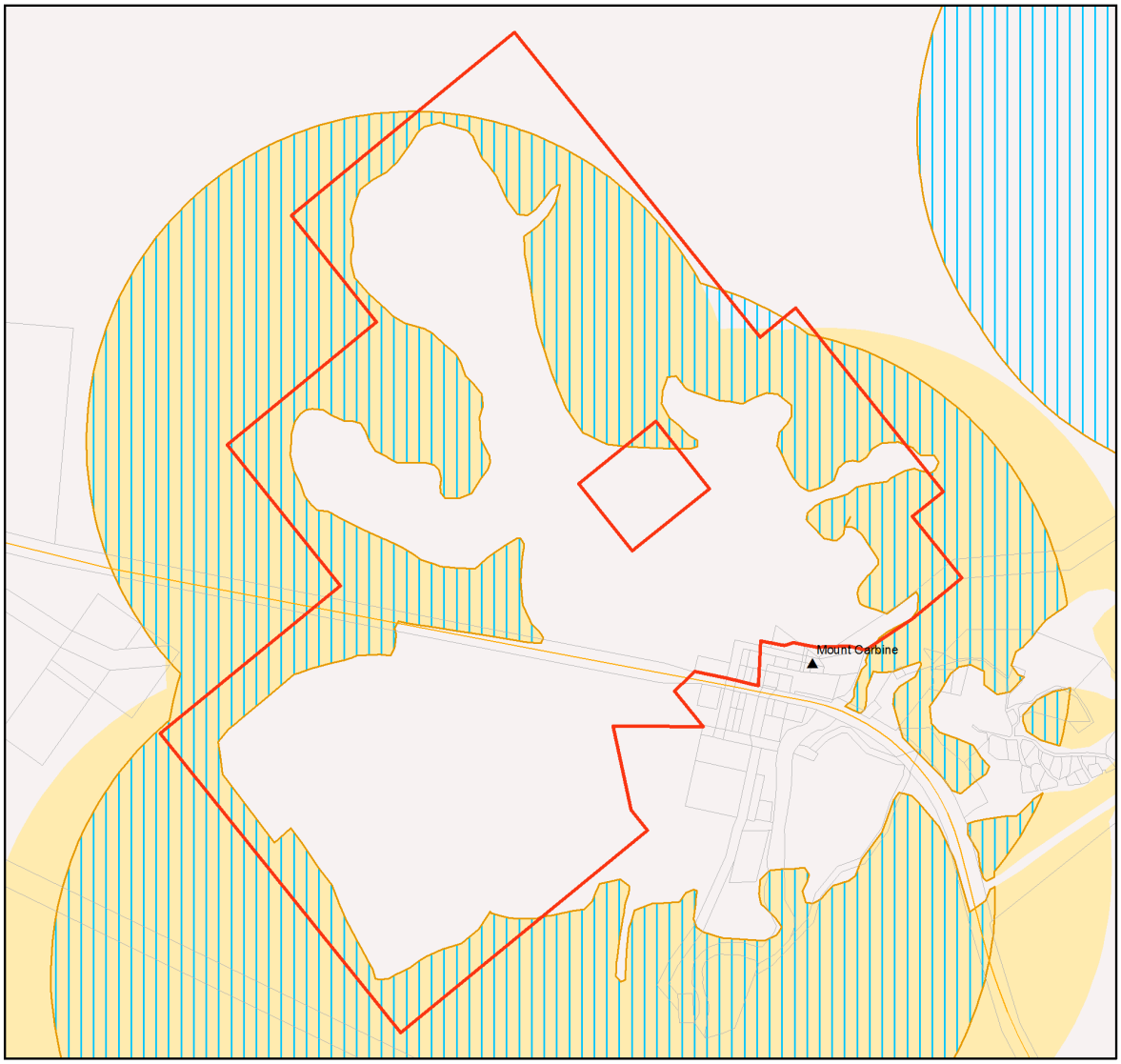
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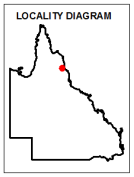
Map 3a - MSES - Species - Threatened (endangered or vulnerable) wildlife and special least concern animals



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

Area of Interest

- Selected Mining Lease (ML)
- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Wildlife habitat (special least concern)
- Wildlife habitat (endangered or vulnerable)



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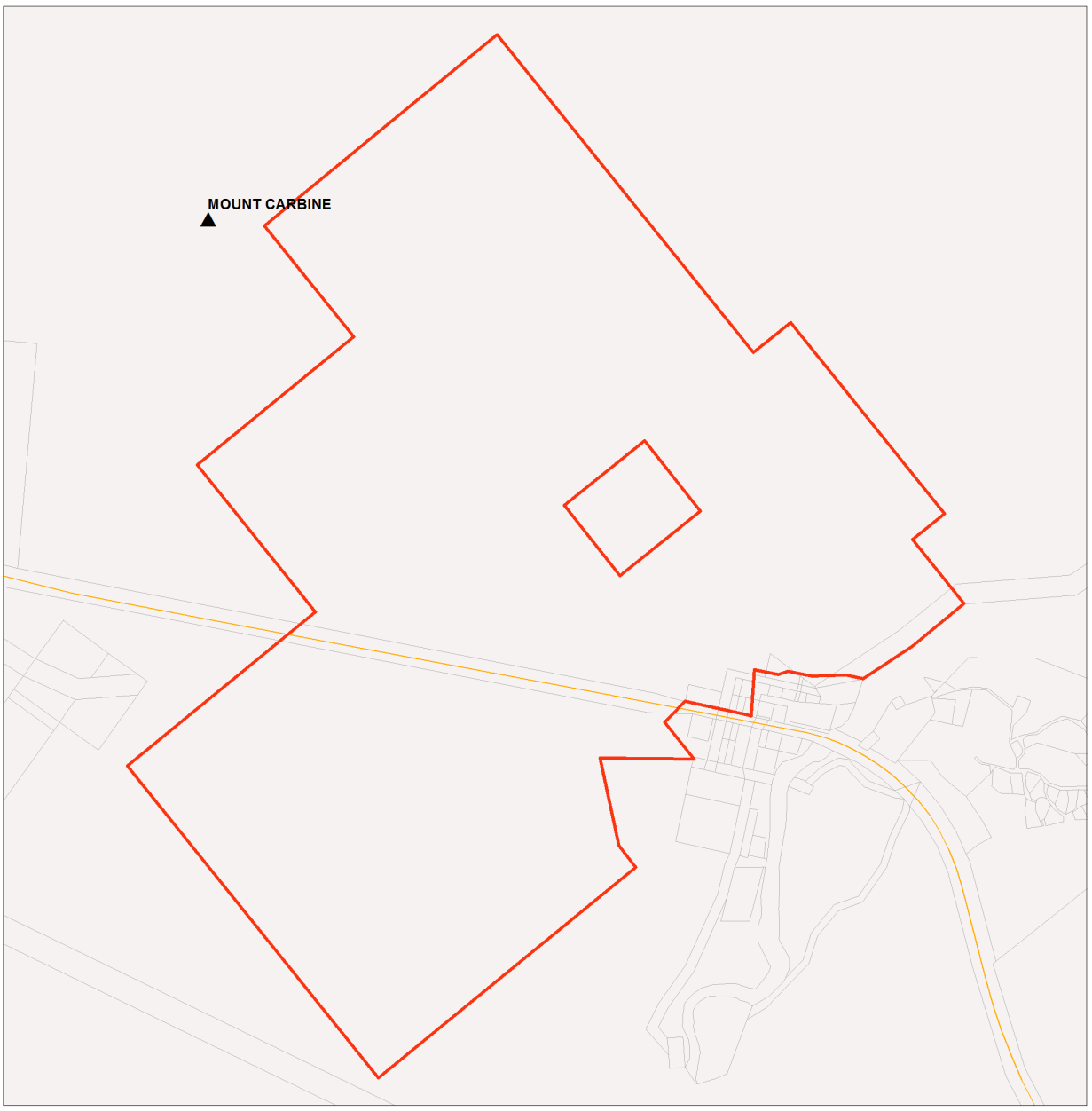
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Map 3b - MSES - Species - Koala habitat area (SEQ)

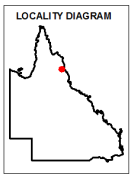


MSES - Species
Koala habitat area (SEQ)

Area of Interest

- Selected Mining Lease (ML)
- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Koala habitat area (core)
- Koala habitat area (locally refined)

LOCALITY DIAGRAM



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The represented layers for SEQ 'koala habitat area-core' and 'koala habitat area- locally refined' in MSES are sourced directly from the regulatory mapping under the Nature Conservation (Koala) Conservation Plan 2017. Whilst every effort is made to ensure the information remains current, there may be delays between updating versions. Please refer to the original mapping for the most recent version. See https://environment.des.qld.gov.au/wildlife/animals/living-with/koalas/mapping

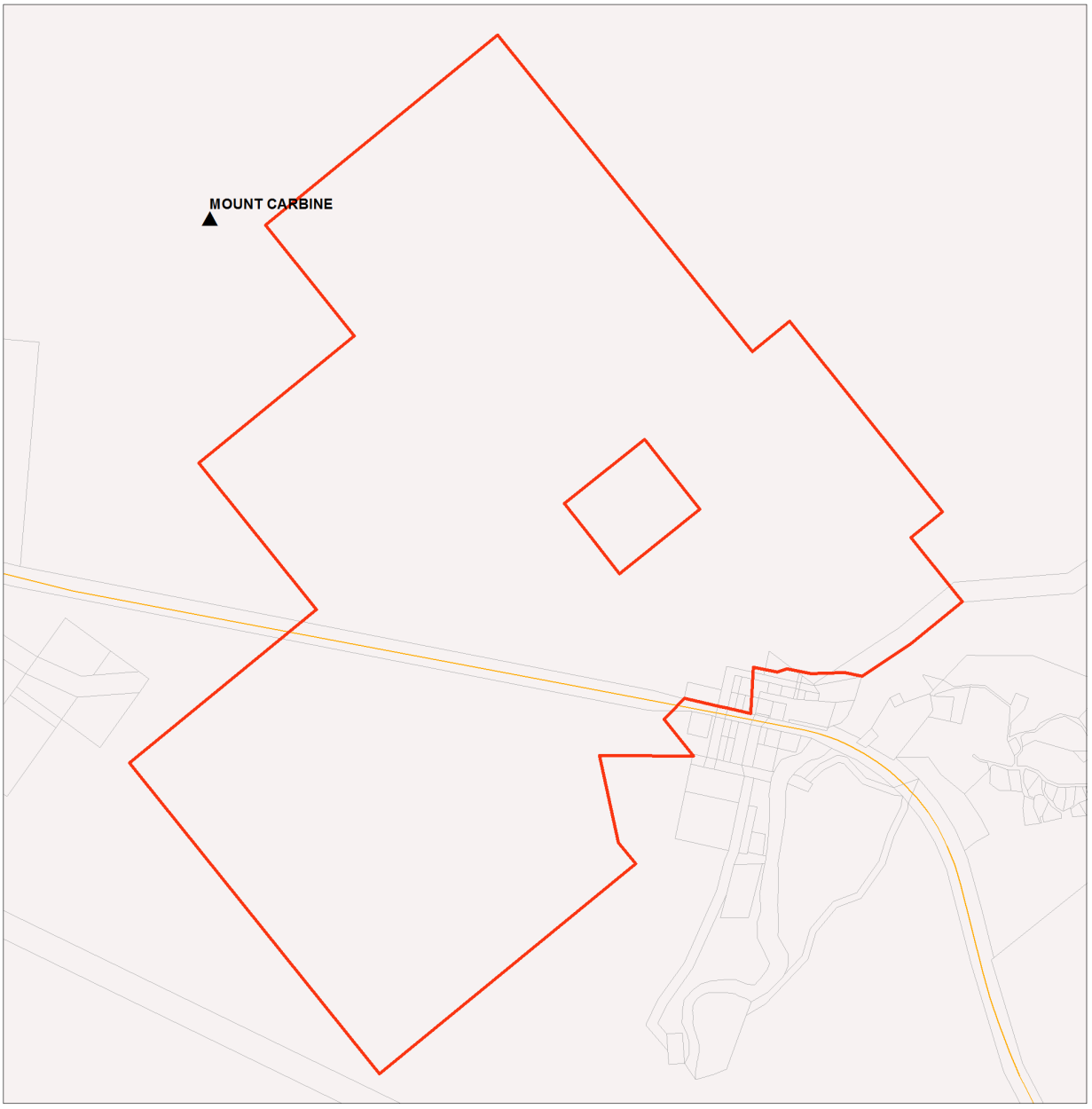
The koala habitat mapping within South East Queensland uses regional ecosystem linework compiled at a scale varying from 1:25,000 to 1:100,000. Linework should be used as a guide only. The positional accuracy of regional ecosystem data mapped at a scale of 1:100,000 is +/- 100 metres.

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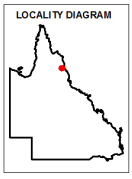
Map 3c - MSES - Wildlife habitat (sea turtle nesting areas)



MSES - Wildlife habitat (sea turtle nesting areas)

Area of Interest
- Selected Mining Lease (ML)
- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Wildlife habitat (sea turtle nesting areas)

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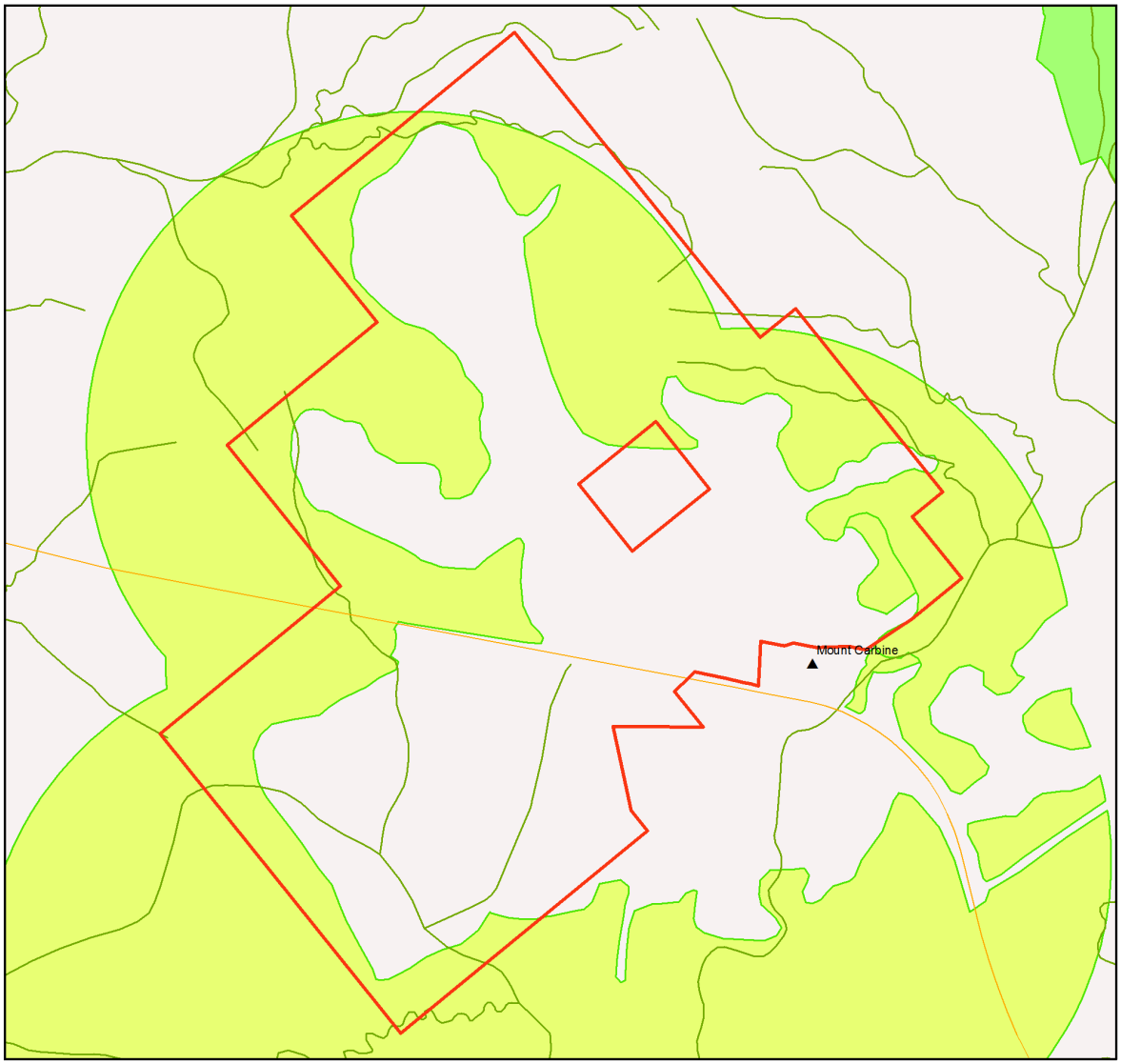
MSES mapping of sea turtle nesting areas identifies beaches where the recorded number of turtle nests are over 1% of the turtle species or genetic stock. The linework is also deliberately extended along nearby rocky coastlines and headlands to recognise that significant numbers of nesting adults and hatchlings can become disoriented by light pollution from development on rocky coastlines and headlands while navigating offshore from nesting beaches.

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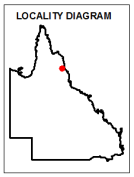
Map 4 - MSES - Regulated Vegetation



MSES - Regulated Vegetation

Area of Interest

- Selected Mining Lease (ML)
- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Regulated vegetation (intersecting a watercourse)
- Regulated vegetation (100m from wetland)
- Regulated vegetation (category B - endangered or of concern)
- Regulated vegetation (category C - endangered or of concern)
- Regulated vegetation (category R - GBR riverine)
- Regulated vegetation (essential habitat)



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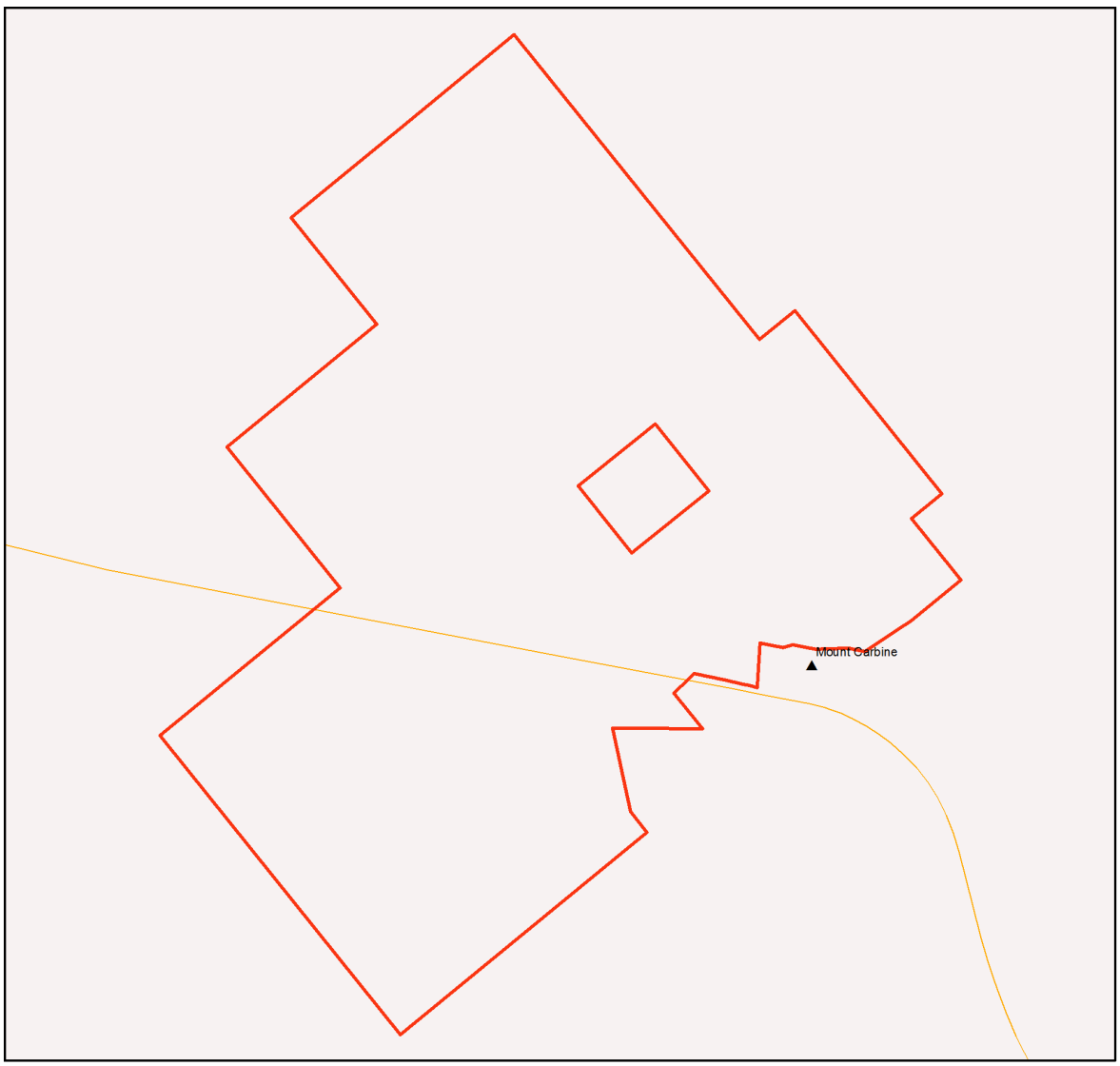
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Map 5 - MSES - Offset Areas

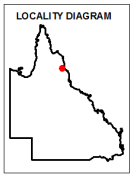


MSES - Offsets

Area of Interest

- Selected Mining Lease (ML)
- Towns
- Freeways/Highways
- Secondary roads
- Major rivers/creeks
- Legally secured offset area (offset register)
- Legally secured offset area (vegetation offsets)

LOCALITY DIAGRAM



N

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Appendices

Appendix 1 - Matters of State Environmental Significance (MSES) methodology

MSES mapping is a regional-scale representation of the definition for MSES under the State Planning Policy (SPP). The compiled MSES mapping product is a guide to assist planning and development assessment decision-making. Its primary purpose is to support implementation of the SPP biodiversity policy. While it supports the SPP, the mapping does not replace the regulatory mapping or environmental values specifically called up under other laws or regulations. Similarly, the SPP biodiversity policy does not override or replace specific requirements of other Acts or regulations.

The Queensland Government's "Method for mapping - matters of state environmental significance for use in land use planning and development assessment" can be downloaded from:

http://www.ehp.qld.gov.au/land/natural-resource/method-mapping-mses.html .

Appendix 2 - Source Data

The datasets listed below are available on request from:

http://qldspatial.information.qld.gov.au/catalogue/custom/index.page

- Matters of State environmental significance

Note: MSES mapping is not based on new or unique data. The primary mapping product draws data from a number of underlying environment databases and geo-referenced information sources. MSES mapping is a versioned product that is updated generally on a twice-yearly basis to incorporate the changes to underlying data sources. Several components of MSES mapping made for the current version may differ from the current underlying data sources. To ensure accuracy, or proper representation of MSES values, it is strongly recommended that users refer to the underlying data sources and review the current definition of MSES in the State Planning Policy, before applying the MSES mapping.

Individual MSES layers can be attributed to the following source data available at QSpatial:

MSES layers	**current QSpatial data (http://qspatial.information.qld.gov.au)**
Protected Areas-Estates, Nature Refuges, Special Wildlife Reserves	- Protected areas of Queensland - Nature Refuges - Queensland - Special Wildlife Reserves- Queensland
Marine Park-Highly Protected Zones	Moreton Bay marine park zoning 2008
Fish Habitat Areas	Queensland fish habitat areas
Strategic Environmental Areas-designated	Regional Planning Interests Act - Strategic Environmental Areas
HES wetlands	Map of Queensland Wetland Environmental Values
Wetlands in HEV waters	HEV waters: - EPP Water intent for waters Source Wetlands: - Queensland Wetland Mapping (Current version 5) Source Watercourses: - Vegetation management watercourse and drainage feature map (1:100000 and 1:250000)
Wildlife habitat (threatened and special least concern)	- WildNet database species records - habitat suitability models (various) - SEQ koala habitat areas under the Koala Conservation Plan 2019 - Sea Turtle Nesting Areas records
VMA regulated regional ecosystems	Vegetation management regional ecosystem and remnant map
VMA Essential Habitat	Vegetation management - essential habitat map
VMA Wetlands	Vegetation management wetlands map
Legally secured offsets	Vegetation Management Act property maps of assessable vegetation. For offset register data-contact DES
Regulated Vegetation Map	Vegetation management - regulated vegetation management map

Appendix 3 - Acronyms and Abbreviations

AOI	- Area of Interest
DES	- Department of Environment and Science
EP Act	- *Environmental Protection Act 1994*
EPP	- Environmental Protection Policy
GDA94	- Geocentric Datum of Australia 1994
GEM	- General Environmental Matters
GIS	- Geographic Information System
MSES	- Matters of State Environmental Significance
NCA	- *Nature Conservation Act 1992*
RE	- Regional Ecosystem
SPP	- State Planning Policy
VMA	- *Vegetation Management Act 1999*

APPENDIX C – ENVIRONMENTAL REPORTS – BIODIVERSITY AND CONSERVATION VALUES – BIODIVERSITY PLANNING ASSESSMENTS AND AQUATIC CONSERVATION ASSESSMENTS

TAILINGS.WATER.WASTE.

Queensland Government

Department of Environment and Science

Environmental Reports

Biodiversity and Conservation Values

Biodiversity Planning Assessments and Aquatic Conservation Assessments

For the selected area of interest
ml: 4867

Environmental Reports - General Information

The Environmental Reports portal provides for the assessment of selected matters of interest relevant to a user specified location, or Area of Interest (AOI). All area and derivative figures are relevant to the extent of matters of interest contained within the AOI unless otherwise stated. Please note, if a user selects an AOI via the "Central co-ordinates" option, the resulting assessment area encompasses an area extending from 2km radius from the point of interest.

All area and area derived figures included in this report have been calculated via reprojecting relevant spatial features to Albers equal-area conic projection (central meridian = 146, datum Geocentric Datum of Australia 1994). As a result, area figures may differ slightly if calculated for the same features using a different co-ordinate system.

Figures in tables may be affected by rounding.

The matters of interest reported on in this document are based upon available state mapped datasets. Where the report indicates that a matter of interest is not present within the AOI (e.g. where area related calculations are equal to zero, or no values are listed), this may be due either to the fact that state mapping has not been undertaken for the AOI, that state mapping is incomplete for the AOI, or that no values have been identified within the site.

The information presented in this report should be considered as a guide only and field survey may be required to validate values on the ground.

Please direct queries about these reports to: biodiversity.planning@des.qld.gov.au

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Summary Information

Tables 1 to 8 provide an overview of the AOI with respect to selected topographic and environmental values.

Table 1: Area of interest details: ml: 4867

Size (ha)	358.48
Local Government(s)	Mareeba Shire
Bioregion(s)	Einasleigh Uplands
Subregion(s)	Hodgkinson Basin
Catchment(s)	Mitchell

The following table identifies available Biodiversity Planning Assessments (BPAs) and Aquatic Conservation Assessments (ACAs) with respect to the AOI.

Table 2: Available Biodiversity Planning and Aquatic Conservation Assessments

Assessment Type	Assessment Area and Version
Biodiversity Planning Assessment(s)	Einasleigh Uplands v1.1
Aquatic Conservation Assessment(s) (riverine)	Eastern Gulf of Carpentaria v1.1
Aquatic Conservation Assessment(s) (non-riverine)	Eastern Gulf of Carpentaria v1.1

Table 3: Remnant regional ecosystems within the AOI as per the Qld Herbarium's 'biodiversity status'

Biodiversity Status	Area (Ha)	% of AOI
Endangered	0.0	0.0
Of concern	0.68	0.19
No concern at present	141.67	39.52

The following table identifies the extent and proportion of the user specified area of interest (AOI) which is mapped as being of "State", "Regional" or "Local" significance via application of the Queensland Department of Environment and Science's *Biodiversity Assessment and Mapping Methodology* (BAMM).

Table 4: Summary table, biodiversity significance

Biodiversity significance	Area (Ha)	% of AOI
State Habitat for EVNT taxa	27.1	7.56
State	119.98	33.47
Regional	211.4	58.97
Local or Other Values	0.0	0.0

Table 5: Non-riverine wetlands intersecting the AOI

Non-riverine wetland types intersecting the area of interest	#
Number of Palustrine wetlands	0
Number of Lacustrine wetlands	3
Total number of non-riverine wetlands	3

NB. The figures presented in the table above are derived from the relevant non-riverine Aquatic Conservation Assessment(s). Later releases of wetland mapping produced via the Queensland Wetland Mapping Program may provide more recent information in regards to wetland extent.

Table 6: Named waterways intersecting the AOI

(no results)

Refer to **Map 1** for general locality information.

The following two tables identify the extent and proportion of the user specified AOI which is mapped as being of "Very High", "High", "Medium", "Low", or "Very Low" aquatic conservation value for riverine and non-riverine wetlands via application of the Queensland Department of Environment and Science's *Aquatic Biodiversity Assessment and Mapping Method* (AquaBAMM).

Table 7: Summary table, aquatic conservation significance (riverine)

Aquatic conservation significance (riverine wetlands)	Area (Ha)	% of AOI
Very High	358.48	100.0
High	0.0	0.0
Medium	0.0	0.0
Low	0.0	0.0
Very Low	0.0	0.0

Table 8: Summary table, aquatic conservation significance (non-riverine)

Aquatic conservation significance (non-riverine wetlands)	Area (Ha)	% of AOI
Very High	0.0	0.0
High	0.0	0.0
Medium	56.93	15.88
Low	0.0	0.0
Very Low	0.0	0.0

Biodiversity Planning Assessments

Introduction

The Department of Environment and Science (DES) attributes biodiversity significance on a bioregional scale through a Biodiversity Planning Assessment (BPA). A BPA involves the integration of ecological criteria using the *Biodiversity assessment and Mapping Methodology* (BAMM) and is developed in two stages: 1) **diagnostic criteria**, and 2) **expert panel criteria**. The diagnostic criteria are based on existing data which is reliable and uniformly available across a bioregion, while the expert panel criteria allows for the refinement of the mapped information from the diagnostic output by incorporating local knowledge and expert opinion.

The BAMM methodology has application for identifying areas with various levels of significance solely for biodiversity reasons. These include threatened ecosystems or taxa, large tracts of habitat in good condition, ecosystem diversity, landscape context and connection, and buffers to wetlands or other types of habitat important for the maintenance of biodiversity or ecological processes. While natural resource values such as dryland salinity, soil erosion potential or land capability are not dealt with explicitly, they are included to some extent within the biodiversity status of regional ecosystems recognised by the DES.

Biodiversity Planning Assessments (BPAs) assign three levels of overall biodiversity significance.

- **State significance** - areas assessed as being significant for biodiversity at the bioregional or state scales. They also include areas assessed by other studies/processes as being significant at national or international scales. In addition, areas flagged as being of State significance due to the presence of endangered, vulnerable and/or near threatened taxa, are identified as "State Habitat for EVNT taxa".
- **Regional significance** - areas assessed as being significant for biodiversity at the subregional scale. These areas have lower significance for biodiversity than areas assessed as being of State significance.
- **Local significance and/or other values** - areas assessed as not being significant for biodiversity at state or regional scales. Local values are of significance at the local government scale.

For further information on released BPAs and a copy of the underlying methodology, go to:

http://www.qld.gov.au/environment/plants-animals/biodiversity/planning/

The GIS results can be downloaded from the Queensland Spatial Catalogue at:

http://qspatial.information.qld.gov.au/geoportal/

The following table identifies the extent and proportion of the user specified AOI which is mapped as being of "State", "Regional" or "Local" significance via application of the BAMM.

Table 9: Summary table, biodiversity significance

Biodiversity significance	Area (Ha)	% of AOI
State Habitat for EVNT taxa	27.1	7.56
State	119.98	33.47
Regional	211.4	58.97
Local or Other Values	0.0	0.0

Refer to **Map 2** for further information.

Diagnostic Criteria

Diagnostic criteria are based on existing data which is reliable and uniformly available across a bioregion. These criteria are diagnostic in that they are used to filter the available data and provide a "first-cut" or initial determination of biodiversity significance. This initial assessment is then combined through a second group of other essential criteria.

A description of the individual diagnostic criteria is provided in the following sections.

Criteria A. Habitat for EVNT taxa: Classifies areas according to their significance based on the presence of endangered, vulnerable and/or rare (EVNT) taxa. EVNT taxa are those scheduled under the *Nature Conservation Act 1992* and/or the

Environment Protection and Biodiversity Conservation Act 1999. It excludes highly mobile fauna taxa which are instead considered in Criterion H and brings together information on EVNT taxa using buffering of recorded sites or habitat suitability models (HSM) where available.

Criteria B. Ecosystem value: Classifies on the basis of biodiversity status of regional ecosystems, their extent in protected areas (presence of poorly conserved regional ecosystems), the presence of significant wetlands; and areas of national importance such as the presence of Threatened Ecological Communities, World Heritage areas and Ramsar sites. Ecosystem value is applied at a bioregional (**B1**) and regional (**B2**) scale.

Criteria C. Tract size: Measures the relative size of tracts of vegetation in the landscape. The size of any tract is a major indicator of ecological significance, and is also strongly correlated with the long-term viability of biodiversity values. Larger tracts are less susceptible to ecological edge effects and are more likely to sustain viable populations of native flora and fauna than smaller tracts.

Criteria D. Relative size of regional ecosystems: Classifies the relative size of each regional ecosystem unit within its bioregion (**D1**) and its subregion (**D2**). Remnant units are compared with all other occurrences with the same regional ecosystem. Large examples of a regional ecosystem are more significant than smaller examples of the same regional ecosystem because they are more representative of the biodiversity values particular to the regional ecosystem, are more resilient to the effects of disturbance, and constitute a significant proportion of the total area of the regional ecosystem.

Criteria F. Ecosystem diversity: Is an indicator of the number of regional ecosystems occurring within an area. An area with high ecosystem diversity will have many regional ecosystems and ecotones relative to other areas within the bioregion.

Criteria G. Context and connection: Represents the extent to which a remnant unit incorporates, borders or buffers areas such as significant wetlands, endangered ecosystems; and the degree to which it is connected to other vegetation.

A summary of the biodiversity status based upon the diagnostic criteria is provided in the following table.

Table 10: Summary of biodiversity significance based upon diagnostic criteria with respect to the AOI

Biodiversity significance	Description	Area (Ha)	% of AOI
State	Remnant contains at least 1 Endangered or 2 Vulnerable or Near Threatened species (A)	27.1	7.56
Regional	Remnant contains at least one Of Concern RE (B1)	18.29	5.1
Local or Other Values	Refer to diagnostic data for additional information	101.7	28.37

Assessment of diagnostic criteria with respect to the AOI

The following table reflects an assessment of the individual diagnostic criteria noted above in regards to the AOI.

Table 11: Assessment of individual diagnostic criteria with respect to the AOI

Diagnostic Criteria	Very High Rating - Area (Ha)	Very High Rating - % of AOI	High Rating - Area (Ha)	High Rating - % of AOI	Medium Rating - Area (Ha)	Medium Rating - % of AOI	Low Rating - Area (Ha)	Low Rating - % of AOI
A: Habitat for EVNT Taxa	27.09	7.6			119.99	33.5		
B1: Ecosystem Value (Bioregion)			41.97	11.7	105.11	29.3		
B2: Ecosystem Value (Subregion)					147.08	41.0		
C: Tract Size			145.36	40.5			1.72	0.5
D1: Relative RE Size (Bioregion)							147.08	41.0
D2: Relative RE Size (Subregion)							147.08	41.0
F: Ecosystem Diversity	31.17	8.7	113.42	31.6	2.49	0.7		
G: Context and Connection	76.29	21.3	28.0	7.8	41.07	11.5	1.72	0.5

Other Essential Criteria

Other essential criteria (also known as expert panel criteria) are based on non-uniform information sources and which may rely more upon expert opinion than on quantitative data. These criteria are used to provide a "second-cut" determination of biodiversity significance, which is then combined with the diagnostic criteria for an overall assessment of relative biodiversity significance. A summary of the biodiversity status based upon the other essential criteria is provided in the following table.

Table 12: Summary of biodiversity significance based upon other essential criteria with respect to the AOI

Biodiversity significance	Description	Area (Ha)	% of AOI
State	Remnant contains Special Biodiversity Values (view Expert Panel data for further information) (I) & Remnant forms part of a bioregional corridor (J)	126.77	35.36

Biodiversity significance	Description	Area (Ha)	% of AOI
Regional	Remnant contains Special Biodiversity Values (view Expert Panel data for further information) (I)	231.71	64.64

A description of each of the other essential criteria and associated assessment in regards to the AOI is provided in the following sections.

Criteria H. Essential and general habitat for priority taxa: Priority taxa are those which are at risk or of management concern, taxa of scientific interest as relictual (ancient or primitive), endemic taxa or locally significant populations (such as a flying fox camp or heronry), highly specialised taxa whose habitat requirements are complex and distributions are not well correlated with any particular regional ecosystem, taxa important for maintaining genetic diversity (such as complex spatial patterns of genetic variation, geographic range limits, highly disjunct populations), taxa critical for management or monitoring of biodiversity (functionally important or ecological indicators), or economic and culturally important taxa.

Criteria I. Special biodiversity values: areas with special biodiversity values are important because they contain multiple taxa in a unique ecological and often highly biodiverse environment. Areas with special biodiversity values can include the following:

- Ia - centres of endemism - areas where concentrations of taxa are endemic to a bioregion or subregion are found.
- Ib - wildlife refugia (Morton *et al*. 1995), for example, islands, mound springs, caves, wetlands, gorges, mountain ranges and topographic isolates, ecological refuges, refuges from exotic animals, and refuges from clearing. The latter may include large areas that are not suitable for clearing because of land suitability/capability.
- Ic - areas with concentrations of disjunct populations.
- Id - areas with concentrations of taxa at the limits of their geographic ranges.
- Ie - areas with high species richness.
- If - areas with concentrations of relictual populations (ancient and primitive taxa).
- Ig - areas containing REs with distinct variation in species composition associated with geomorphology and other environmental variables.
- Ih - an artificial waterbody or managed/manipulated wetland considered by the panel/s to be of ecological significance.
- Ii - areas with a high density of hollow-bearing trees that provide habitat for animals.
- Ij - breeding or roosting sites used by a significant number of individuals.
- Ik - climate change refuge.

The following table identifies the value and extent area of the Other Essential Criteria H and I within the AOI.

Table 13: Relative importance of expert panel criteria (H and I) used to access overall biodiversity significance with respect to the AOI

Expert Panel	Very High Rating - Area (Ha)	Very High Rating - % of AOI	High Rating - Area (Ha)	High Rating - % of AOI	Medium Rating - Area (Ha)	Medium Rating - % of AOI	Low Rating - Area (Ha)	Low Rating - % of AOI
H: Core Habitat Priority Taxa			14.14	3.9	103.7	28.9		
Ia: Centres of Endemism			358.47	100.0				
Ib: Wildlife Refugia			358.47	100.0				
Ic: Disjunct Populations			358.47	100.0				
Id: Limits of Geographic Ranges								
Ie: High Species Richness			358.47	100.0				

Expert Panel	Very High Rating - Area (Ha)	Very High Rating - % of AOI	High Rating - Area (Ha)	High Rating - % of AOI	Medium Rating - Area (Ha)	Medium Rating - % of AOI	Low Rating - Area (Ha)	Low Rating - % of AOI
If: Relictual Populations			358.47	100.0				
Ig: Variation in Species Composition								
Ih: Artificial Wetland								
Ii: Hollow Bearing Trees								
Ij: Breeding or Roosting Site								
Ik: Climate Refugia								

NB. Whilst biodiversity values associated with Criteria I may be present within the site (refer to tables 12 and 15), for the New England Tableland and Central Queensland Coast BPAs, area and % area figures associated with Criteria Ia through to Ij cannot be listed in the table above (due to slight variations in data formats between BPAs).

Criteria J. Corridors: areas identified under this criterion qualify either because they are existing vegetated corridors important for contiguity, or cleared areas that could serve this purpose if revegetated. Some examples of corridors include riparian habitats, transport corridors and "stepping stones".

Bioregional and subregional conservation corridors have been identified in the more developed bioregions of Queensland through the BPAs, using an intensive process involving expert panels. Map 3 displays the location of corridors as identified under the Statewide Corridor network. The Statewide Corridor network incorporates BPA derived corridors and for bioregions where no BPA has been assessed yet, corridors derived under other planning processes. *Note: as a result of updating and developing a statewide network, the alignment of corridors may differ slightly in some instances when compared to those used in individual BPAs.*

The functions of these corridors are:

- **Terrestrial** Bioregional corridors, in conjunction with large tracts of remnant vegetation, maintain ecological and evolutionary processes at a landscape scale, by:

  • Maintaining long term evolutionary/genetic processes that allow the natural change in distributions of species and connectivity between populations of species over long periods of time;

  • Maintaining landscape/ecosystems processes associated with geological, altitudinal and climatic gradients, to allow for ecological responses to climate change;

  • Maintaining large scale seasonal/migratory species processes and movement of fauna;

  • Maximising connectivity between large tracts/patches of remnant vegetation;

  • Identifying key areas for rehabilitation and offsets; and

- **Riparian** Bioregional Corridors also maintain and encourage connectivity of riparian and associated ecosystems.

The location of the corridors is determined by the following principles:

- Terrestrial

  • Complement riparian landscape corridors (i.e. minimise overlap and maximise connectivity);

  • Follow major watershed/catchment and/or coastal boundaries;

  • Incorporate major altitudinal/geological/climatic gradients;

  • Include and maximise connectivity between large tracts/patches of remnant vegetation;

  • Include and maximise connectivity between remnant vegetation in good condition; and

- Riparian

  • Located on the major river or creek systems within the bioregion in question.

The total extent of remnant vegetation triggered as being of "State", "Regional" or "Local" significance due to the presence of an overlying BPA derived terrestrial or riparian corridor within the AOI, is provided in the following table. For further

information on how remnant vegetation is triggered due to the presence of an overlying BPA derived corridor, refer to the relevant landscape BPA expert panel report(s).

Table 14: Extent of triggered remnant vegetation due to the presence of BPA derived corridors with respect to the AOI

Biodiversity Significance	Area (Ha)	% of AOI
State	126.77	35.36
Regional	0.0	0.0
Local	0.0	0.0

NB: area figures associated with the extent of corridor triggered remnant vegetation are only available for those bioregions where a BPA has been undertaken.

Refer to **Map 3** for further information.

Threatening process/condition (Criteria K) - areas identified by experts under this criterion may be used to amend (upgrade or downgrade) biodiversity significance arising from the "first-cut" analysis. The condition of remnant vegetation is affected by threatening processes such as weeds, ferals, grazing and burning regime, selective timber harvesting/removal, salinity, soil erosion, and climate change.

Assessment of Criteria K with respect to the AOI is not currently included in the "Biodiversity and Conservation Values" report, as it has not been applied to the majority of Queensland due to data/information limitations and availability.

Special Area Decisions

Expert panel derived "Special Area Decisions" are used to assign values to Other Essential Criteria. The specific decisions which relate to the AOI in question are listed in the table below.

Table 15: Expert panel decisions for assigning levels of biodiversity significance with respect to the AOI

Decision Number	Description	Panel Recommended Significance	Criteria Values
eiu_fa_27	Areas of Regional significance for invertebrates	Regional	Ia (centre of endemism): HIGH Ib (wildlife refugia): HIGH Ic (disjunct populations): HIGH Ie (high species richness): HIGH If (relictual populations): HIGH
eiu_fa_30	High precision records for priority taxa of Regional significance are contained within the remnant.	Regional	Criterion H: HIGH
eiu_fa_31	Low precision records for priority taxa of Regional significance are contained within the remnant.	None	Criterion H: MEDIUM
eiu_fl_26	High precision records for priority taxa of Regional significance are contained within the remnant.	Regional	Criterion H: HIGH
eiu_fl_27	Low precision records for priority taxa of Regional significance are contained within the remnant.	None	Criterion H: MEDIUM
eiu_l_32	Bioregional Terrestrial Corridors	State or Regional	J (corridors): State or Regional

Expert panel decision descriptions:

eiu_fa_27

Between Carbine and McLeod River: Endemic Buprestidae (**Casturinia** spp.).

Irvinebank/Watsonville Area: Endemic Scarabidae (including **Blackburnium** sp. and Tesserodon sp.) and Bolbocertideae.

SW of Mt. Molloy: Endemic population of Macropenesthie spp (burrowing cockroach).

Southern Hann Tableland: Endemic Scarabidae, Histeridae spp. This area was incorporated into landscape decision eiu_l_12 and removed from here.

Well wooded country on the Newcastle Range: Rich variety of spp. in the Scarabidae (with at least one endemic Buprestid).

eiu_fa_30

Remnant contains Core Habitat for Priority taxa with high precision records.

eiu_fa_31

Remnant contains Core Habitat for Priority taxa with low precision records.

eiu_fl_26

Remnant contains Core Habitat for Priority taxa with high precision records.

eiu_fl_27

Remnant contains Core Habitat for Priority taxa with low precision records.

eiu_l_32

This terrestrial corridors decision identifies major themes of habitat connectivity across the bioregion. They identify north/south and east/west links that cover higher altitude areas along watersheds and mountain ranges, and areas characterised by a relative continuity of similar or related habitats, using the methodology outlined in EPA 2008. Identified corridor centrelines are buffered according to the significance of the centreline and the landscape context within which it occurs

Decision eiu_l_22 Corridor Special Management Areas identifies areas where values associated with landscape scale habitat connectivity have been compromised.

Aquatic Conservation Assessments

Introduction

The Aquatic Biodiversity Assessment and Mapping Method or AquaBAMM (Clayton *et al.* 2006), was developed to assess conservation values of wetlands in queensland, and may also have application in broader geographical contexts. It is a comprehensive method that uses available data, including data resulting from expert opinion, to identify relative wetland conservation/ecological values within a specified study area (usually a catchment). The product of applying this method is an Aquatic Conservation Assessment (ACA) for the study area.

An ACA using AquaBAMM is non-social, non-economic and identifies the conservation/ecological values of wetlands at a user-defined scale. It provides a robust and objective conservation assessment using criteria, indicators and measures that are founded upon a large body of national and international literature. The criteria, each of which may have variable numbers of indicators and measures, are naturalness (aquatic), naturalness (catchment), diversity and richness, threatened species and ecosystems, priority species and ecosystems, special features, connectivity and representativeness. An ACA using AquaBAMM is a powerful decision support tool that is easily updated and simply interrogated through a geographic information system (GIS).

Where they have been conducted, ACAs can provide a source of baseline wetland conservation/ecological information to support natural resource management and planning processes. They are useful as an independent product or as an important foundation upon which a variety of additional environmental and socio-economic elements can be added and considered (i.e. an early input to broader 'triple-bottom-line' decision-making processes). An ACA can have application in:

- determining priorities for protection, regulation or rehabilitation of wetlands and other aquatic ecosystems
- on-ground investment in wetlands and other aquatic ecosystems
- contributing to impact assessment of large-scale development (e.g. dams)
- water resource and strategic regional planning prcesses

For a detailed explanation of the methodology please refer to the summary and expert panel reports relevant to the ACA utilised in this assessment. These reports can be accessed at Wetland *Info*:

http://wetlandinfo.des.qld.gov.au/wetlands/assessment/assessment-methods/aca

The GIS results can be downloaded from the Queensland Spatial Catalogue at:

http://qspatial.information.qld.gov.au/geoportal/

Explanation of Criteria

Under the AquaBAMM, eight criteria are assessed to derive an overall conservation value. Similar to the Biodiversity Assessment and Mapping Methodology, the criteria may be primarily diagnostic (quantitative) or primarily expert opinion (qualitative) in nature. The following sections provide a brief description of each of the 8 criteria.

Criteria 1. Naturalness - Aquatic: This attribute reflects the extent to which a wetland's (riverine, non-riverine, estuarine) aquatic state of naturalness is affected through relevant influencing indicators which include: presence of exotic flora and fauna; presence of aquatic communities; degree of habitat modification and degree of hydrological modification.

Criteria 2. Naturalness - Catchment: The naturalness of the terrestrial systems of a catchment can have an influence on many wetland characteristics including: natural ecological processes e.g. nutrient cycling, riparian vegetation, water chemistry, and flow. The indicators utilised to assess this criterion include: presence of exotic flora and/or fauna; riparian, catchment and flow modification.

Criteria 3. Naturalness - Diversity and Richness: This criterion is common to many ecological assessment methods and can include both physical and biological features. It includes such indicators as species richness, riparian ecosystem richness and geomorphological diversity.

Criteria 4. Threatened Species and Ecosystems: This criterion evaluates ecological rarity characteristics of a wetland. This includes both species rarity and rarity of communities / assemblages. The communities and assemblages are best represented by regional ecosystems. Species rarity is determined by NCA and EPBC status with Endangered, Vulnerable or Near-threatened species being included in the evaluation. Ecosystem rarity is determined by regional ecosystem biodiversity status i.e. Endangered, Of Concern, or Not of Concern.

Criteria 5. Priority Species and Ecosystems: Priority flora and fauna species lists are expert panel derived. These are aquatic, semi-aquatic and riparian species which exhibit at least 1 particular trait in order to be eligible for consideration. For

flora species the traits included:

- It forms significant macrophyte beds (in shallow or deep water).
- It is an important food source.
- It is important/critical habitat.
- It is implicated in spawning or reproduction for other fauna and/or flora species.
- It is at its distributional limit or is a disjunct population.
- It provides stream bank or bed stabilisation or has soil binding properties.
- It is a small population and subject to threatening processes.

Fauna species are included if they meet at least one of the following traits:

- It is endemic to the study area (>75 per cent of its distribution is in the study area/catchment).
- It has experienced, or is suspected of experiencing, a serious population decline.
- It has experienced a significant reduction in its distribution and has a naturally restricted distribution in the study area/catchment.
- It is currently a small population and threatened by loss of habitat.
- It is a significant disjunct population.
- It is a migratory species (other than birds).
- A significant proportion of the breeding population (>one per cent for waterbirds, >75 per cent other species) occurs in the waterbody (see Ramsar criterion 6 for waterbirds).
- Limit of species range.

See the individual expert panel reports for the priority species traits specific to an ACA.

Criteria 6. Special Features: Special features are areas identified by flora, fauna and ecology expert panels which exhibit characteristics beyond those identified in other criteria and which the expert panels consider to be of the highest ecological importance. Special feature traits can relate to, but are not solely restricted to geomorphic features, unique ecological processes, presence of unique or distinct habitat, presence of unique or special hydrological regimes e.g. spring-fed streams. Special features are rated on a 1 - 4 scale (4 being the highest).

Criteria 7. Connectivity: This criterion is based on the concept that appropriately connected aquatic ecosystems are healthy and resilient, with maximum potential biodiversity and delivery of ecosystem services.

Criteria 8. Representativeness: This criterion applies primarily to non-riverine assessments, evaluates the rarity and uniqueness of a wetland type in relation to specific geographic areas. Rarity is determined by the degree of wetland protection within "protected Areas" estate or within an area subject to the *Fisheries Act 1994*, *Coastal Protection and Management Act 1995*, or *Marine Parks Act 2004*. Wetland uniqueness evaluates the relative abundance and size of a wetland or wetland management group within geographic areas such as catchment and subcatchment.

Riverine Wetlands

Riverine wetlands are all wetlands and deepwater habitats within a channel. The channels are naturally or artificially created, periodically or continuously contain moving water, or connecting two bodies of standing water. AquaBAMM, when applied to riverine wetlands uses a discrete spatial unit termed subsections. A subsection can be considered as an area which encompasses discrete homogeneous stream sections in terms of their natural attributes (i.e. physical, chemical, biological and utilitarian values) and natural resources. Thus in an ACA, an aquatic conservation significance score is calculated for each subsection and applies to all streams within a subsection, rather than individual streams as such.

Please note, the area figures provided in Tables 16 and 17, are derived using the extent of riverine subsections within the AOI. Refer to **Map 5** for further information. A summary of the conservation significance of riverine wetlands within the AOI is provided in the following table.

Table 16: Overall level/s of riverine aquatic conservation significance

Aquatic conservation significance (riverine wetlands)	Area (Ha)	% of AOI
Very High	358.48	100.0

Aquatic conservation significance (riverine wetlands)	Area (Ha)	% of AOI
High	0.0	0.0
Medium	0.0	0.0
Low	0.0	0.0
Very Low	0.0	0.0

The individual aquatic conservation criteria ratings for riverine wetlands within the AOI are listed below.

Table 17: Level/s of riverine aquatic conservation significance based on selected criteria

Criteria	Very High Rating - Area (Ha)	Very High Rating - % of AOI	High Rating - Area (Ha)	High Rating - % of AOI	Medium Rating - Area (Ha)	Medium Rating - % of AOI	Low Rating - Area (Ha)	Low Rating - % of AOI
1. Naturalness aquatic			358.48	100.0				
2. Naturalness catchment			358.48	100.0				
3. Diversity and richness	358.48	100.0						
4. Threatened species and ecosystems	358.48	100.0						
5. Priority species and ecosystems	358.48	100.0						
6. Special features	358.48	100.0						
7. Connectivity			358.48	100.0				
8. Representative-ness								

The table below lists and describes the relevant expert panel decisions used to assign conservation significance values to riverine wetlands within the AOI.

Table 18: Expert panel decisions for assigning overall levels of riverine aquatic conservation significance

Decision number	Special feature	Catchment	Criteria/Indicator/Measure	Conservation rating (1-4)
ml_r_ec_06	Perennial waterholes in active streams	Mitchell	5.2.1, 6.1.1, 6.2.1, 6.3.1, 6.3.4, 6.4.1, 7.1.2	3, 3, 3, 4, 3, 3, 3
ml_r_ec_16	Wet Tropics rainforests and associated riverine habitats across the upper Mitchell basin	Mitchell	5.2.1, 6.1.1, 6.2.1, 6.3.1, 6.3.3, 6.3.4, 6.4.1	4, 4, 4, 4, 4, 4, 4
ml_r_ec_18	Priority refugia for freshwater fish	Mitchell	6.2.1, 6.3.1, 6.3.3, 6.3.4, 6.4.1	3, 4, 4, 4, 3

4 is the highest rating/value

Expert panel decision descriptions:

ml_r_ec_06

In the seasonally dry tropics of the Eastern Gulf, perennial waterholes in active streams provide critical refugial (6.3.1) dry season habitat for obligate freshwater species including conservation dependent and listed species such as juvenile

freshwater sawfish **Pristis pristis** and snapping turtles and represent a priority aquatic ecosystems (5.2.1). They are also important for migratory fish species (7.1.2) in particular sooty grunter **Hephaestus fuliginosus** and adult phase eel tailed catfish. Permanent waterholes in active streams support a range of ecological processes that are distinct relative to the more extensive seasonal aquatic habitats that characterise the eastern Gulf (6.2.1). Within the seasonally dry climate of the eastern Gulf the presence of permanent freshwater usually owes its existence to a combination of special geomorphic features (6.1.1) and hydrological regimes (6.4.1). Within the suite of exiting perennial waterholes are subset will also have an increasingly important role as refugia within the increasingly variable rainfall and elevated temperature regimes predicted under climate change (6.4.1).

ml_r_ec_16

The Mitchell is the most bioregionally diverse basin in the eastern Gulf and is unique within all Gulf River basins in having areas of its upper catchment fall within the Wet Tropics Bioregion. Each of the sub basins of the upper Mitchel drain three different Wet Tropics Provinces including the Palmer which drains the Daintree Bloomfield Province, the Upper Mitchel which drains both the Daintree-Bloomfield and the Macalister Provinces and the Walsh which drains the Atherton Province. These areas are fully representative of the Wet Tropics and include extremely high and seasonally distributed rainfall, high cool (6.1.1) altitude mountains and tropical rainforest vegetation. This combination of biophysical features within a Gulf drainage basin generates unique hydrological conditions (6.2.1) and associated riverine (and some unmapped non riverine) wetland habitats, communities and values. High elevation areas receive regular rainfall often via cloud capture, which sustains perennial riverine habitats often via direct rainfall run off (6.4.1) rather than groundwater contributions alone which are associated with perennial streams elsewhere in the eastern Gulf. Cool water temperatures associated with high altitude (>700m) areas support habitats rich in bryophytes and mosses and endemic fauna including a large spiny crayfish **Euastacus fleckeri** restricted within the Mitchell Basin to areas draining Mt Windsor and the Hann Tableland in the adjoining Einasleigh Uplands Bioregion (Ryan et al. 2002). An area also vegetated by Wet Tropics rainforest regional ecosystem. The potential for additional **Euastacus** species to be discovered elsewhere in these upland rainforest catchments is high. Numerous frog species including at least nine that are listed as threatened (6.3.1) also characterise the fauna of the Wet Tropics upper catchments of the Mitchell (Tait et al. 2015). These high altitude areas also include flat tablelands likely to host a number of unmapped non-riverine wetland types including springs and soaks associated with past alluvial deposits. Another restricted crayfish species red tipped yabby **Cherax wassellii** occupies mid altitude uplands ranging from 500m adjoining Black Mountain to 350m in the lower Rifle Creek system adjoining Mt Carbine. This species occurs more widely throughout adjoining eastern drainages and is believed to be a natural translocation (Ryan et al. 2002). Perennial flows from these upland rainforest catchments sustain perennial riverine habitat into lower altitude reaches and contribute to downstream shallow aquifer recharge (6.4.1) beyond the McLeod River - Rifle Creek confluence in the upper Mitchell (Hydrobiology 2005). These perennial habitats act as refugia for aquatic species (6.3.1) including fish and crustaceans more typically associated with lower western reaches. When hosted in Wet Tropics upper catchments unique community types of Gulf basins species juxtaposed within Wet Tropics habitats are formed (Vallance and Hogan 2001, Ryan et al. 2002). Some of these perennial riverine reaches are likely to provide important climate change refugia in future years (6.3.4). Frontage communities associated with these Wet Tropics riverine reaches also include a large number of 'endangered' or 'of concern' regional ecosystems (5.2.1) (e.g. RE 7.3.23, RE 7.3.25, RE 7.3.26, RE 7.3.28, RE 7.3.49, RE 7.11.42). In many cases the threatened status of these regional ecosystems is due to impacts elsewhere within the Wet Tropics and the more limited development pressure within the upper Mitchell has thus far retained good examples of them. Ongoing emerging development pressure in these uplands of the Mitchell basin underpins the need for recognition of the conservation value of these wetland associated priority ecosystems.

ml_r_ec_18

These 'Priority Refugia for Freshwater Fish' (6.3.1) are based on those defined by Hermoso et al. (2013) (6.3.3) for the Mitchell river basin on the basis of water residency (6.4.1) assessed by satellite imagery over multiple years and considerations of fish community distribution across the basin. Fish distribution was used to prioritise candidate refugia by seeking to maximise individual species representation across the set of prioritised refugia. Individual species vagility was also assessed and incorporated in refugia selection by seeking to maximise the length of stream area accessible for colonisation (6.2.1) from refugia following their isolation by extreme droughts including those predicted to occur under future climate change scenarios (6.3.4). Two sets of priority refugia were nominated one using a baseline catchment condition and another using current conditions and projections of ecological pressure that reduce the viability of some candidate refugia. Both sets of prioritised refugia intersected with riverine spatial units have been conservatively used for this decision recognising that not all projected condition pressures have been realised and also that management intervention may have the capacity to mitigate them where they have been realised. Given the use of remote sensing in the identification of potential refugia some caution is needed in the application of identified refugia values recognising that artificial waterbodies including dams may have contributed to satellite based indications of water perenniality in the landscape.

Non-riverine Wetlands

Non-riverine wetlands include both lacustrine and palustrine wetlands, however, do not currently incorporate estuarine, marine or subterranean wetland types. A summary of the conservation significance of non-riverine wetlands within the AOI is provided in the following table. Refer to **Map 6** for further information.

Table 19: Overall level/s of non-riverine aquatic conservation significance

Aquatic conservation significance (non-riverine wetlands)	Area (Ha)	% of AOI
Very High	0.0	0.0
High	0.0	0.0
Medium	56.93	15.88
Low	0.0	0.0
Very Low	0.0	0.0

The following table provides an assessment of non-riverine wetlands within the AOI and associated aquatic conservation criteria values.

Table 20: Level/s of non-riverine aquatic conservation significance based on selected criteria

Criteria	Very High Rating - Area (Ha)	Very High Rating - % of AOI	High Rating - Area (Ha)	High Rating - % of AOI	Medium Rating - Area (Ha)	Medium Rating - % of AOI	Low Rating - Area (Ha)	Low Rating - % of AOI
1. Naturalness aquatic							56.93	15.9
2. Naturalness catchment			47.92	13.4	9.01	2.5		
3. Diversity and richness	56.93	15.9						
4. Threatened species and ecosystems			56.93	15.9				
5. Priority species and ecosystems	56.93	15.9						
6. Special features								
7. Connectivity								
8. Representative-ness								

The table below lists and describes the relevant expert panel decisions used to assign conservation significance values to non-riverine wetlands within the AOI.

Table 21: Expert panel decisions for assigning overall levels of non-riverine aquatic conservation significance.

Decision number	Special feature	Catchment	Criteria/Indicator/Measure	Conservation rating (1-4)
(No Records)				

4 is the highest rating/value

Expert panel decision descriptions:

(No Records)

Threatened and Priority Species

Introduction

This chapter contains a list of threatened and priority flora and/or fauna species that have been recorded on, or within 4km of the Assessment Area.

The information presented in this chapter with respect to species presence is derived from compiled databases developed primarily for the purpose of BPAs and ACAs. Data is collated from a number of sources and is updated periodically.

It is important to note that the list of species provided in this report, may differ when compared to other reports generated from other sources such as the State government's WildNet, Herbrecs or the federal government's EPBC database for a number of reasons.

Records for threatened and priority species are filtered and checked based on a number of rules including:

- Taxonomic nomenclature - current scientific names and status,
- Location - cross-check co-ordinates with location description,
- Taxon by location - requires good knowledge of the taxon and history of the record,
- Duplicate records - identify and remove,
- Expert panels - check records and provide new records,
- Flora cultivated records excluded,
- Use precise records less than or equal to 2000m,
- Use recent records greater than or equal to 1975 animals, greater than or equal to 1950 plants.

Threatened Species

Threatened species are those species classified as "Endangered" or "Vulnerable" under the *Environment Protection and Biodiversity Conservation Act 1999* or "Endangered", "Vulnerable" or "Near threatened" under the *Nature Conservation Act 1992*.

The following threatened species have been recorded on, or within approximately 4km of the AOI.

Table 22: Threatened species recorded on, or within 4km of the AOI

Species	Common name	NCA status	EPBC status	Back on Track rank	Migratory species*	Wetland species**	Identified flora/fauna
Calidris ferruginea	curlew sandpiper	CE	CE	Low	Y	I	FA
Ctenotus monticola	Atherton ctenotus	V		Low			FA
Dasyurus hallucatus	northern quoll	C	E	Medium			FA
Grantiella picta	painted honeyeater	V	V	High			FA
Graptophyllum excelsum		NT		Low			FL
Mesembriomys gouldii	black-footed tree-rat	C	V	Low			FA
Pteropus conspicillatus	spectacled flying-fox	E	E	High			FA
Rostratula australis	Australian painted-snipe	E	E	Medium		I	FA
Stylidium elachophyllum		E				I	FL
Turnix olivii	buff-breasted button-quail	E	E	Data Deficient			FA

NB. Please note that the threatened species listed in this section are based upon the most recently compiled DES internal state-wide threatened species dataset. This dataset may contain additional records that were not originally available for inclusion in the relevant individual BPAs and ACAs.

**JAMBA - Japan-Australia Migratory Bird Agreement; CAMBA - China-Australia Migratory Bird Agreement; ROKAMBA - Republic of Korea-Australia Migratory Bird Agreement; CMS - Convention on the Conservation of Migratory Species*.

***I - wetland indicator species; D - wetland dependent species*.

BPA Priority Species

A list of BPA priority species that have been recorded on, or within approximately 4km of the AOI is contained in the following table.

Table 23: Priority species recorded on, or within 4km of the AOI

Species	Common name	Back on Track rank	Identified flora/fauna
Aepyprymnus rufescens	Rufous Bettong	L	FA
Chlamydosaurus kingii	Frilled Lizard	L	FA
Climacteris picumnus	Brown Treecreeper	L	FA
Eucalyptus atrata	Herberton ironbark	L	FL
Eucalyptus tardecidens	None	L	FL
Heliotropium peninsulare	None	None	FL
Lomandra multiflora subsp. multiflora	None	None	FL
Melaleuca leucadendra	broad-leaved tea-tree	None	FL
Melaleuca monantha	None	L	FL
Melaleuca quinquenervia	swamp paperbark	None	FL
Phyllanthus similis	None	None	FL
Phyllanthus simplex	None	None	FL
Phyllanthus virgatus	None	None	FL
Portulaca bicolor	None	None	FL
Stylidium diffusum	None	None	FL
Tephrosia filipes	None	None	FL
Tephrosia juncea	None	None	FL
Tephrosia leptoclada	None	None	FL
Xanthorrhoea johnsonii	None	None	FL

NB. Please note that the list of priority species is based on those species identified in the BPAs, however records for these species may be more recent than the originals used. furthermore, the BPA priority species databases are updated from time to time. At each update, the taxonomic details for all species are amended as necessary to reflect current taxonomic name and/or status changes.

ACA Priority Species

A list of ACA priority species used in riverine and non-riverine ACAs that have been recorded on, or within approximately 4km of the AOI are contained in the following tables.

Table 24: Priority species recorded on, or within 4 km of the AOI - riverine

Species	Common name	Back on Track rank	Identified flora/fauna
Actitis hypoleucos	Common Sandpiper	None	FA
Calidris ferruginea	Curlew Sandpiper	None	FA

Species	Common name	Back on Track rank	Identified flora/fauna
Eucalyptus camaldulensis	None	None	FL
Gallinago hardwickii	Latham's Snipe	None	FA
Gelochelidon nilotica	Gull-billed Tern	None	FA
Hydroprogne caspia	Caspian Tern	None	FA
Nymphaea violacea	None	None	FL
Pandanus spiralis	None	None	FL
Pandion cristatus	Eastern Osprey	None	FA
Plegadis falcinellus	Glossy Ibis	None	FA
Tringa stagnatilis	Marsh Sandpiper	None	FA

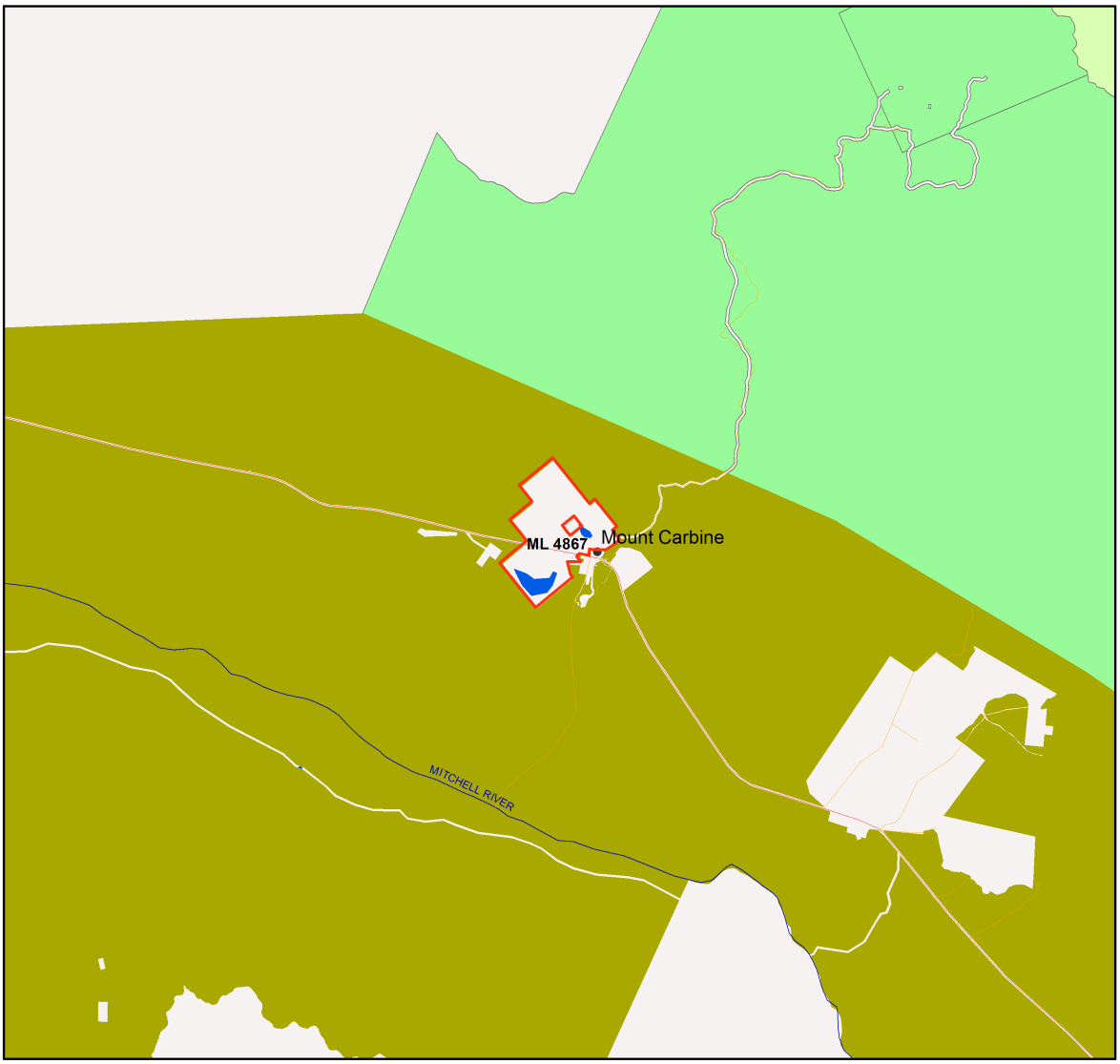
Table 25: Priority species recorded on, or within 4 km of the AOI - non-riverine

Species	Common name	Back on Track rank	Identified flora/fauna
Calidris acuminata	Sharp-tailed Sandpiper	None	FA
Calidris ferruginea	Curlew Sandpiper	None	FA
Calidris ruficollis	Red-necked Stint	None	FA
Eucalyptus camaldulensis	None	None	FL
Gallinago hardwickii	Latham's Snipe	None	FA
Gelochelidon nilotica	Gull-billed Tern	None	FA
Hydroprogne caspia	Caspian Tern	None	FA
Nymphaea violacea	None	None	FL
Pandanus spiralis	None	None	FL
Pandion cristatus	Eastern Osprey	None	FA
Plegadis falcinellus	Glossy Ibis	None	FA
Pluvialis fulva	Pacific Golden Plover	None	FA
Tringa stagnatilis	Marsh Sandpiper	None	FA

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

Maps

Map 1 - Locality Map



Locality Map

Legend

- Selected Mining Lease (ML)
- Towns
- Highway
- Connector
- Street/Local Road
- Reservoirs
- Lakes
- National Park (Scientific)
- National Park
- National Park (CYPAL)
- Conservation Park
- Resources Reserve
- Forest Reserve
- State Forest
- Timber Reserve
- Nature Refuges
- Coordinated Conservation Areas
- Major rivers/creeks
- Queensland

LOCALITY DIAGRAM

N

0 1200 2400 3600 4800 6000 m

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Map 2 - Biodiversity Planning Assessment (BPA)



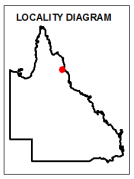
Biodiversity Planning Assessments

Legend

- Selected Mining Lease (ML)
- Towns
- Roads
- Major rivers/creeks
- Queensland

Biodiversity Planning Assessment

- State Habitat for EVNT taxa
- State
- Regional
- Local or Other Values
- Non Bioregion Ecosystem



N

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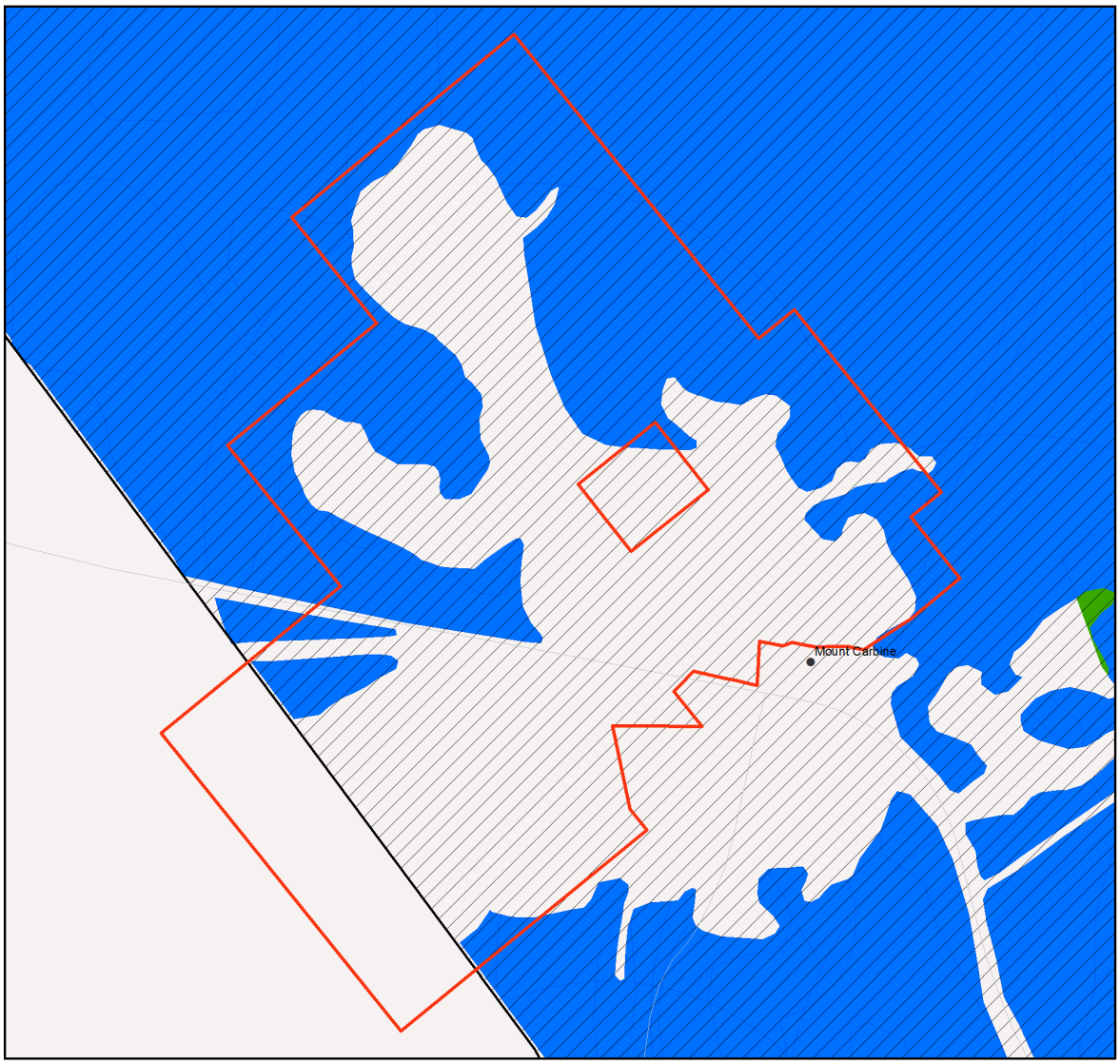
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Map 3 - Corridors



Corridors

Legend

- Selected Mining Lease (ML)
- Towns
- Roads
- Major rivers/creeks
- Queensland

Corridors

- State
- Regional

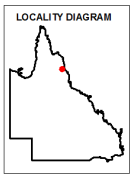
Corridor Triggered Vegetation

- State
- Regional
- Local

Core Area Vegetation

- Brigalow Belt only

LOCALITY DIAGRAM



N

0 180 360 540 720 900 m

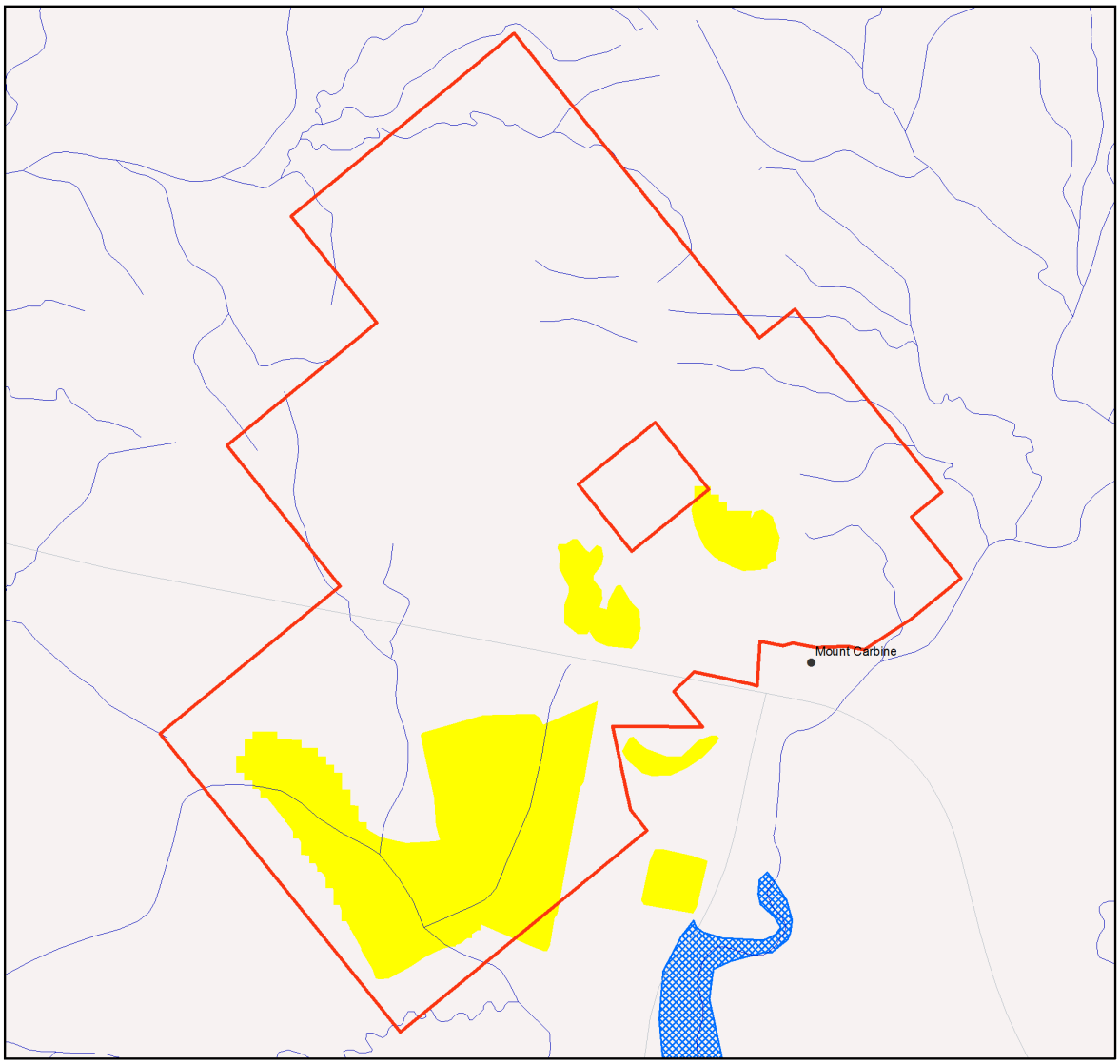
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Map 4 - Wetlands and waterways



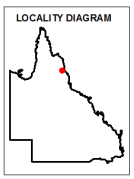
Wetlands and Waterways

Legend

- Selected Mining Lease (ML)
- Towns
- Roads
- Springs
- Rivers/Creeks
- Directory of Important Wetlands
- Ramsar Sites - QLD
- Queensland

Wetland Type

- Marine Waterbodies
- Estuarine Waterbodies
- Riverine Waterbodies
- Lacustrine Waterbodies
- Palustrine Waterbodies
- Marine RE
- Estuarine RE
- Riverine RE
- Lacustrine RE
- Palustrine RE
- RE 51-80% wetland (mosaic units)
- RE 1-50% wetland (mosaic units)



N

0 180 360 540 720 900 m

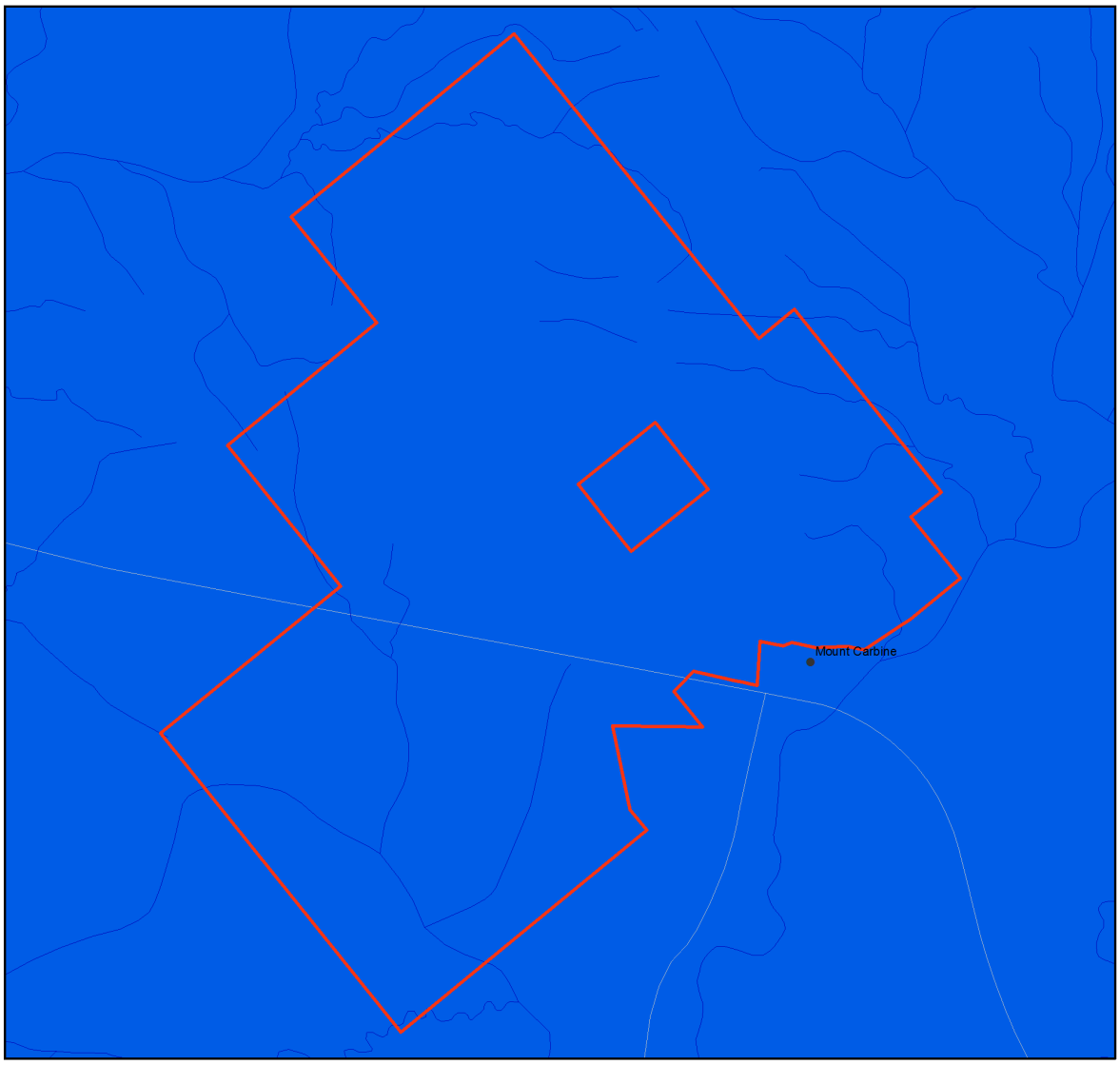
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Map 5 - Aquatic Conservation Assessment (ACA) - riverine



Aquatic Conservation Assessment (ACA) - riverine

Legend

- Selected Mining Lease (ML)
- Towns
- Roads
- Rivers/Creeks
- Queensland

ACA Riverine - Subcatchment Significance

- Very High
- High
- Medium
- Low
- Very Low

LOCALITY DIAGRAM

N

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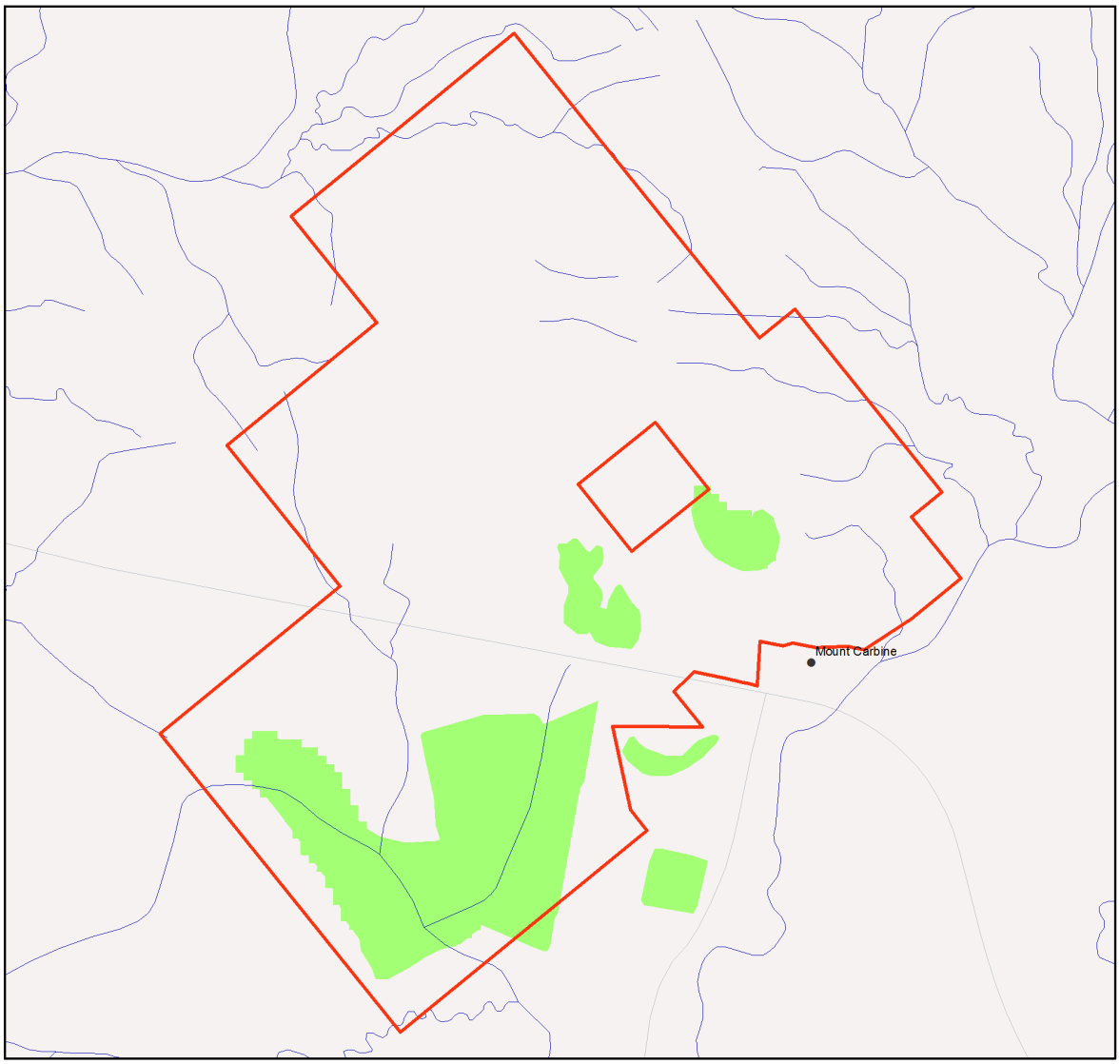
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Map 6 - Aquatic Conservation Assessment (ACA) - non-riverine



Aquatic Conservation Assessment (ACA) - nonriverine

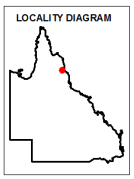
Legend

- Selected Mining Lease (ML)
- Towns
- Roads
- Rivers/Creeks
- Queensland

ACA Non-riverine

- Very High
- High
- Medium
- Low
- Very Low

LOCALITY DIAGRAM



N



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0 180 360 540 720 900 m

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Appendices

Appendix 1 - Source Data

Theme	Datasets
Aquatic Conservation Assessments Non-riverine*	Combination of the following datasets: Cape York Peninsula Non-riverine v1.1 Eastern Gulf of Carpentaria v1.1 Great Barrier Reef Catchment Non-riverine v1.3 Lake Eyre and Bulloo Basins v1.1 QMDB Non-riverine ACA v1.4 Southeast Queensland ACA v1.1 WBB Non-riverine ACA v1.1 Southern Gulf Catchments Non-riverine ACA v1.1
Aquatic Conservation Assessments Riverine*	Combination of the following datasets: Cape York Peninsula Riverine v1.1 Eastern Gulf of Carpentaria v1.1 Great Barrier Reef Catchment Riverine v1.1 Lake Eyre and Bulloo Basins v1.1 QMDB Riverine ACA v1.4 Southeast Queensland ACA v1.1 WBB Riverine ACA v1.1 Southern Gulf Catchments Riverine ACA v1.1
Biodiversity Planning Assessments*	Combination of the following datasets: Brigalow Belt BPA v2.1 Cape York Peninsula BPA v1.1 Central Queensland Coast BPA v1.3 Channel Country BPA v1.1 Desert Uplands BPA v1.3 Einasleigh Uplands BPA v1.1 Gulf Plains BPA v1.1 Mitchell Grass Downs BPA v1.1 Mulga Lands BPA v1.4 New England Tableland v2.3 Northwest Highlands v1.1 Southeast Queensland v4.1 Wet Tropics v1.1
Statewide BPA Corridors*	Statewide corridors v1.6
Threatened Species	An internal DES database compiled from Wildnet, Herbrecs, Corveg, the QLD Museum, as well as other incidental sources.
BPA Priority Species	An internal DES database compiled from Wildnet, Herbrecs, Corveg, the QLD Museum, as well as other incidental sources.
ACA Priority Species	An internal DES database compiled from Wildnet, Herbrecs, Corveg, the QLD Museum, as well as other incidental sources.

***These datasets are available at:**

http://dds.information.qld.gov.au/DDS

Appendix 2 - Acronyms and Abbreviations

AOI	- Area of Interest
ACA	- Aquatic Conservation Assessment
AQUABAMM	- Aquatic Biodiversity Assessment and Mapping Methodology
BAMM	- Biodiversity Assessment and Mapping Methodology
BoT	- Back on Track
BPA	- Biodiversity Planning Assessment
CAMBA	- China-Australia Migratory Bird Agreement
DES	- Department of Environment and Science
EPBC	- *Environment Protection and Biodiversity Conservation Act 1999*
EVNT	- Endangered, Vulnerable, Near Threatened
GDA94	- Geocentric Datum of Australia 1994
GIS	- Geographic Information System
JAMBA	- Japan-Australia Migratory Bird Agreement
NCA	- *Nature Conservation Act 1992*
RE	- Regional Ecosystem
REDD	- Regional Ecosystem Description Database
ROKAMBA	- Republic of Korea-Australia Migratory Bird Agreement

APPENDIX D – ENVIRONMENTAL REPORTS – REGIONAL ECOSYSTEMS – BIODIVERSITY STATUS

TAILINGS.WATER.WASTE.

Queensland Government

Department of Environment and Science

Environmental Reports

Regional Ecosystems

Biodiversity Status

For the selected area of interest
ml: 4867

Environmental Reports - General Information

The Environmental Reports portal provides for the assessment of selected matters of interest relevant to a user specified location, or area of interest (AOI). All area and derivative figures are relevant to the extent of matters of interest contained within the AOI unless otherwise stated. Please note, if a user selects an AOI via the "central coordinates" option, the resulting assessment area encompasses an area extending for a 2km radius from the input coordinates.

All area and area derived figures included in this report have been calculated via reprojecting relevant spatial features to Albers equal-area conic projection (central meridian = 146, datum Geocentric Datum of Australia 1994). As a result, area figures may differ slightly if calculated for the same features using a different co-ordinate system.

Figures in tables may be affected by rounding.

The matters of interest reported on in this document are based upon available state mapped datasets. Where the report indicates that a matter of interest is not present within the AOI (e.g. where area related calculations are equal to zero, or no values are listed), this may be due either to the fact that state mapping has not been undertaken for the AOI, that state mapping is incomplete for the AOI, or that no matters of interest have been identified within the site.

The information presented in this report should be considered as a guide only and field survey may be required to validate values on the ground.

Important Note to User

Information presented in this report is based upon the Queensland Herbarium's Regional Ecosystem framework. The Biodiversity Status has been used to depict the extent of "Endangered", "Of Concern" and "No Concern at Present" regional ecosystems in all cases, rather than the classes used for the purposes of the *Vegetation Management Act 1999* (VMA). Mapping and figures presented in this document reflect the Queensland Herbarium's Remnant and Pre-clearing Regional Ecosystem Datasets, and not the certified mapping used for the purpose of the VMA.

For matters relevant to vegetation management under the VMA, please refer to the Department of Resources website https://www.dnrme.qld.gov.au/

Please direct queries about these reports to: Queensland.Herbarium@qld.gov.au

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Summary Information

The following table provides an overview of the AOI with respect to selected topographic and environmental themes. Refer to **Map 1** for locality information.

Table 1: Area of interest details: ml: 4867

Size (ha)	358.48
Local Government(s)	Mareeba Shire
Bioregion(s)	Einasleigh Uplands
Subregion(s)	Hodgkinson Basin
Catchment(s)	Mitchell

The table below summarizes the extent of remnant vegetation classed as "Endangered", "Of concern" and "No concern at present" regional ecosystems classified by Biodiversity Status within the area of interest (AOI).

Table 2: Summary table, biodiversity status of regional ecosystems within the AOI

Biodiversity Status	Area (Ha)	% of AOI
Endangered	0.0	0.0
Of concern	0.68	0.19
No concern at present	141.67	39.52
Total remnant vegetation	142.35	39.71

Refer to **Map 2** for further information.

Regional Ecosystems

1. Introduction

Regional ecosystems are vegetation communities in a bioregion that are consistently associated with particular combinations of geology, landform and soil (Sattler and Williams 1999). Descriptions of Queensland's Regional ecosystems are available online from the Regional Ecosystem Description Database (REDD). Descriptions are compiled from a broad range of information sources including vegetation, land system and geology survey and mapping and detailed vegetation site data. The regional ecosystem classification and descriptions are reviewed as new information becomes available. A number of vegetation communities may form a single regional ecosystem and are usually distinguished by differences in dominant species, frequently in the shrub or ground layers and are denoted by a letter following the regional ecosystem code (e.g. a, b, c). Vegetation communities and regional ecosystems are amalgamated into a higher level classification of broad vegetation groups (BVGs).

A published methodology for survey and mapping of regional ecosystems across Queensland (Neldner et al 2020) provides further details on regional ecosystem concepts and terminology.

This report provides information on the type, status, and extent of vegetation communities, regional ecosystems and broad vegetation groups present within a user specified area of interest. Please note, for the purpose of this report, the Biodiversity Status is used. This report has not been developed for application of the *Vegetation Management Act 1999* (VMA). Additionally, information generated in this report has been derived from the Queensland Herbarium's Regional Ecosystem Mapping, and not the regulated mapping certified for the purposes of the VMA. If your interest/matter relates to regional ecosystems and the VMA, users should refer to the Department of Resources website.

https://www.dnrme.qld.gov.au/

With respect to the Queensland Biodiversity Status,

"Endangered" regional ecosystems are described as those where:

- remnant vegetation is less than 10 per cent of its pre-clearing extent across the bioregion; or 10-30% of its pre-clearing extent remains and the remnant vegetation is less than 10,000 hectares, or
- less than 10 per cent of its pre-clearing extent remains unaffected by severe degradation and/or biodiversity loss*, or
- 10-30 per cent of its pre-clearing extent remains unaffected by severe degradation and/or biodiversity loss and the remnant vegetation is less than 10,000 hectares; or
- it is a rare** regional ecosystem subject to a threatening process.***

"Of concern" regional ecosystems are described as those where:

- the degradation criteria listed above for 'Endangered' regional ecosystems are not met and,
- remnant vegetation is 10-30 per cent of its pre-clearing extent across the bioregion; or more than 20 per cent of its pre-clearing extent remains and the remnant extent is less than 10,000 hectares, or
- 10-30 percent of its pre-clearing extent remains unaffected by moderate degradation and/or biodiversity loss.****

and "No concern at present" regional ecosystems are described as those where:

- remnant vegetation is over 30 per cent of its pre-clearing extent across the bioregion, and the remnant area is greater than 10,000 hectares, and
- the degradation criteria listed above for 'Endangered' or 'Of concern' regional ecosystems are not met.

**Severe degradation and/or biodiversity loss is defined as: floristic and/or faunal diversity is greatly reduced but unlikely to recover within the next 50 years even with the removal of threatening processes; or soil surface is severely degraded, for example, by loss of A horizon, surface expression of salinity; surface compaction, loss of organic matter or sheet erosion.*

***Rare regional ecosystem: pre-clearing extent (1000 ha); or patch size (100 ha and of limited total extent across its range).*

****Threatening processes are those that are reducing or will reduce the biodiversity and ecological integrity of a regional ecosystem. For example, clearing, weed invasion, fragmentation, inappropriate fire regime or grazing pressure, or infrastructure development.*

*****Moderate degradation and/or biodiversity loss is defined as: floristic and/or faunal diversity is greatly reduced but unlikely to recover within the next 20 years even with the removal of threatening processes; or soil surface is moderately degraded.*

2. Remnant Regional Ecosystems

The following table identifies the remnant regional ecosystems and vegetation communities mapped within the AOI and provides their short descriptions, Biodiversity Status, and remnant extent within the selected AOI. Please note, where heterogeneous vegetated patches (mixed patches of remnant vegetation mapped as containing multiple regional ecosystems) occur within the AOI, they have been split and listed as individual regional ecosystems (or vegetation communities where present) for the purposes of the table below. In such instances, associated area figures have been generated based upon the estimated proportion of each regional ecosystem (or vegetation community) predicted to be present within the larger mixed patch.

Table 3: Remnant regional ecosystems, description and status within the AOI

Regional Ecosystem	Short Description	BD Status	Area (Ha)	% of AOI
9.11.25	Eucalyptus tardecidens or E. chlorophylla +/- Corymbia spp. +/- E. cullenii low woodland on steep to rolling metamorphic hills and rises	No concern at present	9.72	2.71
9.11.26a	Eucalyptus leptophleba and/or E. cullenii and/or Corymbia clarksoniana +/- E. platyphylla woodland on undulating terrain to rolling hills	No concern at present	14.58	4.07
9.11.3b	Eucalyptus cullenii or E. staigeriana +/- Corymbia clarksoniana woodland on skeletal soils on metamorphic hills	No concern at present	68.03	18.98
9.11.7b	Eucalyptus platyphylla and/or E. cullenii +/- Corymbia clarksoniana woodland on texture contrast soils on metamorphic hills	No concern at present	4.86	1.36
9.12.7a	Eucalyptus cullenii +/- Corymbia leichhardtii +/- C. erythrophloia woodland on igneous rocks	No concern at present	1.72	0.48
9.3.2	Eucalyptus leptophleba and/or E. chlorophylla +/- Corymbia dallachiana woodland on river levees and terraces	No concern at present	2.73	0.76
9.3.3c	Corymbia spp. and Eucalyptus spp. dominated mixed woodland on alluvial flats, levees and plains	Of concern	0.68	0.19
9.5.12	Eucalyptus chlorophylla and/or E. tardecidens woodland on Tertiary plains	No concern at present	29.11	8.12
9.5.13a	Melaleuca citrolens and/or Macropteranthes montana low woodland with Eucalyptus spp. emergents on Tertiary sand sheets	No concern at present	3.59	1.0
9.5.9c	Corymbia clarksoniana and/or Eucalyptus leptophleba and/or E. platyphylla woodland on plains	No concern at present	7.32	2.04
non-remnant	None	None	188.08	52.47
water	None	None	28.04	7.82

Refer to **Map 2** for further information. **Map 3** also provides a visual estimate of the distribution of regional ecosystems present before clearing.

Table 4 provides further information in regards to the remnant regional ecosystems present within the AOI. Specifically, the extent of remnant vegetation remaining within the bioregion, the 1:1,000,000 broad vegetation group (BVG) classification, whether the regional ecosystem is identified as a wetland, and extent of representation in Queensland's Protected Area Estate. For a description of the vegetation communities within the AOI and classified according to the 1:1,000,000 BVG, refer to **Table 6**.

Table 4: Remnant regional ecosystems within the AOI, additional information

Regional Ecosystem	Remnant Extent	BVG (1 Million)	Wetland	Representation in protected estate
9.11.25	Pre-clearing 195000 ha; Remnant 2019 193000 ha	19d	Not a Wetland	Low
9.11.26a	Pre-clearing 67000 ha; Remnant 2019 66000 ha	13a	Not a Wetland	Low
9.11.3b	Pre-clearing 923000 ha; Remnant 2019 916000 ha	13a	Not a Wetland	Low
9.11.7b	Pre-clearing 41000 ha; Remnant 2019 39000 ha	21a	Not a Wetland	Low
9.12.7a	Pre-clearing 610000 ha; Remnant 2019 606000 ha	13a	Not a Wetland	Low
9.3.2	Pre-clearing 19000 ha; Remnant 2019 18000 ha	16b	Not a Wetland	Low
9.3.3c	Pre-clearing 151000 ha; Remnant 2019 131000 ha	16b	Not a Wetland	Low
9.5.12	Pre-clearing 30000 ha; Remnant 2019 27000 ha	18c	Not a Wetland	Low
9.5.13a	Pre-clearing 31000 ha; Remnant 2019 31000 ha	21b	Not a Wetland	High
9.5.9c	Pre-clearing 92000 ha; Remnant 2019 55000 ha	9e	Not a Wetland	Low
non-remnant	None	None	None	None
water	None	None	None	None

Representation in Protected Area Estate: High greater than 10% of pre-clearing extent is represented; Medium 4 - 10% is represented; Low less than 4% is represented, No representation.

The distribution of mapped wetland systems within the area of interest is displayed in **Map 6**.

The following table lists known special values associated with a regional ecosystem type.

Table 5: Remnant regional ecosystems within the AOI, special values

Regional Ecosystem	Special Values
9.11.25	Potential habitat for NCA listed species: Acacia guymeri, Acacia purpureopetala, Cucumis costatus
9.11.26a	None
9.11.3b	Potential habitat for NCA listed species: Acacia guymeri, Acacia purpureopetala, Cucumis costatus, Dianella incollata, Ehretia microphylla, Euphorbia carissoides, Macropteranthes montana, Panicum chillagoanum, Stenanthemum argenteum
9.11.7b	None
9.12.7a	Habitat for near threatened and threatened flora species. 9.12.7a: Potential habitat for the vulnerable plant species Cycas platyphylla.
9.3.2	Significant habitat particularly for herbivores such as macropods and arboreal mammals
9.3.3c	Significant habitat as drought refuge, wildlife corridors and for arboreal animals.
9.5.12	Potential habitat for NCA listed species: Habenaria rumphii

Regional Ecosystem	Special Values
9.5.13a	Habitat for the vulnerable plant species Macropteranthes montana.
9.5.9c	Potential habitat for NCA listed species: Habenaria rumphii
non-remnant	None
water	None

3. Remnant Regional Ecosystems by Broad Vegetation Group

BVGs are a higher-level grouping of vegetation communities. Queensland encompasses a wide variety of landscapes across temperate, wet and dry tropics and semi-arid climatic zones. BVGs provide an overview of vegetation communities across the state or a bioregion and allow comparison with other states. There are three levels of BVGs which reflect the approximate scale at which they are designed to be used: the 1:5,000,000 (national), 1:2,000,000 (state) and 1:1,000,000 (regional) scales.

A comprehensive description of BVGs is available at:

https://publications.qld.gov.au/dataset/redd/resource/

The following table provides a description of the 1:1,000,000 BVGs present and their associated extent within the AOI.

Table 6: Broad vegetation groups (1 million) within the AOI

BVG (1 Million)	Description	Area (Ha)	% of AOI
None	None	216.12	60.29
13a	Woodlands and open woodlands dominated by ironbarks such Eucalyptus cullenii (Cullen's ironbark), E. staigeriana (lemon-scented ironbark) or E. melanophloia (silver-leaved ironbark) and bloodwoods such as Corymbia stockeri subsp. peninsularis, C. clarksoniana (grey bloodwood) or C. leichhardtii (rustyjacket). (land zones 11, 12, 7, 5) (EIU, CYP, GUP)	84.33	23.52
16b	Woodlands dominated by Eucalyptus leptophleba (Molloy red box), with Corymbia tessellaris (carbeen) or C. clarksoniana (grey bloodwood) or C. dallachiana. On sandy levees. (land zones 3, 5) (GUP, EIU, CYP)	3.42	0.95
18c	Woodlands and open woodlands dominated by Eucalyptus chlorophylla (E. microtheca or E. leptophleba on heavy soils) frequently with Corymbia spp. (land zones 9, 5, 3, 12, [4]) (CYP, GUP, EIU, MGD, [NWH])	29.11	8.12
19d	Low open woodlands dominated by Eucalyptus persistens (or E. normantonensis (Normanton box), E. tardecidens, E. provecta) with Triodia spp. dominated ground layer, mainly on hills and ranges. (land zones 7, 11, 12, 5, [4, 10]) (EIU, MGD, CHC, BRB, GUP, DEU)	9.72	2.71
21a	Low woodlands and low open woodlands dominated by Melaleuca viridiflora (coarse-leaved paperbark) on depositional plains. (land zones 3, 5, 11, [10]) (GUP, CYP, BRB, CQC, EIU, WET, SEQ)	4.86	1.36
21b	Low open woodlands and tall shrublands of Melaleuca citrolens or M. stenostachya or other Melaleuca spp. (land zones 5, 3, 7, 10, 11, 12) (GUP, CYP, EIU, DEU, BRB, [SEQ])	3.59	1.0

BVG (1 Million)	Description	Area (Ha)	% of AOI
9e	Open forests, woodlands and open woodlands dominated by Corymbia clarksoniana (grey bloodwood) (or C. novoguinensis or C. intermedia (pink bloodwood) or C. polycarpa (long-fruited bloodwood)) frequently with Erythrophleum chlorostachys (red ironwood) or Eucalyptus platyphylla (poplar gum) predominantly on coastal sandplains and alluvia. (land zones 3, 5, 2) (CYP, BRB, CQC, WET, EIU)	7.32	2.04

Refer to **Map 4** for further information. **Map 5** also provides a representation of the distribution of vegetation communities as per the 1:5,000,000 BVG believed to be present prior to European settlement.

4. Technical and BioCondition Benchmark Descriptions

Technical descriptions provide a detailed description of the full range in structure and floristic composition of regional ecosystems (e.g. 11.3.1) and their component vegetation communities (e.g. 11.3.1a, 11.3.1b). See:

http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/technical-descriptions/

The descriptions are compiled using site survey data from the Queensland Herbarium's CORVEG database. Distribution maps, representative images (if available) and the pre-clearing and remnant extent (hectares) of each vegetation community derived from the regional ecosystem mapping data are included. The technical descriptions should be used in conjunction with the fields from the regional ecosystem description database (REDD) for a full description of the regional ecosystem.

Technical descriptions include data on canopy height, canopy cover and native plant species composition of the predominant layer, which are attributes relevant to assessment of the remnant status of vegetation under the *Vegetation Management Act 1999*. However, as technical descriptions reflect the full range in structure and floristic composition across the climatic, natural disturbance and geographic range of the regional ecosystem, local reference sites should be used for remnant assessment where possible (Neldner et al. 2020 (PDF)* section 3.3 of:

https://publications.qld.gov.au/dataset/redd/resource/

The technical descriptions are subject to review and are updated as additional data becomes available.

When conducting a BioCondition assessment, these technical descriptions should be used in conjunction with BioCondition benchmarks for the specific regional ecosystem, or component vegetation community.

http://www.qld.gov.au/environment/plants-animals/biodiversity/benchmarks/

Benchmarks are based on a combination of quantitative and qualitative information and should be used as a guide only. Benchmarks are specific to one regional ecosystem vegetation community, however, the natural variability in structure and floristic composition under a range of climatic and natural disturbance regimes has been considered throughout the geographic extent of the regional ecosystem. Local reference sites should be used for this spatial and temporal (seasonal and annual) variability.

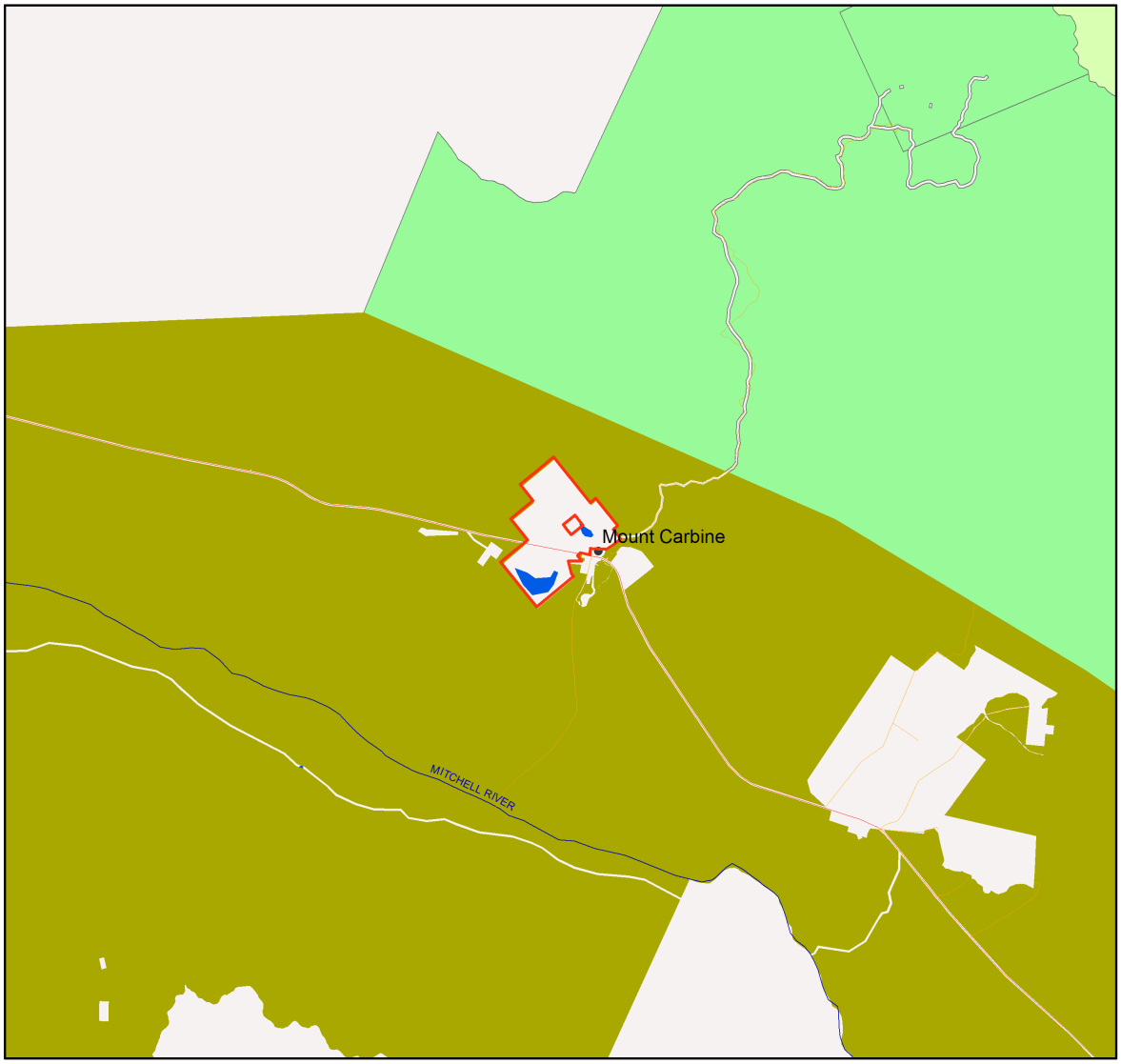
Table 7: List of remnant regional ecosystems within the AOI for which technical and biocondition benchmark descriptions are available

Regional ecosystems mapped as within the AOI	Technical Descriptions	Biocondition Benchmarks
9.11.25	Available	Available
9.11.26a	Available	Not currently available
9.11.3b	Available	Not currently available
9.11.7b	Available	Not currently available
9.12.7a	Available	Not currently available
9.3.2	Available	Not currently available
9.3.3c	Available	Not currently available
9.5.12	Available	Not currently available

Regional ecosystems mapped as within the AOI	Technical Descriptions	Biocondition Benchmarks
9.5.13a	Available	Not currently available
9.5.9c	Available	Not currently available
non-remnant	Not currently available	Not currently available
water	Not currently available	Not currently available

Maps

Map 1 - Location



Locality Map

Legend

- Selected Mining Lease (ML)
- Towns
- Highway
- Connector
- Street/Local Road
- Reservoirs
- Lakes
- National Park (Scientific)
- National Park
- National Park (CYPAL)
- Conservation Park
- Resources Reserve
- Forest Reserve
- State Forest
- Timber Reserve
- Nature Refuges
- Coordinated Conservation Areas
- Major rivers/creeks
- Queensland

LOCALITY DIAGRAM

N

0 1200 2400 3600 4800 6000 m

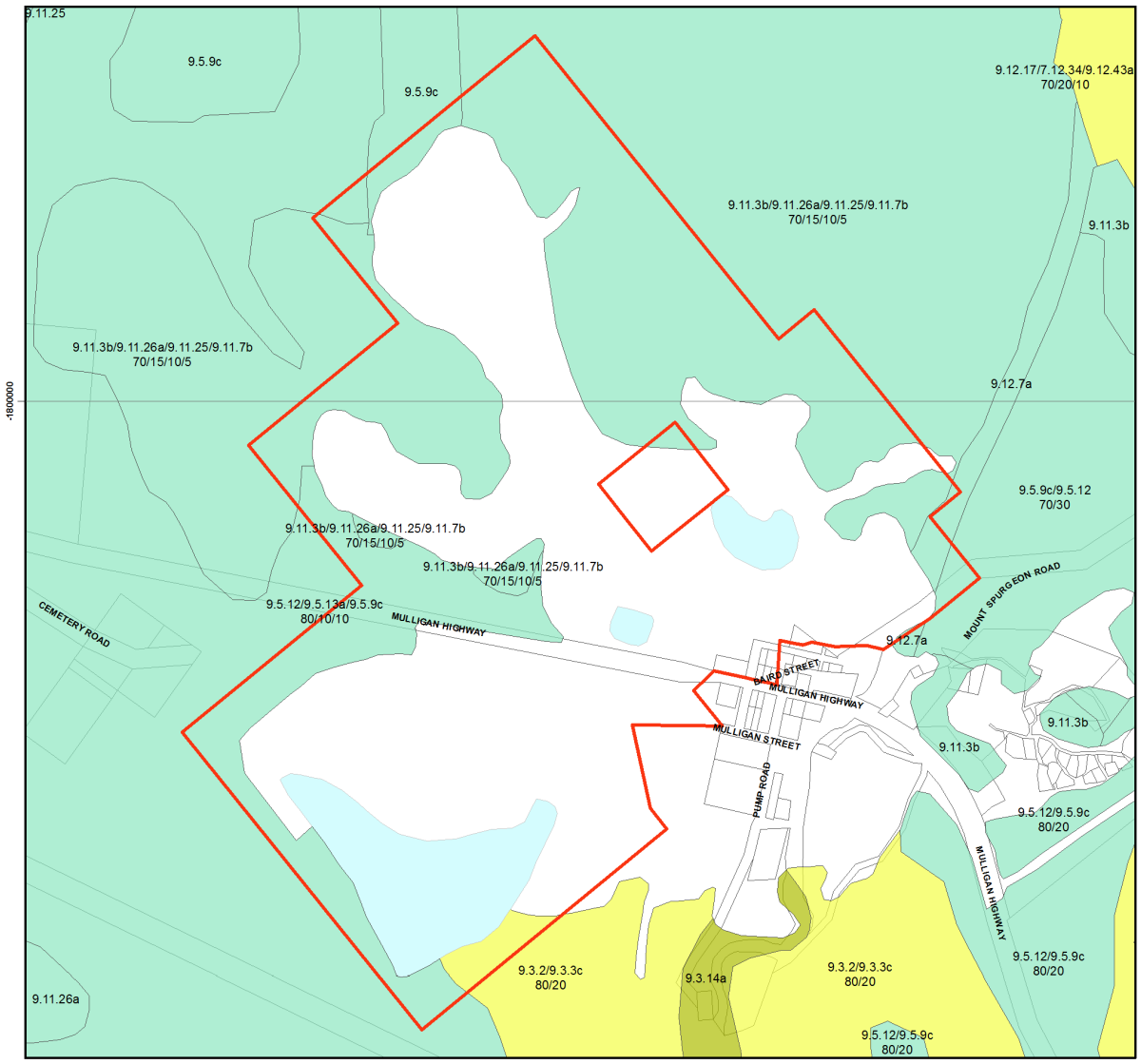
This product is projected into GDA 1994 Queensland Albers

DISCLAIMER:
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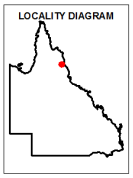
Map 2 - Remnant 2019 regional ecosystems



Remnant 2019 Regional Ecosystems

Biodiversity Status

- Selected Mining Lease (ML)
- Endangered - Dominant vegetation
- Endangered - Sub-dominant
- Of Concern - Dominant
- Of Concern - Sub-dominant
- No concern at present
- Non-remnant vegetation, cultivated or built environment
- Plantation
- Water
- Cadastral Boundaries



N

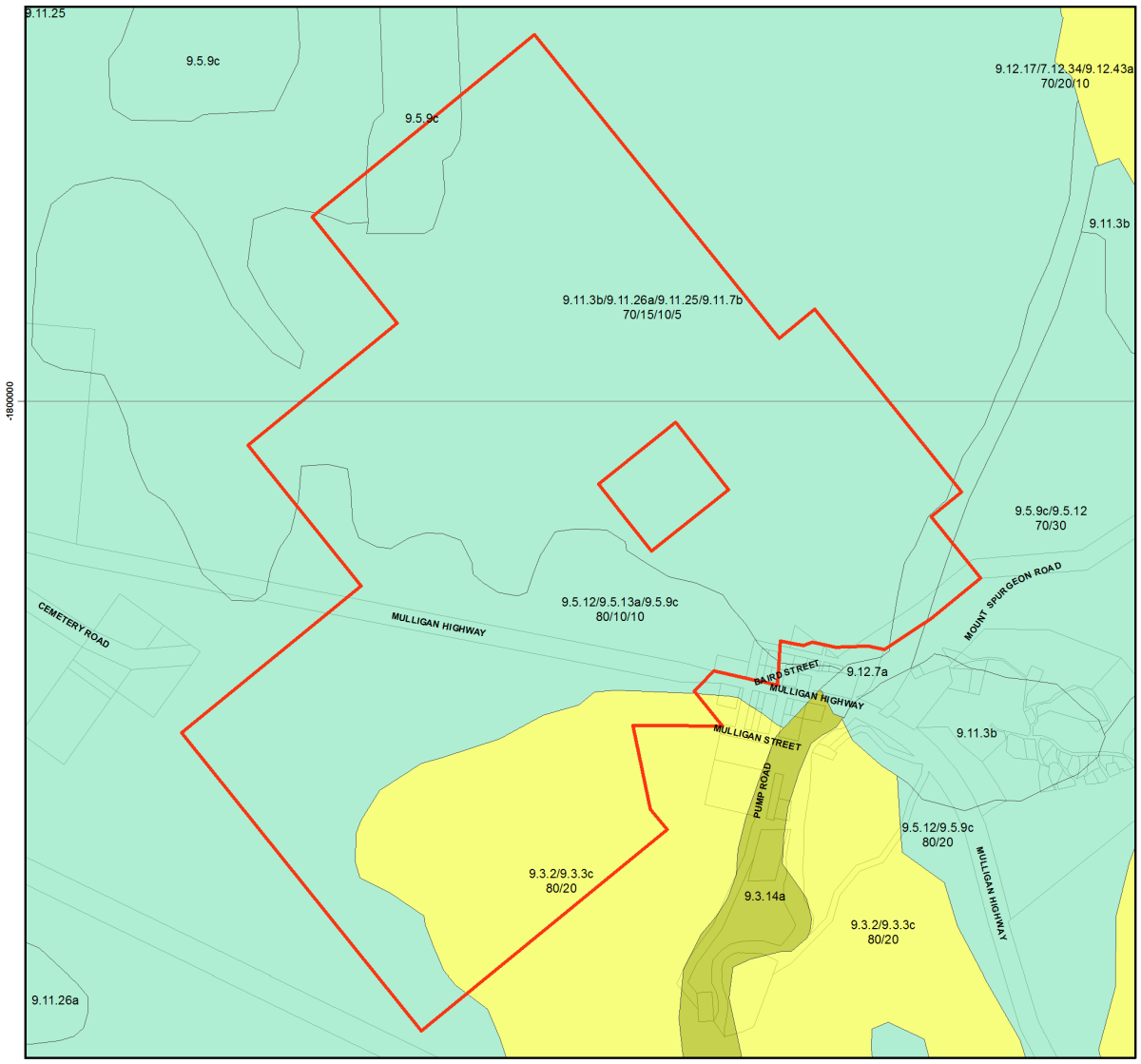
0 0.2 0.4 0.6 0.8 km

This product is projected into GDA 1994 Queensland Albers

Regional ecosystem mapping over the majority of Queensland is produced at a scale of 1:100,000. At this scale, the minimum remnant polygon area is 5 hectares or minimum remnant width of 75 metres. Regional ecosystem linework reproduced at a scale greater than 1:100,000, except in designated areas, should be used as a guide only. The precision of polygon boundaries or positional accuracy of linework is 100 metres.
Regional ecosystems are defined as vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform and soil.
The polygons are labelled by regional ecosystem (RE); where more than one RE occurs, the percentage of each is labelled. The label consists of 3 components: bioregion, land zone, and vegetation community – the dominant canopy species. e.g.: RE 12.3.3. Descriptions of REs are found online. Use the search term "Regional Ecosystem Framework".
Regional ecosystem mapping at 1:100,000 map scale is derived from the following sources: 1:80,000 B&W 1960's aerial photography, Landsat TM imagery, geology, soils, land systems data, field survey and historical records.
Remnant woody vegetation is defined as vegetation that has not been cleared or vegetation that has been cleared but where the dominant canopy has >70% of the height and >50% of the cover relative to the undisturbed height and cover of that stratum and is dominated by species characteristic of the vegetation's undisturbed canopy.
Non-remnant vegetation includes regrowth and disturbed native vegetation.

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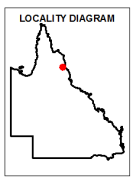
Map 3 - Pre-clearing regional ecosystems

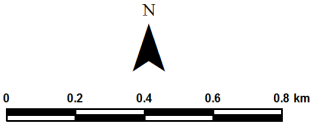


Pre-clearing Regional Ecosystems

Biodiversity Status

- Selected Mining Lease (ML)
- Endangered - Dominant vegetation
- Endangered - Sub-dominant
- Of Concern - Dominant
- Of Concern - Sub-dominant
- No concern at present
- Water
- Cadastral Boundaries



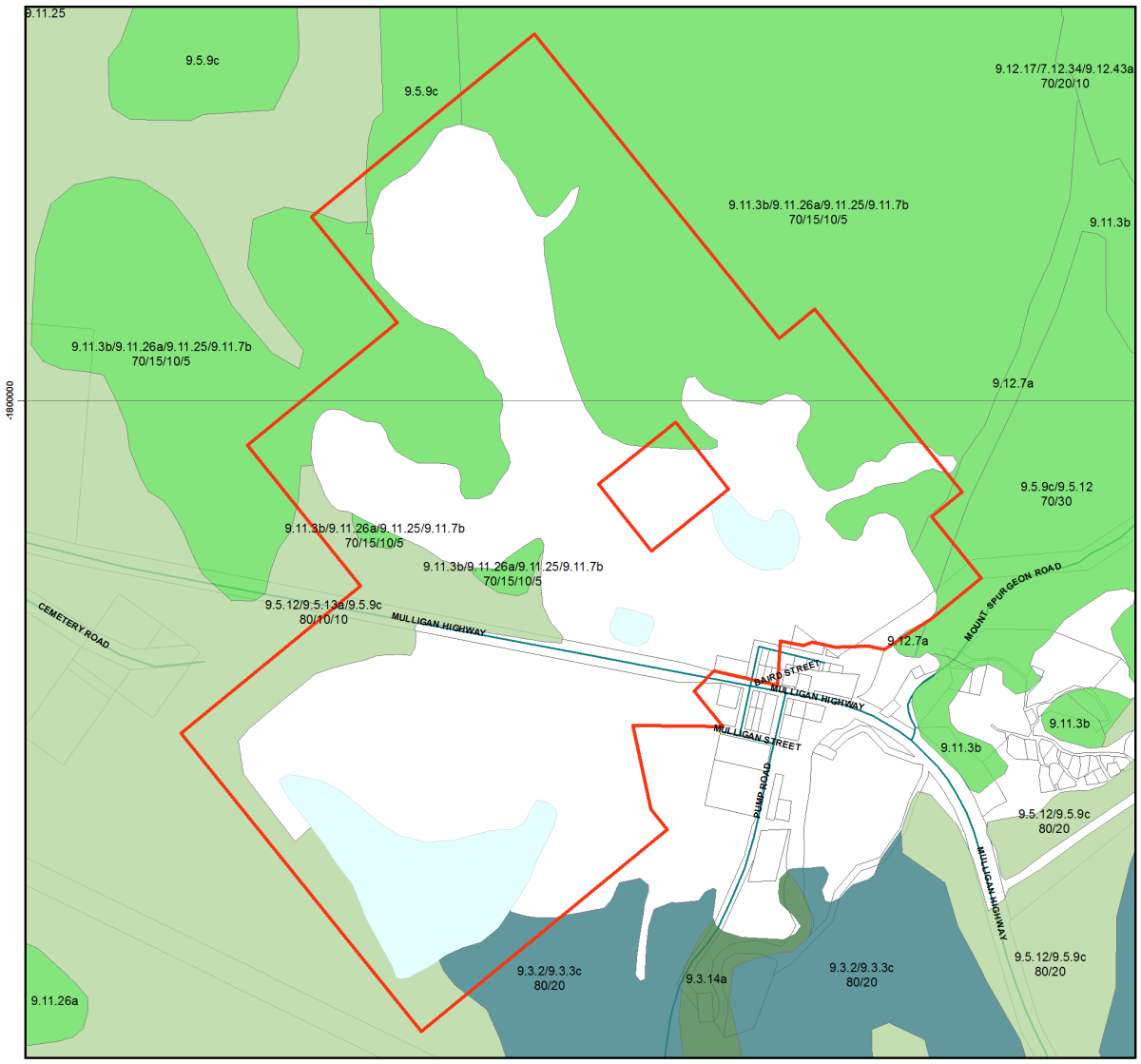


This product is projected into GDA 1994 Queensland Albers

Regional ecosystem mapping over the majority of Queensland is produced at a scale of 1:100,000. At this scale, the minimum remnant polygon area is 5 hectares or minimum remnant width of 75 metres. Regional ecosystem linework reproduced at a scale greater than 1:100,000, except in designated areas, should be used as a guide only. The precision of polygon boundaries or positional accuracy of linework is 100 metres.
Regional ecosystems are defined as vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform and soil.
The polygons are labelled by regional ecosystem (RE); where more than one RE occurs, the percentage of each is labelled. The label consists of 3 components: bioregion, land zone, and vegetation community – the dominant canopy species. e.g.: RE 12.3.3. Descriptions of REs are found online. Use the search term "Regional Ecosystem Framework".
Regional ecosystem mapping at 1:100,000 map scale is derived from the following sources: 1:80,000 B&W 1960's aerial photography, Landsat TM imagery, geology, soils, land systems data, field survey and historical records.

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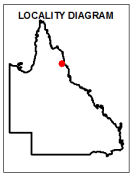
Map 4 - Remnant 2019 regional ecosystems by BVG (5M)



Remnant 2019 Regional Ecosystems coloured by Broad Vegetation Groups

Broad Vegetation Groups
BVG5M Description (BVG1M codes)

- Selected Mining Lease (ML)
- 1. Rainforests and scrubs (1-7b)
- 2. Wet eucalypt open forests (8-8b)
- 3. Eucalypt woodlands to open forests (mainly eastern Qld) (9-15b)
- 4. Eucalypt open forests to woodlands on floodplains (16-16d)
- 5. Eucalypt dry woodlands on inland depositional plains (17-18d)
- 6. Eucalypt low open woodlands usually with spinifex understorey (19-19d)
- 7. Callitris woodland - open forests (20a)
- 8. Melaleuca open woodlands on depositional plains (21-22c)
- 9. Acacia aneura (mulga) dominated open forests, woodlands and shrublands (23-23b)
- 10. Other acacia dominated open forests, woodlands and shrublands (24-26a)
- 11. Mixed species woodlands, open woodland - (inland bioregions) includes wooded downs (27-27c)
- 12. Other coastal communities or heaths (28-29b)
- 13. Tussock grasslands, forblands (30-32b)
- 14. Hummock grasslands (33-33b)
- 15. Wetlands (swamps and lakes) (34-34g)
- 16. Mangroves and saltmarshes (35-35b)
- Non-remnant vegetation, cultivated or built environment
- Water
- Cadastral Boundaries



N

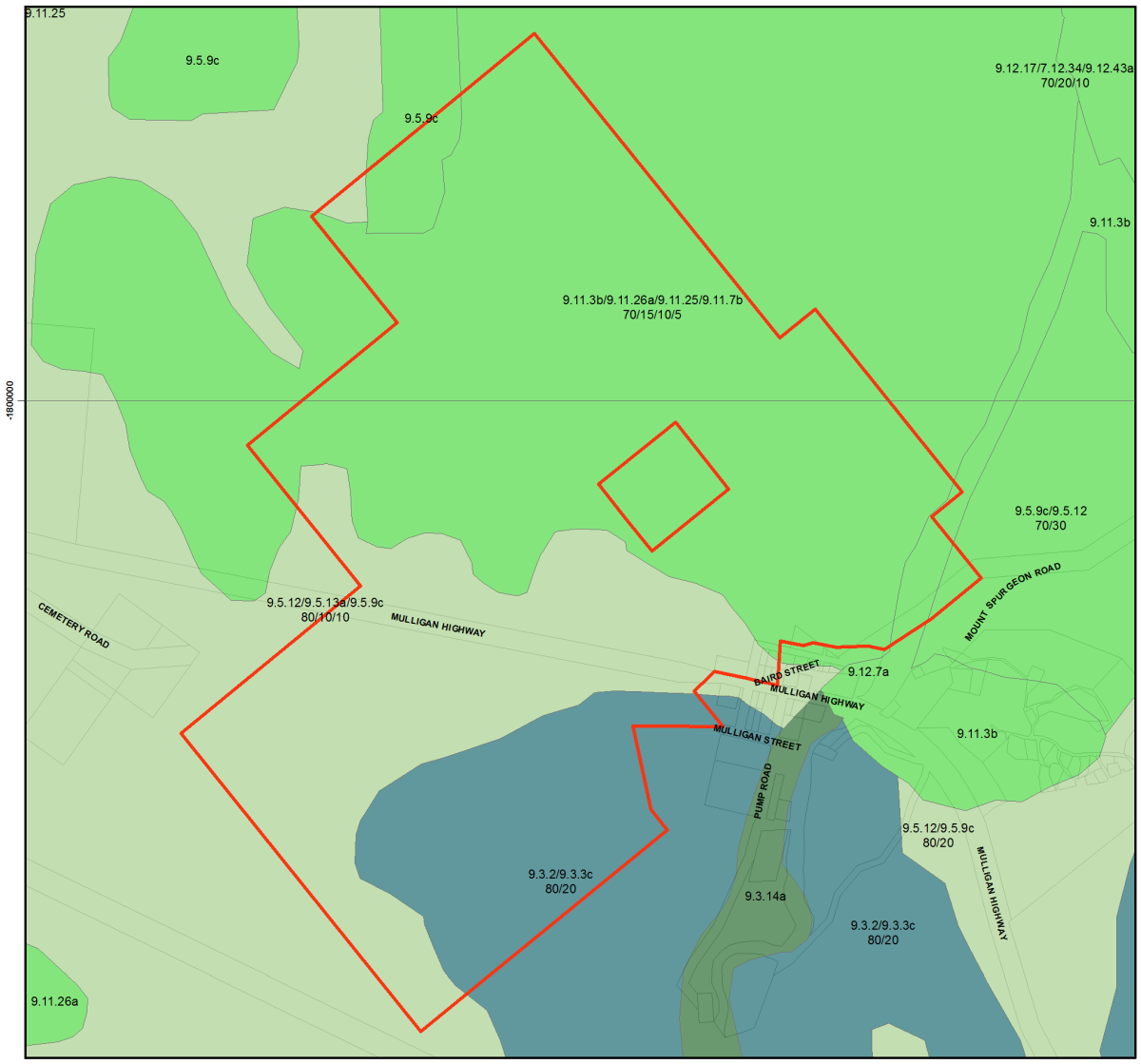
0 0.2 0.4 0.6 0.8 km

This product is projected into GDA 1994 Queensland Albers

Broad Vegetation Groups (BVG) of Queensland are applied by look up table to the regional ecosystem vegetation communities. Each polygon is coloured by the dominant BVG5M and the component regional ecosystems labelled. Where more than one regional ecosystem occurs, the percentage of each is labelled.
Regional ecosystem mapping over the majority of Queensland is produced at a scale of 1:100,000. At this scale, the minimum remnant polygon area is 5 hectares or minimum remnant width of 75 metres. Regional ecosystem linework reproduced at a scale greater than 1:100,000, except in designated areas, should be used as a guide only. The precision of polygon boundaries or positional accuracy of linework is 100 metres.
Regional ecosystems are defined as vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform and soil.
The label consists of 3 components: bioregion, land zone, and vegetation community – the dominant canopy species. e.g.: RE 12.3.3. Descriptions of REs are found online. Use the search term "Regional Ecosystem Framework".
Regional ecosystem mapping at 1:100,000 map scale is derived from the following sources: 1:80,000 B&W 1960's aerial photography, Landsat TM imagery, geology, soils, land systems data, field survey and historical records.
Remnant woody vegetation is defined as vegetation that has not been cleared or vegetation that has been cleared but where the dominant canopy has >70% of the height and >50% of the cover relative to the undisturbed height and cover of that stratum and is dominated by species characteristic of the vegetation's undisturbed canopy.
Non-remnant vegetation includes regrowth and disturbed native vegetation.

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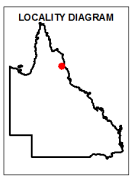
Map 5 - Pre-clearing regional ecosystems by BVG (5M)

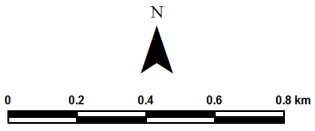


Pre-clearing Regional Ecosystems coloured by Broad Vegetation Groups

Broad Vegetation Groups
BVG5M Description (BVG1M codes)

- Selected Mining Lease (ML)
- 1. Rainforests and scrubs (1-7b)
- 2. Wet eucalypt open forests (8-8b)
- 3. Eucalypt woodlands to open forests (mainly eastern Qld) (9-15b)
- 4. Eucalypt open forests to woodlands on floodplains (16-16d)
- 5. Eucalypt dry woodlands on inland depositional plains (17-18d)
- 6. Eucalypt low open woodlands usually with spinifex understorey (19-19d)
- 7. Callitris woodland - open forests (20a)
- 8. Melaleuca open woodlands on depositional plains (21-22c)
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- 10. Other acacia dominated open forests, woodlands and shrublands (24-26a)
- 11. Mixed species woodlands, open woodland - (inland bioregions) includes wooded downs (27-27c)
- 12. Other coastal communities or heaths (28-29b)
- 13. Tussock grasslands, forblands (30-32b)
- 14. Hummock grasslands (33-33b)
- 15. Wetlands (swamps and lakes) (34-34g)
- 16. Mangroves and saltmarshes (35-35b)
- Water
- Cadastral Boundaries



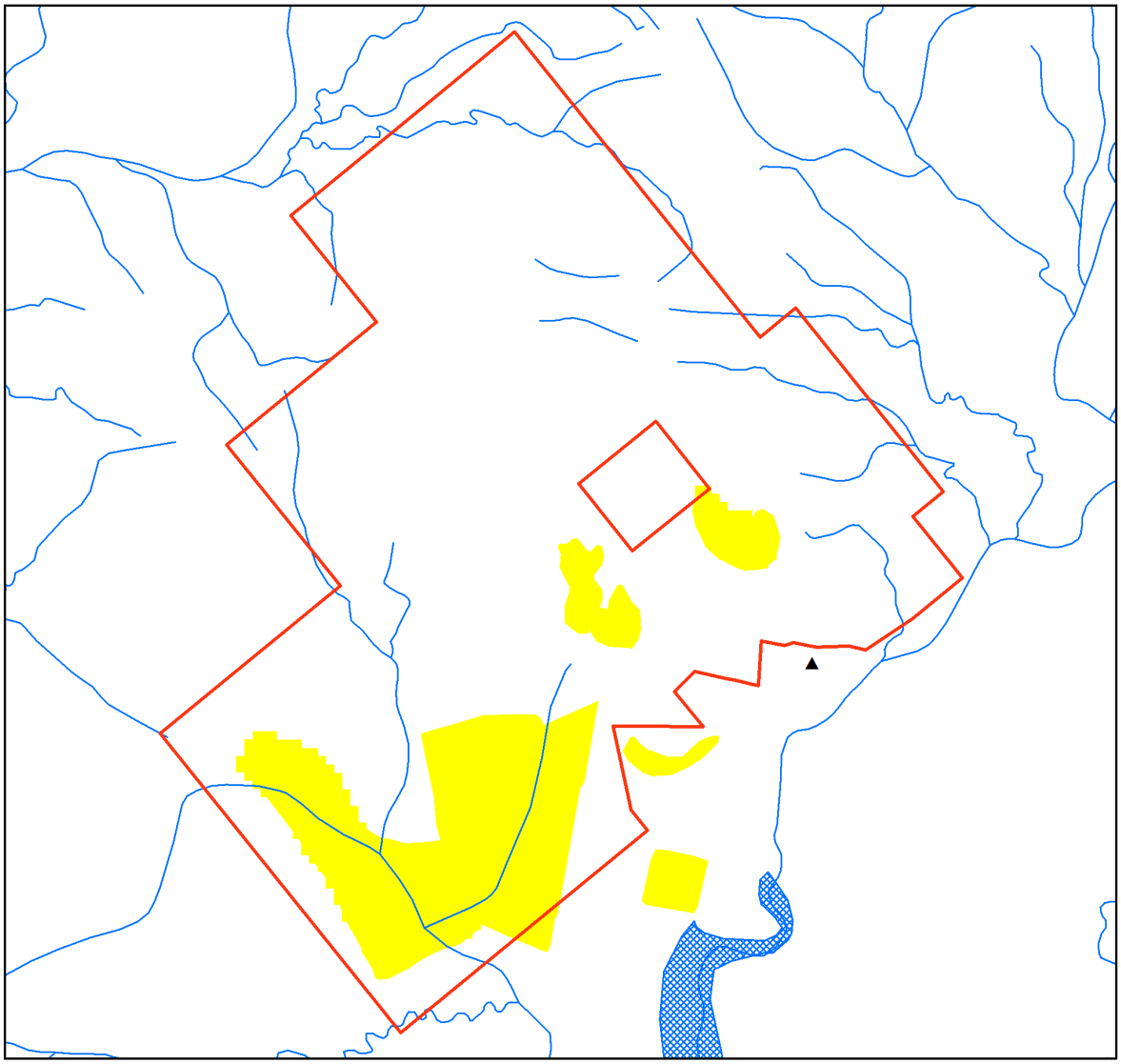


This product is projected into GDA 1994 Queensland Albers

Broad Vegetation Groups (BVG) of Queensland are applied by look up table to the regional ecosystem vegetation communities. Each polygon is coloured by the dominant BVG5M and the component regional ecosystems labelled. Where more than one regional ecosystem occurs, the percentage of each is labelled.
Regional ecosystem mapping over the majority of Queensland is produced at a scale of 1:100,000. At this scale, the minimum remnant polygon area is 5 hectares or minimum remnant width of 75 metres. Regional ecosystem linework reproduced at a scale greater than 1:100,000, except in designated areas, should be used as a guide only. The precision of polygon boundaries or positional accuracy of linework is 100 metres.
Regional ecosystems are defined as vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform and soil.
The label consists of 3 components: bioregion, land zone, and vegetation community – the dominant canopy species. e.g.: RE 12.3.3. Descriptions of REs are found online. Use the search term "Regional Ecosystem Framework".
Regional ecosystem mapping at 1:100,000 map scale is derived from the following sources: 1:80,000 B&W 1960's aerial photography, Landsat TM imagery, geology, soils, land systems data, field survey and historical records.

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Map 6 - Wetlands and waterways



Queensland Wetland Data

Legend

- Selected Mining Lease (ML)
- Towns

Queensland Wetland Data

- Riverine Drainage Lines
- Springs

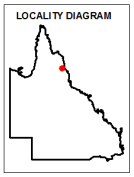
Wetland System - Water Bodies

- Marine Waterbodies
- Estuarine Waterbodies
- Riverine Waterbodies
- Lacustrine Waterbodies
- Palustrine Waterbodies

Wetland System - Regional Ecosystems

- Marine RE
- Estuarine RE
- Riverine RE
- Lacustrine RE
- Palustrine RE
- RE 51-80% wetland (mosaic units)
- RE 1-50% wetland (mosaic units)

LOCALITY DIAGRAM



N

0 180 360 540 720 900 m

Accuracy information: The positional accuracy of wetland data mapped at a scale of 1:100,000 is +/-100m with a minimum polygon size of 5ha or 75m wide for linear features, except for areas along the east coa st which are mapped at the 1:50,000 scale with a positional accuracy of +/-50m, with a minimum polygon size of 1ha or 35m wide for linear features. Wetlands smaller than 1ha are not delineated on the wetland data. Consideration of the effects of mapped scale is necessary when interpret ing data at a larger scale, e.g. 1:25,000. For property assessment, digital linework should be used as a guide only. The extent of wetlands depicted on this map is based on rectified 2013 Landsat ETM+ imagery supplied by Statewide Landcover and Trees Study (SLATS), Department of Environment and Science. The extent of water bodies is based on the maximum extent of inundation derived from available Landsat imagery up to and including the 2013 imagery.

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This product is projected into GDA 1994 Queensland Albers

Links and Other Information Sources

The Department of Environment and Science's Website -

http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/

provides further information on the regional ecosystem framework, including access to links to the Regional Ecosystem Database, Broad Vegetation Group Definitions, Regional Ecosystem and Land zone descriptions.

Descriptions of the broad vegetation groups of Queensland can be downloaded from:

https://publications.qld.gov.au/dataset/redd/resource/

The methodology for mapping regional ecosystems can be downloaded from:

https://publications.qld.gov.au/dataset/redd/resource/

Technical descriptions for regional ecosystems can be obtained from:

http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/technical-descriptions/

Benchmarks can be obtained from:

http://www.qld.gov.au/environment/plants-animals/biodiversity/benchmarks/

For further information associated with the remnant regional ecosystem dataset used by this report, refer to the metadata associated with the Biodiversity status of pre-clearing and Remnant Regional Ecosystems of Queensland dataset (version listed in **Appendix 1**) which is available through the Queensland Government Information System portal,

http://dds.information.qld.gov.au/dds/

The Queensland Globe is a mapping and data application. As an interactive online tool, Queensland Globe allows you to view and explore Queensland maps, imagery (including up-to-date satellite images) and other spatial data, including regional ecosystem mapping. To further view and explore regional ecosystems over an area of interest, access the Biota Globe (a component of the Queensland Globe). The Queensland Globe can be accessed via the following link:

http://www.dnrm.qld.gov.au/mapping-data/queensland-globe

References

Neldner, V.J., Niehus, R.E., Wilson, B.A., McDonald, W.J.F., Ford, A.J. and Accad, A. (2019). The Vegetation of Queensland. Descriptions of Broad Vegetation Groups. Version 4.0. Queensland Herbarium, Department of Environment and Science.

(https://publications.qld.gov.au/dataset/redd/resource/78209e74-c7f2-4589-90c1-c33188359086)

Neldner, V.J., Wilson, B.A., Dillewaard, H.A., Ryan, T.S., Butler, D.W., McDonald, W.J.F, Addicott, E.P. and Appelman, C.N. (2020). Methodology for survey and mapping of regional ecosystems and vegetation communities in Queensland. Version 5.1. Updated March 2020. Queensland Herbarium, Queensland Department of Environment and Science, Brisbane.

(https://publications.qld.gov.au/dataset/redd/resource/6dee78ab-c12c-4692-9842-b7257c2511e4)

Sattler, P.S. and Williams, R.D. (eds) (1999). *The Conservation Status of Queensland's Bioregional Ecosystems*. Environmental Protection Agency, Brisbane.

Appendices

Appendix 1 - Source Data

The dataset listed below is available for download from:

http://www.qld.gov.au/environment/plants-animals/plants/ecosystems/download/

- Regional Ecosystem Description Database

The datasets listed below are available for download from:

http://dds.information.qld.gov.au/dds/

- Biodiversity status of pre-clearing and 2019 remnant regional ecosystems of Queensland
- Pre-clearing Vegetation Communities and Regional Ecosystems of Queensland
- Queensland Wetland Data Version - Wetland lines
- Queensland Wetland Data Version - Wetland points
- Queensland Wetland Data Version - Wetland areas

Appendix 2 - Acronyms and Abbreviations

AOI	- Area of Interest
GDA94	- Geocentric Datum of Australia 1994
GIS	- Geographic Information System
RE	- Regional Ecosystem
REDD	- Regional Ecosystem Description Database
VMA	- *Vegetation Management Act 1999*

APPENDIX E – FORM OF CERTIFICATION

TAILINGS.WATER.WASTE.

Form of Certification (Consequence Assessment)

Name of Registered Professional Engineer providing certification:

Ralph Holding (RPEQ 23741)
on behalf of ATC Williams Pty Ltd

Address of Registered Professional Engineer providing certification:

PO Box 3309
Ground Floor, 16-20 Edmondstone Street
Newmarket, Queensland 4051, AUSTRALIA

This consequence category assessment was prepared by ATC Williams Pty Ltd and certified by Ralph Holding (RPEQ 23741).

Statement of Relevant Experience

I hereby state that I am a Registered Professional Engineer of Queensland and meet the requirements of the definition of 'suitably qualified and experienced person'.

Statement of Certification

All relevant material relied upon by me, including subsidiary certifications of specialist components, where required by the environmental authority, is provided in the attached report *Mt Carbine Mine Stage 3 Waste and Water Management Design Report – Appendix A Consequence Category Assessment*.

I hereby certify that the Consequence Assessment section enclosed in the Mt Carbine Mine *Stage 3 Waste and Water Management Design Report Consequence Category Assessment* for the TSF 3 and TSF 4 Storages at the Mt Carbine Mine:

- That the consequence category assessment (CCA) has been prepared in accordance with the Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (DES, 2016) and that it is not based on information that I know is false or misleading;
- That I am not the owner, an employee of the owner, the operator, or an employee of the operator of the dam being assessed;
- That the information and analyses included in the assessment are appropriate and sufficiently accurate, and that the assessment has been made from these.

I, Ralph Holding, declare that the information provided as part of this certification is true to the best of my knowledge. I acknowledge that it is an offence under section 480 of the Environmental Protection Act 1994 to give the administering authority a document containing information that I know is false, misleading or incomplete in a material particular.

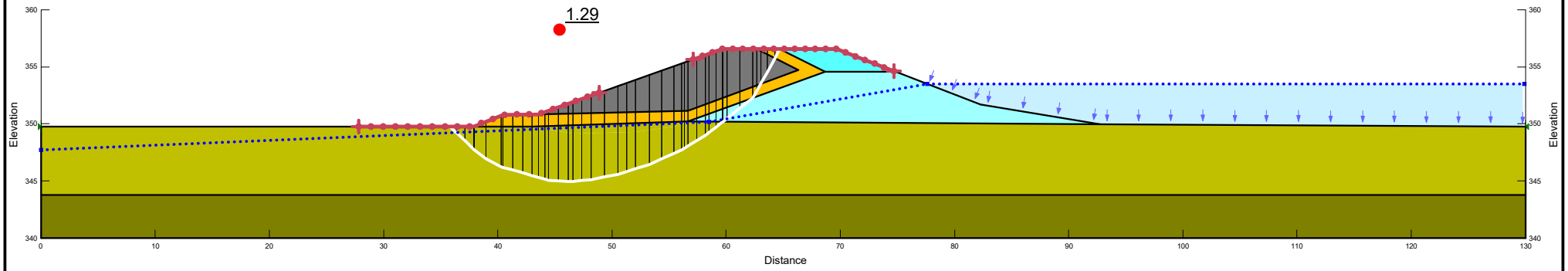


Signature _____ Date: 30 November 2022

APPENDIX B – SLOPE STABILITY ANALYSIS

TAILINGS.WATER.WASTE.

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Minimum Strength (kPa)	Tau/Sigma Ratio	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)	Piezometric Line	B-bar	Add Weight
	(Undrained) Embankment Rockfill Buttress	Mohr-Coulomb	21			0	38	0	1	0	Yes
	(Undrained) Embankment Rockfill Transition	Mohr-Coulomb	20			0	35	0	1	0	Yes
	(Undrained) Existing Embankment Clay Fill	SHANSEP	18	25	0.35				1	0.4	No
	(Undrained) New Embankment Clay Fill	SHANSEP	18	25	0.35				1	0	Yes
	(Undrained) Silty Clay	SHANSEP	18	25	0.35				1	0.4	No
	(Undrained) Weathered Shale	Mohr-Coulomb	23			5	34	0	1	0	No

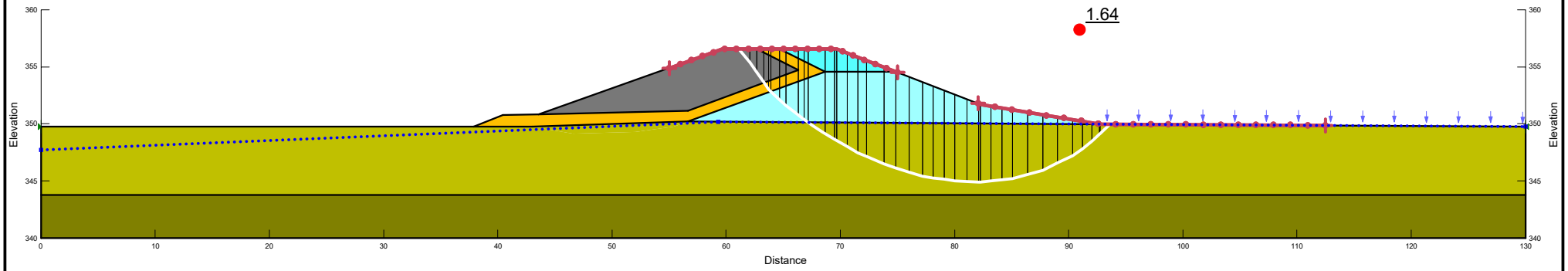


End of Construction-Undrained-Global DS-B bar

Mt Carbine-TD4 raise-03082022.gsz

03/08/2022 1:511.24345

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Minimum Strength (kPa)	Tau/Sigma Ratio	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)	Piezometric Line	B-bar	Add Weight
	(Undrained) Embankment Rockfill Buttress	Mohr-Coulomb	21			0	38	0	1	0	Yes
	(Undrained) Embankment Rockfill Transition	Mohr-Coulomb	20			0	35	0	1	0	Yes
	(Undrained) Existing Embankment Clay Fill	SHANSEP	18	25	0.35				1	0.4	No
	(Undrained) New Embankment Clay Fill	SHANSEP	18	25	0.35				1	0	Yes
	(Undrained) Silty Clay	SHANSEP	18	25	0.35				1	0.4	No
	(Undrained) Weathered Shale	Mohr-Coulomb	23			5	34	0	1	0	No

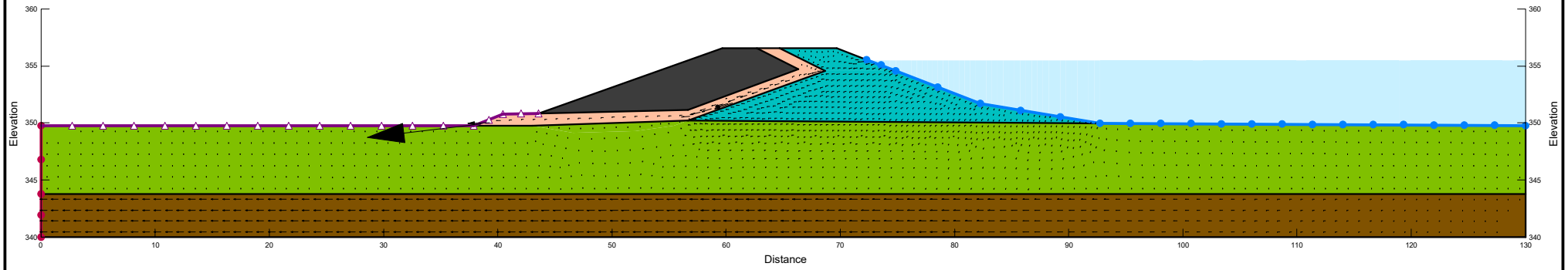


End of Construction-Undrained-Global US-B bar

Mt Carbine-TD4 raise-03082022.gsz

03/08/2022 1:511.24345

Color	Name	Hydraulic Material Model	Sat Kx (m/sec)	Vol. WC. Function	K-Function	Ky'/Kx' Ratio	Volumetric Water Content	Compressibility (/kPa)
	(Drained) Embankment Rockfill Buttress	Saturated / Unsaturated		Embankment Rockfill	Embankment Rockfill (K=1e-04m/s)	1		
	(Drained) Embankment Rockfill Transition	Saturated / Unsaturated		Embankment Rockfill Transition	Embankment Rockfill Transition (K=1e-05m/s)	1		
	(Drained) Existing Embankment Clay Fill	Saturated / Unsaturated		Silty Clay Fill	Silty Clay Fill (K=1e-08m/s)	0.2		
	(Drained) Silty Clay	Saturated / Unsaturated		Silty Clay Fill	Silty Clay Fill (K=1e-08m/s)	0.2		
	(Drained) Weathered Shale	Saturated Only	1e-07			1	0.32	1e-05

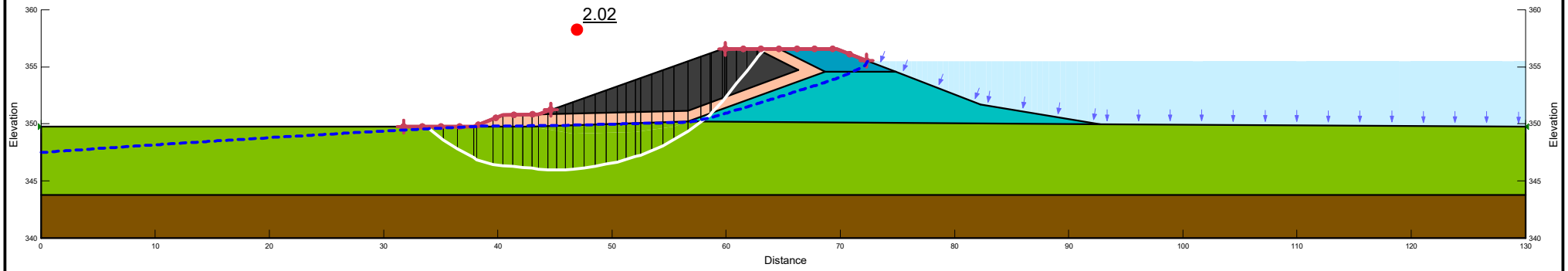


Steady-State Seepage

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Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
	(Drained) Embankment Rockfill Buttress	Mohr-Coulomb	21	0	38	0
	(Drained) Embankment Rockfill Transition	Mohr-Coulomb	20	0	35	0
	(Drained) Existing Embankment Clay Fill	Mohr-Coulomb	18	5	29	0
	(Drained) New Embankment Clay Fill	Mohr-Coulomb	18	5	29	0
	(Drained) Silty Clay	Mohr-Coulomb	18	5	28	0
	(Drained) Weathered Shale	Mohr-Coulomb	23	5	34	0

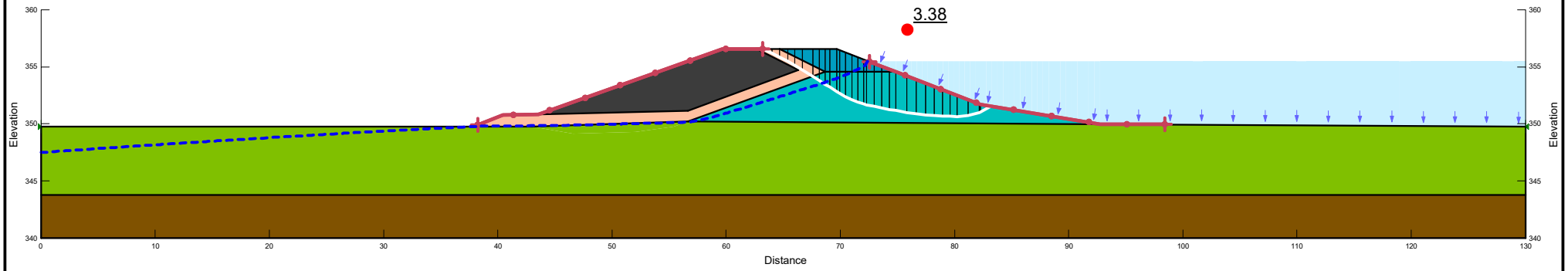


Drained-Global DS

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Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
	(Drained) Embankment Rockfill Buttress	Mohr-Coulomb	21	0	38	0
	(Drained) Embankment Rockfill Transition	Mohr-Coulomb	20	0	35	0
	(Drained) Existing Embankment Clay Fill	Mohr-Coulomb	18	5	29	0
	(Drained) New Embankment Clay Fill	Mohr-Coulomb	18	5	29	0
	(Drained) Silty Clay	Mohr-Coulomb	18	5	28	0
	(Drained) Weathered Shale	Mohr-Coulomb	23	5	34	0

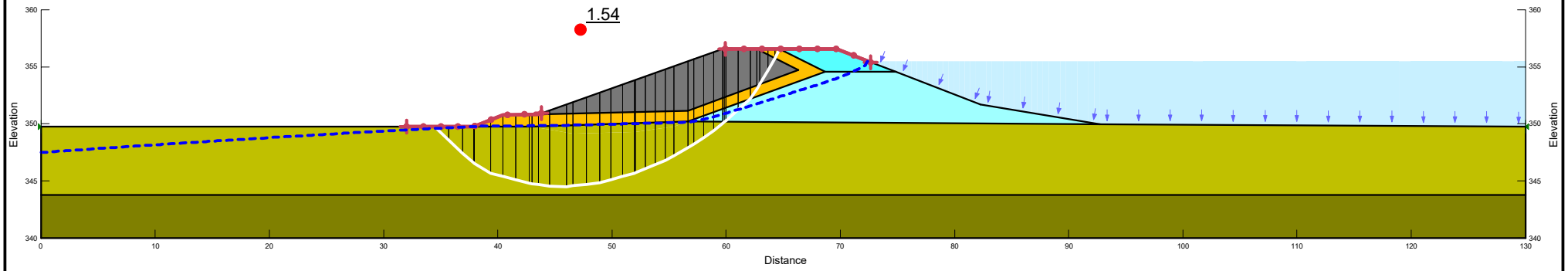


Drained-Global US

Mt Carbine-TD4 raise-03082022.gsz

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Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Minimum Strength (kPa)	Tau/Sigma Ratio	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
	(Undrained) Embankment Rockfill Buttress	Mohr-Coulomb	21			0	38	0
	(Undrained) Embankment Rockfill Transition	Mohr-Coulomb	20			0	35	0
	(Undrained) Existing Embankment Clay Fill	SHANSEP	18	25	0.35			
	(Undrained) New Embankment Clay Fill	SHANSEP	18	25	0.35			
	(Undrained) Silty Clay	SHANSEP	18	25	0.35			
	(Undrained) Weathered Shale	Mohr-Coulomb	23			5	34	0

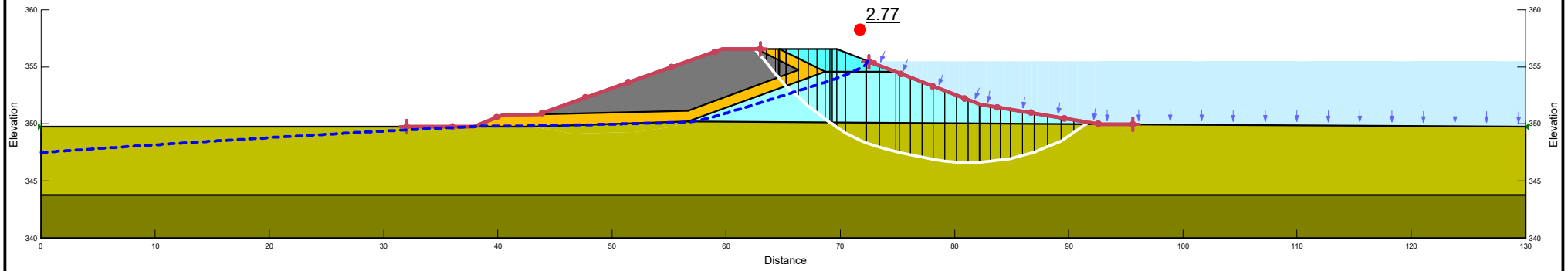


End of Construction-Undrained-Global DS

Mt Carbine-TD4 raise-03082022.gsz

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Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Minimum Strength (kPa)	Tau/Sigma Ratio	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
	(Undrained) Embankment Rockfill Buttress	Mohr-Coulomb	21			0	38	0
	(Undrained) Embankment Rockfill Transition	Mohr-Coulomb	20			0	35	0
	(Undrained) Existing Embankment Clay Fill	SHANSEP	18	25	0.35			
	(Undrained) New Embankment Clay Fill	SHANSEP	18	25	0.35			
	(Undrained) Silty Clay	SHANSEP	18	25	0.35			
	(Undrained) Weathered Shale	Mohr-Coulomb	23			5	34	0

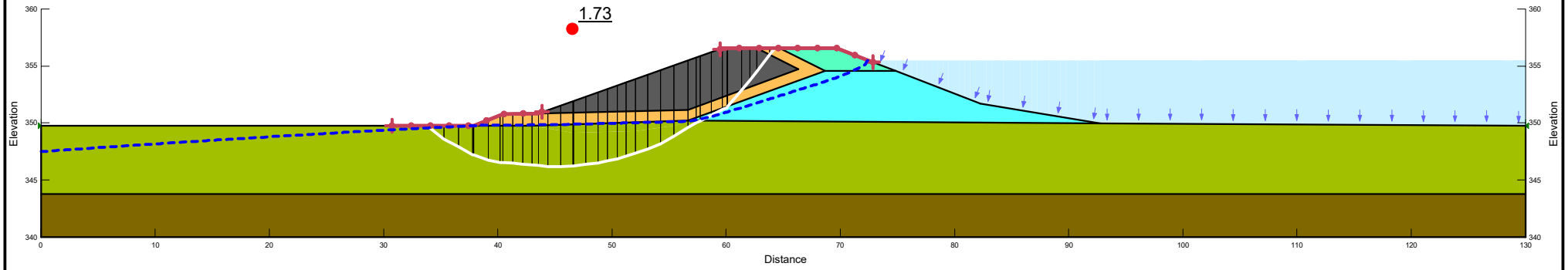


End of Construction-Undrained-Global US

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Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Minimum Strength (kPa)	Tau/Sigma Ratio	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
	(Softened Drained) Embankment Rockfill Buttress	Mohr-Coulomb	21			0	32	0
	(Softened Drained) Embankment Rockfill Transition	Mohr-Coulomb	20			0	29.3	0
	(Softened Drained) New Embankment Clay Fill	SHANSEP	18	12	0.28			
	(Softened Drained) Weathered Shale	Mohr-Coulomb	23			5	34	0
	(Softened Undrained) Existing Embankment Clay Fill	SHANSEP	18	12	0.28			
	(Softened Undrained) Silty Clay	Mohr-Coulomb	18			1	28	0

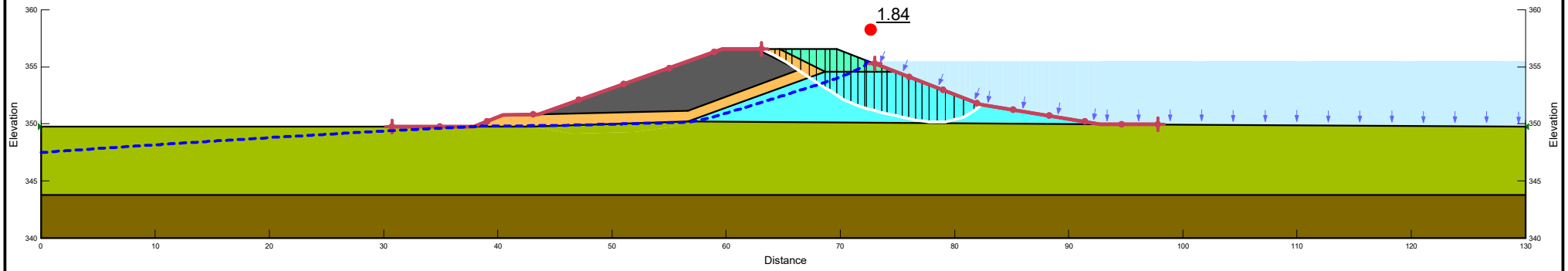


Post-Seismic-Global DS

Mt Carbine-TD4 raise-03082022.gsz

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Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Minimum Strength (kPa)	Tau/Sigma Ratio	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
	(Softened Drained) Embankment Rockfill Buttress	Mohr-Coulomb	21			0	32	0
	(Softened Drained) Embankment Rockfill Transition	Mohr-Coulomb	20			0	29.3	0
	(Softened Drained) New Embankment Clay Fill	SHANSEP	18	12	0.28			
	(Softened Drained) Weathered Shale	Mohr-Coulomb	23			5	34	0
	(Softened Undrained) Existing Embankment Clay Fill	SHANSEP	18	12	0.28			
	(Softened Undrained) Silty Clay	Mohr-Coulomb	18			1	28	0

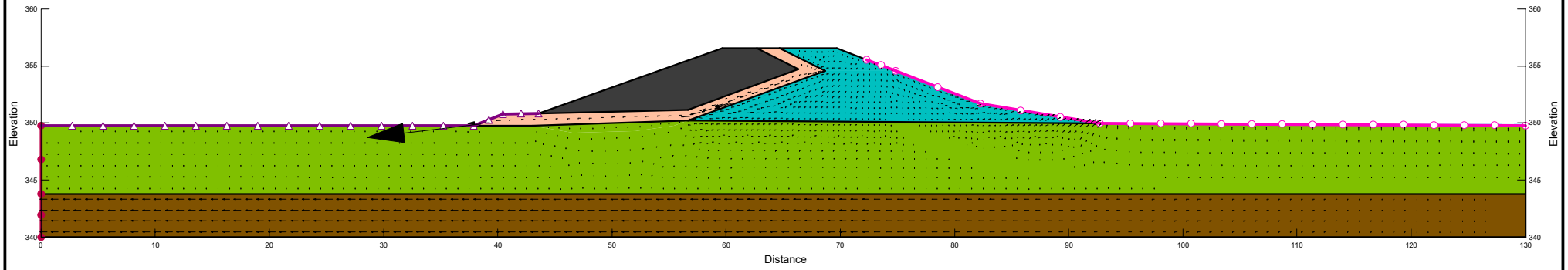


Post-Seismic-Global US

Mt Carbine-TD4 raise-03082022.gsz

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Color	Name	Hydraulic Material Model	Sat Kx (m/sec)	Vol. WC. Function	K-Function	Ky'/Kx' Ratio	Volumetric Water Content	Compressibility (/kPa)
	(Drained) Embankment Rockfill Buttress	Saturated / Unsaturated		Embankment Rockfill	Embankment Rockfill (K=1e-04m/s)	1		
	(Drained) Embankment Rockfill Transition	Saturated / Unsaturated		Embankment Rockfill Transition	Embankment Rockfill Transition (K=1e-05m/s)	1		
	(Drained) Existing Embankment Clay Fill	Saturated / Unsaturated		Silty Clay Fill	Silty Clay Fill (K=1e-08m/s)	0.2		
	(Drained) Silty Clay	Saturated / Unsaturated		Silty Clay Fill	Silty Clay Fill (K=1e-08m/s)	0.2		
	(Drained) Weathered Shale	Saturated Only	1e-07			1	0.32	1e-05



Transient Seepage

Mt Carbine-TD4 raise-03082022.gsz

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APPENDIX C – CONSTRUCTION SPECIFICATION

TAILINGS.WATER.WASTE.

1 INTRODUCTION

1.1 Definition

This Technical Specification refers to the construction works associated with the Stage 3 Development at Mt Carbine Mine. The construction works comprise the following:

- Buttressing/formalisation of TSF 3 Embankment and Emergency Spillway;
- Raise of TSF4 embankment to increase storage capacity to 750 ML and construction of an Emergency Spillway at the southwest perimeter;
- Formation of a Waste Rock Dump platform and Basal Lining.

This Technical Specification aims to describe the scope of the Lifts' construction works and outline the construction standard to be achieved. For this Technical Specification, the following definitions will be referred to:

- **Principal:** EQ Resources Limited (EQR)
- **Superintendent:** Operations Manager – EQR (or nominated delegate)
- **Contractor:** Organisation or individual commissioned by the Principal to undertake the construction works in accordance with the terms and conditions of EQR's Contract and this Technical Specification.
- **Contractor's Representative:** Nominated Contractor delegate responsible for maintaining day-to-day communication with the Superintendent about the works.
- **Designer's Representative:** Principal Engineer, ATC Williams Pty Ltd (or nominated delegate)
- **Site:** The land area that has been made available by the Principal for the works

This Technical Specification supersedes in total any other documentation given in any form to the Contractor by the Principal for whatever reason before the issue of the Tender Document for the works unless otherwise stated in writing by the Superintendent.

1.2 Location of works

The works will be carried out within the Mt Carbine Mine lease area, located approximately 80 km northwest of Cairns, Queensland, adjacent to the township of Mount Carbine.

1.3 History and Current Status

The Mt Carbine TSFs are classified as Low Consequence facilities in accordance with the Manual for Assessing Consequence Categories and Hydraulic Performance of Structures (2016), as produced by the Queensland Department of Environment and Science (DES, formerly DEHP). Whilst no as-built documentation is available, it is interpreted that the perimeter embankments forming the TSFs were constructed using locally borrowed earth fill from the immediate surrounds of the TSFs.

1.4 Extent of Works

1.4.1 Works by Contractor

The TSF3 and 4 Lifts are required to increase the capacity of the TSFs for storing excess water pumped from the pit. The construction works include, but shall not be limited to:

- Stripping natural surfaces and the existing embankment surfaces and foundations to expose suitable foundations and the Earth Fill.
- Construction of the embankment lifts using Earth Fill, Select Rock Fil (transition/filter)l and Rock Fill materials.
- Gravel sheeting of the embankment crest.
- Construction of emergency spillways.
- Associated drainage works and Waste Rock Dump Platform.

The Contractor shall supply all labour, plant, materials (other than those earthworks materials made available within the property) and incidentals required to carry out and complete the works associated with the Lift works, as shown on the Drawings and outlined in this Technical Specification.

1.4.2 Works by Principal

Works to be completed by the Principal to facilitate or enable the Contractor's works will include the following:

- Remove any existing pipework from within the defined construction area.
- Provision of access to site amenities, including messing areas and ablution areas at the site office. The Contractor shall provide additional facilities as required within the area of work.
- Provision of access to telephone and email communication within the project's office.
- Provision of access around the TSFs to access the Embankments.
- The Principal will also make available the borrowed areas for Earth Fill, Select Rock Fill, Rock Fill, Rock Armouring and Gravel Sheeting materials, as well as any additional materials required for upgrading and maintenance of haul roads as is considered reasonable by the Superintendent. The borrow locations will be as directed by the Principal and generally in accordance with the following:
  - Earth Fill from local borrow areas shall be confirmed before construction.
  - Select Rock Fill, Rock Fill and Rock Fill and Rock Armouring – from nominated waste rock stockpiles adjacent to the TSFs.
  - Gravel Sheeting from nominated waste rock stockpiles adjacent to the TSFs.

1.4.3 Other Contractor's Obligations

Subject to the relevant clauses of the Technical Specification, the Contractor will be required to work in close liaison with the Superintendent in respect of the programming and sequencing of construction works associated with the Contract. Other obligations of the Contractor shall include the following:

(i) Obligations as related to minimum requirements for vehicles and plants:

- UHF radios
- Flashing lights (for all vehicles other than haul trucks)
- Reversing beepers
- Flags (for light vehicles and service trucks only) In addition:
- Certificates of mechanical inspection for all construction plants are to be submitted to the Superintendent before mobilisation to the site. Each plant item shall also be made available

- to the Superintendent on arrival at to site for inspection to confirm mechanical soundness.
- Pre-start inspections of all vehicles shall be undertaken, with records of pre-start inspections to be maintained and kept within the vehicle.

(ii) Obligations as related to speed limits to be observed within the site:

- As outlined in the Contractor's Safety, Health and Environment Requirements Manual, speed limits shall apply as a minimum requirement.
- Speed limits specific to this Contract shall apply in the following areas:

– All haul roads: 30km/h to 40km/h (as signposted)

– Along or crossing roads used by road vehicles: 40km/h

– Perimeter roads around tailings storage area: 25km/h

– All TSF embankments crests: 25km/h

(iii) Obligations as related to Personal Protection Equipment (PPE):

- PPE for all workers shall comply with the Contractor's Safety, Health and Environment Requirements Manual. All PPE obligations shall be the responsibility of the Contractor.

1.5 Construction Management and Quality System Requirements

The Contractor shall maintain experienced management, supervisory and quality control team under his nominated site-based project manager committed to achieving and maintaining the standards specified for the works.

The Contractor shall prepare a detailed works program showing all significant activities, durations, interrelationships and sequences. Meetings from time to time shall be held, during which construction and/or operational progress will be discussed with respect to the program or productivity requirements. At these meetings, the Contractor shall submit revised/updated versions of the program to reflect works completed to date, highlighting adjusted milestones and variations in construction sequencing.

1.6 Environmental Management Plan

The Contractor shall submit to the Company an Environmental Management Plan (EMP) relevant to the proposed works required under this Contract if requested.

The EMP shall include, as a minimum, the following operations:

- Air and Noise Quality Management
- Diesel, Oil, Grease and Chemical Management
- Water Management, including Stormwater and Dewatering of the Works
- Sediment and Erosion Control
- Waste Management
- Spill Response Training

1.7 Authorities

All work shall be carried out in accordance with the requirements of all authorities having jurisdiction over the works.

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1.8 Standards

Plant, materials, and workmanship shall comply with the requirements of current standards and Codes of Practice of the Standards Association of Australia (Standards Australia) as appropriate. All materials and workmanship not covered by a Standards Australia standard shall be used in first-class work suitable for the environment and conditions under which the works are to be constructed.

1.9 Survey and Setting Out

1.9.1 Survey

Available survey baselines and reference benchmarks, which are relevant to the setting out of the works, are indicated on the Drawings or shall otherwise be established by the Principal. The Contractor shall also locate, as required, any additional reference benchmarks at the site to assist with setting out the works and shall ensure that these marks are suitably protected at all times.

The Contractor shall undertake an audit survey before any earthworks operations are commenced to verify the survey information provided in the contract. Site infrastructure locations need to be confirmed with pertinent survey information. This may include existing access roads, decant structure, tailings pipelines, underground pipes, service pipes and cables, overhead powerlines, HV substations, standpipe piezometers, diversion drain, etc. Any discrepancies shall be reported to the Principal. If no discrepancies are reported, the provided survey will be the basis for all measurements of the Works.

1.9.2 Setting Out

The Contractor shall set such line and level pegs as necessary for properly controlling earthworks. The Contractor shall employ on the works a suitably qualified surveyor approved by the Principle as capable of exercising control of all survey requirements.

The Contractor shall submit to the Principle in writing details of all offset pegs, construction pegs and chainage markers (at appropriate intervals) as required. Setting out of line, offset, and level pegs shall not start until the Principle has approved the details—[HOLD POINT].

The Principal reserves the right to periodically check construction levels and set out during and on completion of construction.

1.10 As-Constructed Information

During the progress of the works, the Contractor shall accurately survey and plot all work carried out and all services installed. This information shall be prepared in a properly drafted, scaled and detailed form to prepare "as-constructed" drawings for the works.

The Contractor shall prepare this information in the following forms:

- One set of A1-sized printed plans; and
- USB Drive containing the data in DWG format.

1.11 Clean-Up

On completion of the works, the Contractor shall generally clean the site, make good any damage, and restore the site to a neat and tidy condition. All work areas should be smoothed and graded to conform to the landscape's natural appearance. Where unnecessary destruction, scarring, damage or defacing has occurred due to the Contractor's operations, the same shall be repaired, replanted, reseeded, or otherwise corrected.

TAILINGS.WATER.WASTE.

2 SCHEDULE OF DRAWINGS

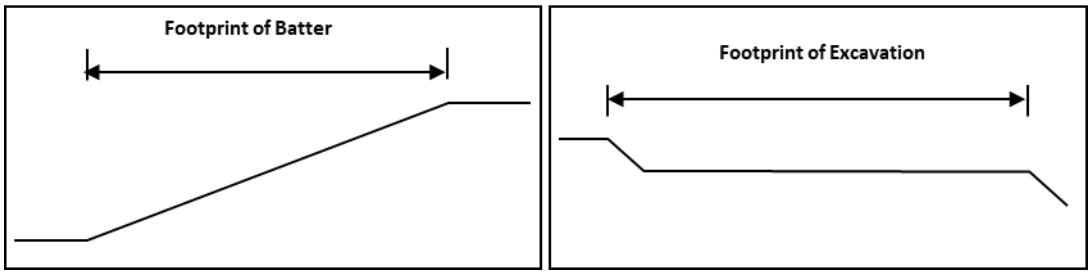
The following Drawings are included in and form part of the Construction Specification. (**APPENDIX F**-Design report).

Figure No.	Drawing No.	Title	Revision
001	119190-05-100-001	Site Locality Plan and Drawing List	A
002	119190-05-100-002	Site Existing Conditions	A
003	119190-05-100-003	Site Layout	B
004	119190-05-200-001	Tailings Storage Facility 3- General Arrangement	A
005	119190-05-200-002	Tailings Storage Facility 3- Cross Sections	A
006	119190-05-300-001	Tailings Storage Facility 4- General Arrangement	A
007	119190-05-300-002	Tailings Storage Facility 4- Cross Sections	A
008	119190-05-400-001	Waste Rock Dump- General Arrangement	A
009	119190-05-400-002	Waste Rock Dump- Cross Sections and Details	A

3 DEFINITIONS

- **Embankment Lift**: shall downstream embankment lift for the Embankments,
- **Footprint**: shall mean the surface extension of the embankment over which foundation preparations and sub-excavations shall be carried out.

Sketch Showing Definition of Footprint



- **Topsoil**: shall mean the surface or top layer of soil, including fine roots, herbaceous vegetation and overlying grass, and is characterised by organic matter, including dormant seeds.
- **Earth Fill**: shall mean the construction materials sourced from approved borrow areas and used to construct the embankment lift.
- **Rock Fill**: shall mean the construction materials sourced from nominated waste rock stockpiles adjacent to the TSFs, designated as either Rock Fill or Select Rock Fill subject to the specific applications as stated in the specification, and shall be used to construct the rock fill embankment zones, transition zone, and haul road.
- **Gravel Sheeting**: shall mean the construction materials sourced from a local borrow and /or stockpile and shall be used for the sheeting of the embankment crest to provide a trafficable surface.

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- **Refusal**: shall be defined as excavations that cannot be excavated with a well-maintained tracked excavator in good condition with a short tip radius bucket curling force of not less than 227kN equipped with a bucket not greater than 1.16m bite width and fresh sharp teeth (this refers to a CAT 330B excavator with an M2.6E Boom or its equivalent) at a rate of 20 cubic metres (solid) per hour.

4 CONSTRUCTION WORKS

4.1 Scope

This section describes the technical requirements for the TSF3 and TSF4 Lifts construction and associated works under the following headings:

- Construction Preparation
- Foundation Preparation
- Earthworks
- Emergency Spillway Construction Works
- Haul Road and Rock Fill Buttress Construction Works

4.2 Construction Preparation

4.2.1 Clearing and Grubbing

Clearing and grubbing shall be carried out within the uncleared borrow areas and areas delineated by the Superintendent.

Clearing and grubbing shall generally include the removal of all debris, trees, stumps, scrub and fallen timber. Clearing in areas to be excavated or filled shall also include the grubbing of stumps and roots above 25mm in diameter.

Materials removed in clearing operations shall be stockpiled in windrows or dealt with as directed by the Superintendent.

4.2.2 Topsoil Stripping

Topsoil shall be stripped to the depth specified on the Drawings or as directed by the Superintendent to ensure no significant visible organic materials are retained **[HOLD POINT]** in the borrow areas, embankment and storage footprints. The nominal topsoil stripping thickness is 0.2m. Stripped topsoils shall be stockpiled at locations as nominated by the Superintendent. Topsoil windrows shall be profiled as directed by the Superintendent.

4.3 Foundation Excavation

4.3.1 Excavations

4.3.1.1 General

Excavations shall be carried out in construction areas, as required, to expose or form a competent surface over which construction activities can be safely or appropriately undertaken and to enable the construction works to meet the standards as outlined in this Technical Specification. Excavations include, but shall not be limited to, the following:

- Foundation Sub-excavation for the new embankments.

- Excavation of placed Rock Fill at the Haul Road bridged areas over the TSF Embankment to expose the Earth Fill surfaces before Earth Fill placement.

The Contractor shall make provision for the safety of all workers within excavations by sloping batters to a stable angle (subject to the assessment of the excavation profile, a maximum slope of 1(H):1(V)), or other means of batter stabilisation as approved by the Superintendent. The Contractor shall also be responsible for removing or excluding water from the excavations by using temporary drains, coffer dams, pumps or other means, as required. Surface water from the surrounding areas shall be prevented from entering the excavation areas, and any natural drainage or stream shall be directed around the works, as appropriate. Excavation areas shall, wherever practicable, be graded to facilitate surface drainage by gravitation.

4.3.1.2 Foundation Excavations

General excavation below the cleared and topsoil-stripped surface shall be carried out beneath the entire width of the embankment foundations and Rock Fill Buttress areas to remove weak, rolled, soft, compressible or over-saturated soils, as delineated by the Superintendent **[HOLD POINT]**. The anticipated depth range of foundation sub-excavation is 0.2m to 0.5m. Material so excavated shall be used as Earth Fill, Rock Fill or Gravel Sheeting, subject to the requirements of this Technical Specification or as otherwise specified. The Contractor shall avoid over-excavation of the foundation.

4.3.1.3 Rock Fill Bridged Areas

Rock Fill bridged areas include the haul road embankment crossovers. These bridged areas shall be excavated to expose underlying Earth Fill such that the embankment Earth Fill core can be continuously formed to the details provided in the Drawings. Excavated Rock Fill shall be used as Rock Fill in accordance with this Technical Specification.

4.4 Surface Preparations

4.4.1.1 Foundations

After all necessary foundation excavations have been carried out and any standing water has been drained or pumped away, the Superintendent shall inspect and approve such surfaces for placement of any fill **[HOLD POINT]**. Prepared surfaces shall be free of local areas of soft or loose materials which cannot be satisfactorily dealt with in the first layer of fill placed without reducing the quality or compaction standards of the fill below Specification standards. Trimming and cleaning of the foundation surface may therefore be required to enable the Superintendent to identify any zones that may need to be locally removed. The Designer's Representative shall inspect and confirm suitability for all foundation areas, with in-situ testing to be undertaken as considered necessary.

Areas upon which embankment fill is to be constructed, including the subgrade beneath the capping material (gravel sheeting) and where deemed necessary (along benches) by the Superintendent, the compacted subgrade shall be proof rolled to identify "soft spots" **[HOLD POINT]**.

The Contractor shall undertake proof rolling with a fully loaded water cart or similar equipment with a minimum ground bearing pressure of 400 kPa. Proof rolling shall be undertaken in the company's presence before placing any fill material.

Foundation surfaces shall be deemed compliant where proof rolling results in a surface deflection of less than 20 mm. Where deflections above 20 mm are observed, the soft/loose material shall be excavated to an extent approved by the company and backfilled with specified material compacted to a density ratio of not less than 97% of standard maximum dry density (SMDD) to AS1289.5.1.1.

4.4.1.2 Existing Earth Fill Surfaces

Existing Earth fill surfaces constructed as part of previous embankment lift works shall be trimmed back to a depth to remove desiccated materials. The depth of trimming shall be as directed by the Superintendent. Following trimming, the exposed surface shall be proof rolled to identify any loose, soft, or compressible soil. All identified loose, soft or compressible soil shall be removed from the surface to

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the satisfaction of the Superintendent and backfilled with Clay fill material compacted to a density ratio of not less than 98% of Standard Maximum Dry Density (SMDD) to AS 1289.5.1.

Embankment material shall not be placed until the Superintendent has inspected and approved the surface preparation **[HOLD POINT]**. Before placing the embankment fill, the exposed existing embankment and working platform surfaces, including the excavated foundation surface, shall be lightly scarified to a depth of approximately 50 mm and moisture conditioned to achieve an adequate bond with the new fill.

4.5 Earthworks

4.5.1 General

The Contractor shall direct their operations to avoid wastage of materials that would be suitable for use as fill if excavations, stockpiles, and borrow areas were drained effectively and if materials were selectively used (within the bounds of this specification) and/or mixed and conditioned making all use of favourable weather. Particular attention shall be paid to the control of runoff and prevention of surface water ponding within active Earth Fill borrows to avoid any delay to the works.

All materials used to reconstruct the embankment shall be free from deleterious matter and be approved by the Superintendent **[HOLD POINT]**.

No material containing the following may be used:

- Roots or other vegetable matter.
- Organic clays or silts.
- In the opinion of the Superintendent, materials will suffer undue erosion or dispersion.

The Contractor is responsible for ensuring that the materials they incorporate in the Works fully meet the requirements of this specification.

4.5.2 Earthworks Materials - Definitions and Sources

4.5.2.1 Earth Fill

Earth Fill shall be used to construct the Earth Fill Zones of the Embankment Lifts as shown on the Drawings. Earth Fill shall comprise fine-grained, cohesive materials that produce a competent fill with minimal air voids and low permeability when compacted to Specification requirements. Typical properties for the Earth Fill shall be as follows:

- Percentage passing 75µm size — greater than 35%
- A percentage greater than 25mm in size (particles that do not break down under the specification compaction effort) — less than 10%
- Maximum particle size — 50mm
- Liquid Limit — greater than 20%
- Plasticity Index — 10 to 35%
- Emerson Class Number — ≥ 3 (tested with distilled water)

As the Superintendent delineates, Earth Fill shall also be free of significant organic material and comprise material of the highest available plasticity. Earth Fill shall be sourced from the stockpile and borrow areas as identified on-site by the Superintendent.

4.5.2.2 Rockfill

Rockfill shall be used to form the following:

TAILINGS.WATER.WASTE.

- The downstream zones of the Embankment lift.
- Rock Buttress
- Haul Road Embankment

Rockfill shall generally be sourced from stockpile locations provided by the mining operations and general excavations. It shall be placed on the embankment perimeter downstream of the Earth Fill Zones and be non-acid producing, with non-acid producing and acid-producing materials delineated on site by the Superintendent.

Rockfill shall generally comprise a well-graded material possessing a maximum particle size of 500mm and not greater than 5% fines (i.e., fraction passing the 75μm size) by weight.

4.5.2.3 Selected Rockfill

Selected Rockfill shall be used for the Transition Zone between the Earth Fill and Rockfill and act as a filter layer to prevent fines-contracting from the upstream zones into the Rockfill. The material may be imported from local borrow or off-site. It shall generally comprise well-graded material and be free from sticks, organic matter, clay lumps and other harmful substances.

Furthermore, Selected Rockfill shall not be susceptible to significant weathering, breakdown or degradation following placement. Its gradation will be confirmed by the Superintendent or Designer's Representative **[HOLD POINT]**, depending on the gradation of the Earth Fill material.

4.5.2.4 Rock Armour

Rock Armour shall generally comprise a well-graded material possessing a maximum particle size of 500mm, a D_{50} of 250mm and a D_{20} of 150mm and not greater than 5% fines (i.e., fraction passing the 75μm size) by weight. Rock Armouring shall be used to protect the line, the invert and the batters of the spillway, as indicated on the Drawings. The Designer's Representative shall delineate these areas during construction. Rock Armouring shall comprise strong and fresh rock material, well-graded, and sourced as directed by Superintendent from a Superintendent approved source. The material shall not be subject to weathering. It shall be durable to the extent that minimal breakdown or degradation of the material occurs during placement and compaction or under service conditions. The material shall also be non-acid producing.

4.5.2.5 Gravel Sheeting (Embankment Lift Crest)

Gravel sheeting shall form a wearing course on the Earth Fill embankment crest areas as indicated on the Drawings. The Superintendent shall provide Gravel sheeting at stockpile locations and/or recover from the existing embankment crest areas. It will generally comply with the following grading specification (Percentage Passing (by weight)):

- Particle size 53mm 100%
- Particle size 19mm 60 to 90%
- Particle size 2.36mm 20 to 45%
- Particle size 0.075mm 4 to 15%

4.5.3 Placement and Compaction

4.5.3.1 General Requirements

All filling shall be done to the lines and levels indicated on the Drawings or as otherwise directed by the Superintendent. The Contractor shall submit compaction procedures to the Superintendent for approval. Procedures shall include details of the equipment proposed for use, the number of passes and the layer thicknesses proposed. The Contractor shall state in the procedures the steps that will be taken to control the moisture content of the fill materials **[HOLD POINT]**.

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The Earth fill and Rockfill placement shall not exceed a nominated rate of 2.0m per week or otherwise be advised by the Designer's representative. Fill slopes shall be neatly trimmed and left without excessive loose surface materials. Fill slopes steeper than 20% gradient shall be overfilled as necessary and trimmed back with an item of a plant equipped with a smooth blade to ensure that all fill in the slope face is adequately compacted.

4.5.3.2 Compaction Trials

To confirm moisture contents and compaction densities using the Contractors' proposed procedures, under the supervision of the Superintendent, the Contractor shall carry out a section of works and compaction trials with the plant proposed to be used to compact the embankment materials. The trials shall assess work methods to achieve material breakdown and compaction. The trials shall be continued until at least 4 out of every 5 tests are taken to conform to the specification for the embankment in respect of grading and relative density.

When the Superintendent has approved the compaction method, the Contractor shall maintain this approved method throughout the works or until the Superintendent approves an alternative method. The trials shall determine the plant, number and pattern of passes to be used, thickness of the loose layer to be compacted, and the moisture content of the layer for compaction. The area of the trial shall be incorporated into the Works.

4.5.3.3 Placement and Compaction of Earth Fill

After the Superintendent has inspected and approved the foundation in writing, the Contractor shall only commence work placing fill, for the construction of embankment, on the prepared foundation (subgrade) areas.

Earth Fill shall be constructed at appropriate moisture content and compacted using specialised compaction equipment. The compaction of this material shall be by sheepsfoot or a similar protruding foot-type compactor.

The material shall be placed as near as possible to optimum moisture content (OMC) (with a permissible range of OMC 1% to OMC +3%) and shall be compacted to a density ratio not less than 98% of standard maximum dry density (SMDD) to AS 1289.5.1.1

Before compaction, Earth Fill shall be broken up and/or rock raked to meet the size requirements of the specification, be laid out in a layer of approximately uniform loose thickness and be brought to an appropriate water content by wetting or aeration and drying (as the case may be), and/or blending and mixing wet and dry materials. Earth Fill material shall be spread and compacted in layers that do not exceed 200mm loose thickness before compaction to ensure that fill of adequate quality and bonding between layers can be obtained.

Earth Fill shall be mixed and/or conditioned thoroughly so that immediately before compaction, the moisture content of the fill is reasonably uniform within any area. Before placing the first Earth Fill layer over the sub-excavated surface, the surface shall be scarified, wetted and conditioned as necessary to ensure that the first fill layer will blend with the foundation materials to achieve a tight bond and the specified compacted density and moisture. Fill surfaces that have dried, have been rolled smooth or are in any other condition which may preclude obtaining a good bond between successive fill layers or zones shall be scarified and conditioned as necessary before the placement of the next fill layer.

4.5.3.4 Placement and Compaction of Rockfill

Rockfill used in the embankment, haul road, and rock buttress construction shall be placed by paddock dumping from the haul plant to form a lift, the surface of the lifting blade smoothed to allow access and the lift compacted by a minimum of 6 passes using 20- ton vibratory steel drum rollers or equivalent equipment. A maximum lift thickness of 0.8m is permissible. Rockfill used in this application may be placed without moisture content adjustment.

At the Embankment zone, every effort shall be made to place a coarser Rockfill towards the external face of the embankment and a finer Rockfill towards the upstream Earth Fill or Select Rockfill zone. The Rockfill batters adjacent to the Select Rockfill shall be suitably trimmed and compacted to form a uniform, smooth surface without significant voids to allow placement and compaction of the Select Rockfill layers.

4.5.3.5 Placement and Compaction of Select Rock Fill

Select Rock Fill shall be spread in layers of approximately uniform loose thickness and compacted by a minimum of 4 passes of a 10-ton vibrating roller or between 70% and 80% of MDD. Select Rockfill shall be spread and compacted in layers that do not exceed 400mm loose thickness before compaction. Select Rock Fill used in this application may be placed without moisture content adjustment. The Select Rockfill batters adjacent to the Earth Fill shall be suitably trimmed and compacted to form a uniform, smooth surface without significant voids to allow placement and compaction of the Earth Fill layers.

4.5.3.6 Earthworks Tolerances

Construction shall generally be to the levels and dimensions shown on the Drawings. The following tolerances in finished dimensions shall not be exceeded:

Level of embankment crest	+100 to -0 mm
Level of the emergency spillway crest	+50 to -0 mm
Maximum variation from a 4m long straight edge placed in any direction on any formed surface other than the spillway crests	-200 to +200 mm

4.5.4 Material Quality Testing

In accordance with their Quality Plan procedures, the Contractor shall undertake all inspections and testing necessary to ensure that materials used comply with the specification and have been placed in accordance with the specification.

A NATA shall undertake all testing registered laboratory in accordance with AS1289 and the soil and gravel testing frequency specification (BMAPR01-0000-CC-SP-0008) unless otherwise noted in this specification [HOLD POINT].

Where fill is placed in more than one layer, the Contractor shall undertake tests in each layer. Lots shall be essentially horizontal layers of fill from one particular source and shall be distributed through the Works in such a manner as to enable easy rectification of non-conforming lots

4.6 Emergency Spillway Construction Works

4.6.1 Spillway Construction and Rock Armour

The spillway for the TSFs shall be formed subject to the relevant clauses of this Technical Specification or as otherwise directed or approved by the Superintendent. Rock Armour used in spillway construction shall be selectively placed and interlocked as a single layer. A geotextile shall be placed beneath Rock Fill Armouring to the lines and dimensions shown on the Drawings or as directed by the Superintendent.

4.6.2 Geotextile Materials

The Geotextile shall be non-woven, needle-punched fabric as provided by the Superintendent. The Geotextile shall be uniform and homogeneous in appearance and composition and free from tears, cuts or any defect that may affect serviceability. The grade of Geotextile shall be 'Bidim A44' for spillway construction or its equivalent.

4.6.3 Geotextile Placement

The Geotextile shall not be placed until the subgrade has been inspected and approved by the Superintendent.

The Geotextile shall be loosely laid (not stretched) without any gaps or excessive wrinkles. Adjacent strips shall be overlapped a minimum of 500 mm, beneath the previously placed layer when placing

Geotextile in the flow direction. Care shall be taken to prevent the unravelling of the stitching thread at the end of a seam or at cuts and patches in the seam, including manually tying the end of the stitching thread as needed.

Care shall be exercised during all phases of construction not to damage the Geotextile. All tears, punctures, thinly stretched sections, holes created by removal of samples or coupons for destructive testing, or any other defect that may, as determined by the Superintendent, render the Geotextile unsuitable shall be repaired by the Contractor at his expense.

4.6.4 Geotextile Repairs.

Repairs shall be made by overlaying another sheet of Geotextile (or patch) over the damaged area with a 500 mm minimum lap. Geotextile that becomes contaminated or coated with soil or other material that renders the Geotextile unsuitable, as determined by the Superintendent, shall be replaced at the Contractor's expense.

4.7 Bunds

Bunds shall be constructed along the crest of Embankment lifts, Haul roads and in front of the workshop and plant, as indicated on the drawings or as directed by the Superintendent on site. Bund height should be at least half the diameter of the tyre of the largest vehicle to use the access and should be constructed so that it is as vertical as possible. Bunds are to be constructed using the same material as that used in the structure it lies on unless directed otherwise by the Superintendent.

4.8 Hold Points

Hold points are tasks required to be completed before construction activities can continue. Key hold points where the Superintendent or Designer's Representative will be required to be present to witness are summarised below:

- Embankment foundation preparation (including proof rolling)
- Existing crest preparation
- Natural foundation preparation
- Compaction trials
- Embankment placement – initial layers, with a particular focus on tying into the existing embankment

Construction activities hold points and their respective acceptance criteria to proceed shall be detailed in Inspection Test Plans, to be submitted by the Contractor and approval to be provided by the Superintendent.

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APPENDIX D – GEOTECHNICAL TESTS CERTIFICATES

TAILINGS.WATER.WASTE.

Construction Sciences

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Laboratory: **Sunshine Coast Laboratory**
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Fax: 07 5452 0133
Email: SunshineCoast@constructionsciences.net

EMERSON CLASS NUMBER REPORT

Client:	Construction Sciences Pty Ltd - Cairns	Report Number:	3740/R/56711-1
Client Address:	Shed 3, 5 Commercial Place, Earlville	Project Number:	3740/P/2508
Project:	EQ Resources Ltd - EQ Resources - Supplied Samples	Lot Number:	
Location:	Supplied Sample	Internal Test Request:	3740/T/42488
Supplied To:	n/a	Client Reference/s:	11512/CC/782
Area Description:		Report Date / Page:	26/10/2022 Page 1 of 2

Test Procedures:	AS1289.3.8.1

Sample Number	3740/S/227391	3740/S/227392	3740/S/227393	3740/S/227394
ID / Client ID	11512/S/108919	11512/S/108920	11512/S/108921	11512/S/108922
Lot Number	-	-	-	-
Date / Time Sampled	11/08/2022	11/08/2022	11/08/2022	11/08/2022
Date Tested	21/10/2022	21/10/2022	21/10/2022	21/10/2022
Material Source	-	-	-	-
Material Type	-	-	-	-
Sampling Method	Tested As Received	Tested As Received	Tested As Received	Tested As Received
Prep Material > 53mm (%)	-	-	-	-
Water Type	Distilled	Distilled	Distilled	Distilled
Water Temperature (°C)	21	21	21	21
Location1	Pit Sample	TP01	TP02	TP02
Location2	Outcrop	2.1 - 2.5	0.3 - 1.0	1.0 - 2.2
Location3				
Location4				
Soil Description	Gravelly Sandy Clay	Sandy Clay	Sandy Clay	Sandy Clay
Emerson Class Number	**2**	**2**	**2**	**2**

Remarks	Some or all of the testing within this report was conducted at our department 25313 located at Kunda Park. Results apply to the sample/s as received.,

Accredited for compliance with ISO/IEC 17025 – Testing

NATA

Accreditation Number: 1986
Corporate Site Number: 3740

Approved Signatory: Paul Mayes
Form ID: W22Rep Rev 3

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EMERSON CLASS NUMBER REPORT

Client:	Construction Sciences Pty Ltd - Cairns	Report Number:	3740/R/56711-1
Client Address:	Shed 3, 5 Commercial Place, Earlville	Project Number:	3740/P/2508
Project:	EQ Resources Ltd - EQ Resources - Supplied Samples	Lot Number:	
Location:	Supplied Sample	Internal Test Request:	3740/T/42488
Supplied To:	n/a	Client Reference/s:	11512/CC/782
Area Description:		Report Date / Page:	26/10/2022 Page 2 of 2

Test Procedures:	AS1289.3.8.1

Sample Number	3740/S/227395	3740/S/227396	3740/S/227397	
ID / Client ID	11512/S/108923	11512/S/108924	11512/S/108925	
Lot Number	-	-	-	
Date / Time Sampled	11/08/2022	11/08/2022	11/08/2022	
Date Tested	21/10/2022	21/10/2022	21/10/2022	
Material Source	-	-	-	
Material Type	-	-	-	
Sampling Method	Tested As Received	Tested As Received	Tested As Received	
Prep Material > 53mm (%)	-	-	-	
Water Type	Distilled	Distilled	Distilled	
Water Temperature (°C)	21	21	21	
Location1	TP02	TP06	TP09	
Location2	2.2 - 3.0	1.9 - 2.2	0 - 1.0	
Location3				
Location4				
Soil Description	Sandy Clay	Gravelly Sandy Clay	Sandy Clay	
Emerson Class Number	**2**	**2**	**2**	

Remarks	Some or all of the testing within this report was conducted at our department 25313 located at Kunda Park. Results apply to the sample/s as received.,

Accredited for compliance with ISO/IEC 17025 – Testing

NATA

Accreditation Number: 1986
Corporate Site Number: 3740

Approved Signatory: Paul Mayes
Form ID: W22Rep Rev 3

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ATTERBERG LIMITS REPORT

Client:	Construction Sciences Pty Ltd - Cairns	Report Number:	3740/R/56776-1
Client Address:	Shed 3, 5 Commercial Place, Earlville	Project Number:	3740/P/2508
Project:	EQ Resources Ltd - EQ Resources - Supplied Samples	Lot Number:	
Location:	Supplied Sample	Internal Test Request:	3740/T/42488
Supplied To:	n/a	Client Reference/s:	11512/CC/782
Area Description:		Report Date / Page:	31/10/2022 Page 1 of 7

Test Procedures:	AS1289.3.1.2, AS 1289.3.3.1, AS1289.3.2.1, AS1289.3.4.1, AS1289.2.1.1		
Sample Number	3740/S/227391	Sample Location	
Sampling Method	Tested As Received	Location1	Pit Sample
Date Sampled	11/08/2022	Location2	Outcrop
Sampled By	Client Sampled	Location3	
Date Tested	27/10/2022	Location4	
Drying / Prep Method	Oven Dried / Dry Sieved	Material Source	-
LL Water Type	Potable	Material Type	-
LL Device Type	Cassagrande	Prep Mat > 53mm (%)	-
Material Description	Gravelly Sandy Clay		

Atterberg Limit	Specification Minimum	Test Result	Specification Maximum
Liquid Limit (%)		**25**	
Plastic Limit (%)		**20**	
Plasticity Index (%)		**5**	
Linear Shrinkage (%)		**4.5**	
Linear Shrinkage Mould Length / Defects:	Mould Length: 249.8mm / -		

Remarks	Results apply to the sample/s as received.,

Accredited for compliance with ISO/IEC 17025 – Testing

NATA

Accreditation Number: 1986
Corporate Site Number: 3740

Approved Signatory: Thomas Hewitt
Form ID: W11bRep Rev 2

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ATTERBERG LIMITS REPORT

Client:	Construction Sciences Pty Ltd - Cairns	Report Number:	3740/R/56776-1
Client Address:	Shed 3, 5 Commercial Place, Earlville	Project Number:	3740/P/2508
Project:	EQ Resources Ltd - EQ Resources - Supplied Samples	Lot Number:	
Location:	Supplied Sample	Internal Test Request:	3740/T/42488
Supplied To:	n/a	Client Reference/s:	11512/CC/782
Area Description:		Report Date / Page:	31/10/2022 Page 2 of 7

Test Procedures:	AS1289.3.1.2, AS 1289.3.3.1, AS1289.3.2.1, AS1289.3.4.1, AS1289.2.1.1		
Sample Number	3740/S/227392	Sample Location	
Sampling Method	Tested As Received	Location1	TP01
Date Sampled	11/08/2022	Location2	2.1 - 2.5
Sampled By	Client Sampled	Location3	
Date Tested	27/10/2022	Location4	
Drying / Prep Method	Oven Dried / Dry Sieved	Material Source	-
LL Water Type	Potable	Material Type	-
LL Device Type	Cassagrande	Prep Mat > 53mm (%)	-
Material Description	Sandy Clay		

Atterberg Limit	Specification Minimum	Test Result	Specification Maximum
Liquid Limit (%)		**28**	
Plastic Limit (%)		**15**	
Plasticity Index (%)		**13**	
Linear Shrinkage (%)		**7.5**	
Linear Shrinkage Mould Length / Defects:	Mould Length: 250.1mm / -		

Remarks	Results apply to the sample/s as received.,

Accredited for compliance with ISO/IEC 17025 – Testing

NATA

Accreditation Number: 1986
Corporate Site Number: 3740

Approved Signatory: Thomas Hewitt
Form ID: W11bRep Rev 2

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ATTERBERG LIMITS REPORT

Client:	Construction Sciences Pty Ltd - Cairns	Report Number:	3740/R/56776-1
Client Address:	Shed 3, 5 Commercial Place, Earlville	Project Number:	3740/P/2508
Project:	EQ Resources Ltd - EQ Resources - Supplied Samples	Lot Number:	
Location:	Supplied Sample	Internal Test Request:	3740/T/42488
Supplied To:	n/a	Client Reference/s:	11512/CC/782
Area Description:		Report Date / Page:	31/10/2022 Page 3 of 7

Test Procedures:	AS1289.3.1.2, AS 1289.3.3.1, AS1289.3.2.1, AS1289.3.4.1, AS1289.2.1.1		
Sample Number	3740/S/227393	Sample Location	
Sampling Method	Tested As Received	Location1	TP02
Date Sampled	11/08/2022	Location2	0.3 - 1.0
Sampled By	Client Sampled	Location3	
Date Tested	27/10/2022	Location4	
Drying / Prep Method	Oven Dried / Dry Sieved	Material Source	-
LL Water Type	Potable	Material Type	-
LL Device Type	Cassagrande	Prep Mat > 53mm (%)	-
Material Description	Sandy Clay		

Atterberg Limit	Specification Minimum	Test Result	Specification Maximum
Liquid Limit (%)		**26**	
Plastic Limit (%)		**17**	
Plasticity Index (%)		**9**	
Linear Shrinkage (%)		**6.5**	
Linear Shrinkage Defects:	-		

Remarks	Results apply to the sample/s as received.,

Accredited for compliance with ISO/IEC 17025 – Testing

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Accreditation Number: 1986
Corporate Site Number: 3740

Approved Signatory: Thomas Hewitt
Form ID: W11bRep Rev 2

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ATTERBERG LIMITS REPORT

Client:	Construction Sciences Pty Ltd - Cairns	Report Number:	3740/R/56776-1
Client Address:	Shed 3, 5 Commercial Place, Earlville	Project Number:	3740/P/2508
Project:	EQ Resources Ltd - EQ Resources - Supplied Samples	Lot Number:	
Location:	Supplied Sample	Internal Test Request:	3740/T/42488
Supplied To:	n/a	Client Reference/s:	11512/CC/782
Area Description:		Report Date / Page:	31/10/2022 Page 4 of 7

Test Procedures:	AS1289.3.1.2, AS 1289.3.3.1, AS1289.3.2.1, AS1289.3.4.1, AS1289.2.1.1		
Sample Number	3740/S/227394	Sample Location	
Sampling Method	Tested As Received	Location1	TP02
Date Sampled	11/08/2022	Location2	1.0 - 2.2
Sampled By	Client Sampled	Location3	
Date Tested	27/10/2022	Location4	
Drying / Prep Method	Oven Dried / Dry Sieved	Material Source	-
LL Water Type	Potable	Material Type	-
LL Device Type	Cassagrande	Prep Mat > 53mm (%)	-
Material Description	Sandy Clay		

Atterberg Limit	Specification Minimum	Test Result	Specification Maximum
Liquid Limit (%)		**26**	
Plastic Limit (%)		**17**	
Plasticity Index (%)		**9**	
Linear Shrinkage (%)		**6.5**	
Linear Shrinkage Mould Length / Defects:	Mould Length: 250.1mm / -		

Remarks	Results apply to the sample/s as received.,

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Accreditation Number: 1986
Corporate Site Number: 3740

Approved Signatory: Thomas Hewitt
Form ID: W11bRep Rev 2

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ATTERBERG LIMITS REPORT

Client:	Construction Sciences Pty Ltd - Cairns	Report Number:	3740/R/56776-1
Client Address:	Shed 3, 5 Commercial Place, Earlville	Project Number:	3740/P/2508
Project:	EQ Resources Ltd - EQ Resources - Supplied Samples	Lot Number:	
Location:	Supplied Sample	Internal Test Request:	3740/T/42488
Supplied To:	n/a	Client Reference/s:	11512/CC/782
Area Description:		Report Date / Page:	31/10/2022 Page 5 of 7

Test Procedures:	AS1289.3.1.2, AS 1289.3.3.1, AS1289.3.2.1, AS1289.3.4.1, AS1289.2.1.1		
Sample Number	3740/S/227395	Sample Location	
Sampling Method	Tested As Received	Location1	TP02
Date Sampled	11/08/2022	Location2	2.2 - 3.0
Sampled By	Client Sampled	Location3	
Date Tested	27/10/2022	Location4	
Drying / Prep Method	Oven Dried / Dry Sieved	Material Source	-
LL Water Type	Potable	Material Type	-
LL Device Type	Cassagrande	Prep Mat > 53mm (%)	-
Material Description	Sandy Clay		

Atterberg Limit	Specification Minimum	Test Result	Specification Maximum
Liquid Limit (%)		**34**	
Plastic Limit (%)		**17**	
Plasticity Index (%)		**17**	
Linear Shrinkage (%)		**10.0**	
Linear Shrinkage Mould Length / Defects:	Mould Length: 250.2mm / -		

Remarks	Results apply to the sample/s as received.,

Accredited for compliance with ISO/IEC 17025 – Testing

NATA

Accreditation Number: 1986
Corporate Site Number: 3740

Approved Signatory: Thomas Hewitt
Form ID: W11bRep Rev 2

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ATTERBERG LIMITS REPORT

Client:	Construction Sciences Pty Ltd - Cairns	Report Number:	3740/R/56776-1
Client Address:	Shed 3, 5 Commercial Place, Earlville	Project Number:	3740/P/2508
Project:	EQ Resources Ltd - EQ Resources - Supplied Samples	Lot Number:	
Location:	Supplied Sample	Internal Test Request:	3740/T/42488
Supplied To:	n/a	Client Reference/s:	11512/CC/782
Area Description:		Report Date / Page:	31/10/2022 Page 6 of 7

Test Procedures:	AS1289.3.1.2, AS 1289.3.3.1, AS1289.3.2.1, AS1289.3.4.1, AS1289.2.1.1		
Sample Number	3740/S/227396	Sample Location	
Sampling Method	Tested As Received	Location1	TP06
Date Sampled	11/08/2022	Location2	1.9 - 2.2
Sampled By	Client Sampled	Location3	
Date Tested	27/10/2022	Location4	
Drying / Prep Method	Oven Dried / Dry Sieved	Material Source	-
LL Water Type	Potable	Material Type	-
LL Device Type	Cassagrande	Prep Mat > 53mm (%)	-
Material Description	Gravelly Sandy Clay		

Atterberg Limit	Specification Minimum	Test Result	Specification Maximum
Liquid Limit (%)		**31**	
Plastic Limit (%)		**17**	
Plasticity Index (%)		**14**	
Linear Shrinkage (%)		**8.5**	
Linear Shrinkage Mould Length / Defects:	Mould Length: 250.1mm / -		

Remarks	Results apply to the sample/s as received.,

Accredited for compliance with ISO/IEC 17025 – Testing

NATA

Accreditation Number: 1986
Corporate Site Number: 3740

Approved Signatory: Thomas Hewitt
Form ID: W11bRep Rev 2

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ATTERBERG LIMITS REPORT

Client:	Construction Sciences Pty Ltd - Cairns	Report Number:	3740/R/56776-1
Client Address:	Shed 3, 5 Commercial Place, Earlville	Project Number:	3740/P/2508
Project:	EQ Resources Ltd - EQ Resources - Supplied Samples	Lot Number:	
Location:	Supplied Sample	Internal Test Request:	3740/T/42488
Supplied To:	n/a	Client Reference/s:	11512/CC/782
Area Description:		Report Date / Page:	31/10/2022 Page 7 of 7

Test Procedures:	AS1289.3.1.2, AS 1289.3.3.1, AS1289.3.2.1, AS1289.3.4.1, AS1289.2.1.1		
Sample Number	3740/S/227397	Sample Location	
Sampling Method	Tested As Received	Location1	TP09
Date Sampled	11/08/2022	Location2	0 - 1.0
Sampled By	Client Sampled	Location3	
Date Tested	27/10/2022	Location4	
Drying / Prep Method	Oven Dried / Dry Sieved	Material Source	-
LL Water Type	Potable	Material Type	-
LL Device Type	Cassagrande	Prep Mat > 53mm (%)	-
Material Description	Sandy Clay		

Atterberg Limit	Specification Minimum	Test Result	Specification Maximum
Liquid Limit (%)		**44**	
Plastic Limit (%)		**18**	
Plasticity Index (%)		**26**	
Linear Shrinkage (%)		**13.0**	
Linear Shrinkage Mould Length / Defects:	Mould Length: 250.2mm / -		

Remarks	Results apply to the sample/s as received.,

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Accreditation Number: 1986
Corporate Site Number: 3740

Approved Signatory: Thomas Hewitt
Form ID: W11bRep Rev 2

Construction Sciences

Laboratory: Sunshine Coast Laboratory

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Website:
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Particle Size Distribution-Hydrometer

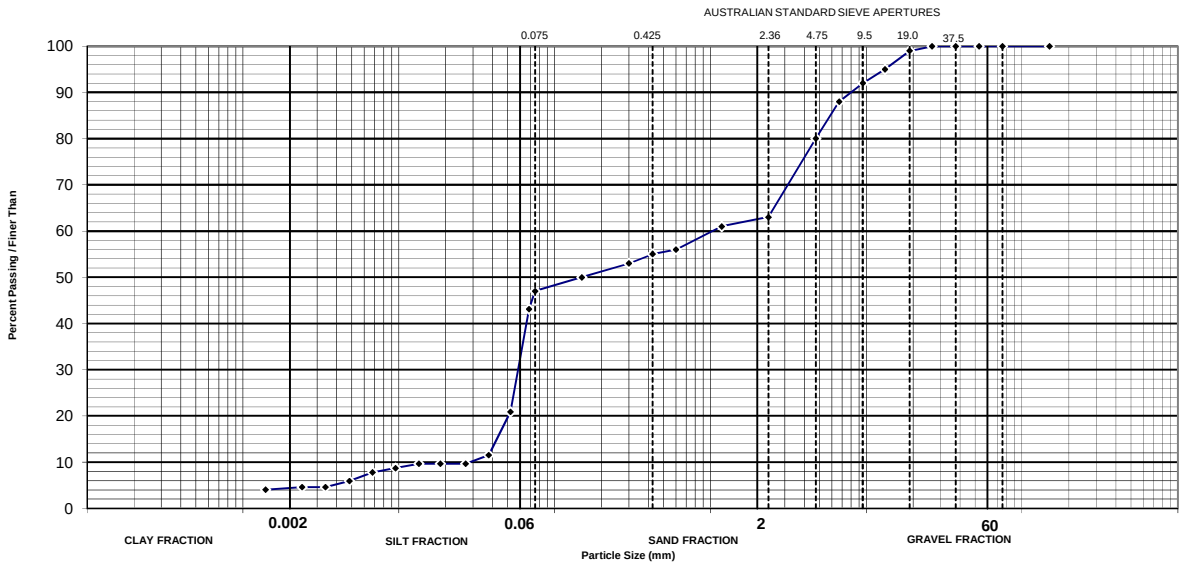
Client:	**Construction Sciences Pty Ltd - Cairns**	Report Number:	**3740/S/227391Hyd**
Clients Address:	**Shed 3, 5 Commercial Place, Earlville QLD 4870**	Project Number:	**3740/P/2508**
Project:	**EQ Resources Ltd - EQ Resources - Supplied Samples**	Lot Number:	**-**
		Internal Test Request:	**3740/T/42488**
Location	**Supplied Sample**	Client Reference:	**11512/S/108919**
Component:	**-**	Purchase Order No:	**11512/CC/782**
Area Description:	**-**	Report Date:	**15/09/2022**
Remarks:	**Some or all of the testing within this report was conducted at our department 25313 located at Kunda Park.**		
Remarks:	**Results apply to the sample as received.**		

Test Procedures: AS1289.3.6.1, AS1289.3.6.3, AS1289.3.5.1

Sample Number:	**3740/S/227391**	Date Tested:	**14/09/2022**	Sample Location:	**Pit Sample**
Sampling Method:	**Tested as Received**	Material Source:	**Supplied Sample**		**Outcrop**
Date Sampled:	**11/08/2022**	Material Type (Spec):	**Insitu**		
Sampled By:		Material Description:	**Gravelly Sandy Clay**		
Pre-treatment Loss:	**n/a**	Hydrometer Type:	**grams/Litre**	Dispersion Method:	**mechanical**

Particle Size (mm)	Cummulative Percent Passing	Particle Size (mm)	Cummulative Percent Passing	Particle Size (mm)	Cummulative Percent Passing
		1.180	61	0.0135	10
		0.600	56	0.0096	9
		0.425	55	0.0068	8
		0.300	53	0.0048	6
26.5	100	0.150	50	0.0034	5
19	99	0.075	47	0.0024	5
13.2	95	0.069	43	0.0014	4
9.5	92	0.052	21		
6.7	88	0.038	12		
4.75	80	0.027	10		
2.36	63	0.018	10		

PARTICLE SIZE DISTRIBUTION - HYDROMETER



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Corporate Site Number: 3740

Form Number

REP HYD-6
11/07/2022

% Finer than 0.02mm:	10
% Finer than 0.005mm:	6

APPROVED SIGNATORY: Paul Mayes

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Particle Size Distribution-Hydrometer

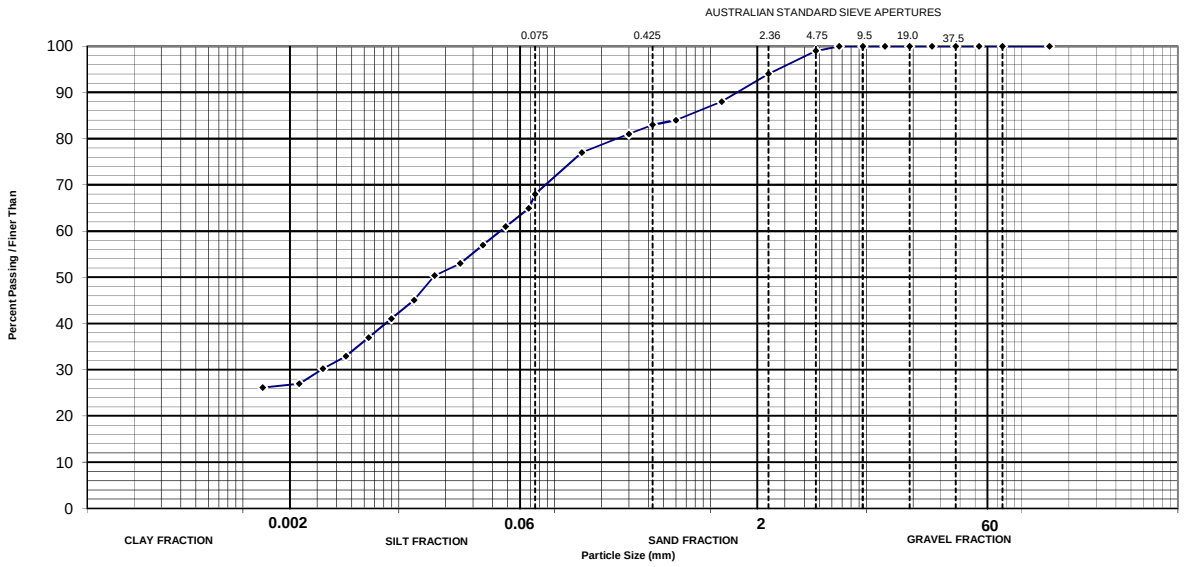
Client:	**Construction Sciences Pty Ltd - Cairns**	Report Number:	**3740/S/227382Hyd**
Clients Address:	**Shed 3, 5 Commercial Place, Earlville QLD 4870**	Project Number:	**3740/P/2508**
Project:	**EQ Resources Ltd - EQ Resources - Supplied Samples**	Lot Number:	**-**
		Internal Test Request:	**3740/T/42488**
Location	**Supplied Sample**	Client Reference:	**11512/S/108920**
Component:	**-**	Purchase Order No:	**11512/CC/782**
Area Description:	**-**	Report Date:	**14/09/2022**
Remarks:	**Some or all of the testing within this report was conducted at our department 25313 located at Kunda Park.**		
Remarks:	**Results apply to the sample as received.**		

Test Procedures: AS1289.3.6.1, AS1289.3.6.3, AS1289.3.5.1

Sample Number:	**3740/S/227382**	Date Tested:	**13/09/2022**	Sample Location:	**TP01**
Sampling Method:	**Tested as Received**	Material Source:	**Supplied Sample**		**2.1 - 2.5**
Date Sampled:	**11/08/2022**	Material Type (Spec):	**Insitu**		
Sampled By:		Material Description:	**Sandy Clay**		
Pre-treatment Loss:	**n/a**	Hydrometer Type:	**grams/Litre**	Dispersion Method:	**mechanical**

Particle Size (mm)	Cummulative Percent Passing	Particle Size (mm)	Cummulative Percent Passing	Particle Size (mm)	Cummulative Percent Passing
		1.180	88	0.0126	45
		0.600	84	0.0090	41
		0.425	83	0.0064	37
		0.300	81	0.0046	33
		0.150	77	0.0033	30
		0.075	68	0.0023	27
		0.068	65	0.0013	26
		0.049	61		
6.7	100	0.035	57		
4.75	99	0.025	53		
2.36	94	0.017	50		

PARTICLE SIZE DISTRIBUTION - HYDROMETER



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Form Number

REP HYD-6
11/07/2022

% Finer than 0.02mm:	52
% Finer than 0.005mm:	34

APPROVED SIGNATORY: Paul Mayes

Laboratory: Sunshine Coast Laboratory

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Particle Size Distribution-Hydrometer

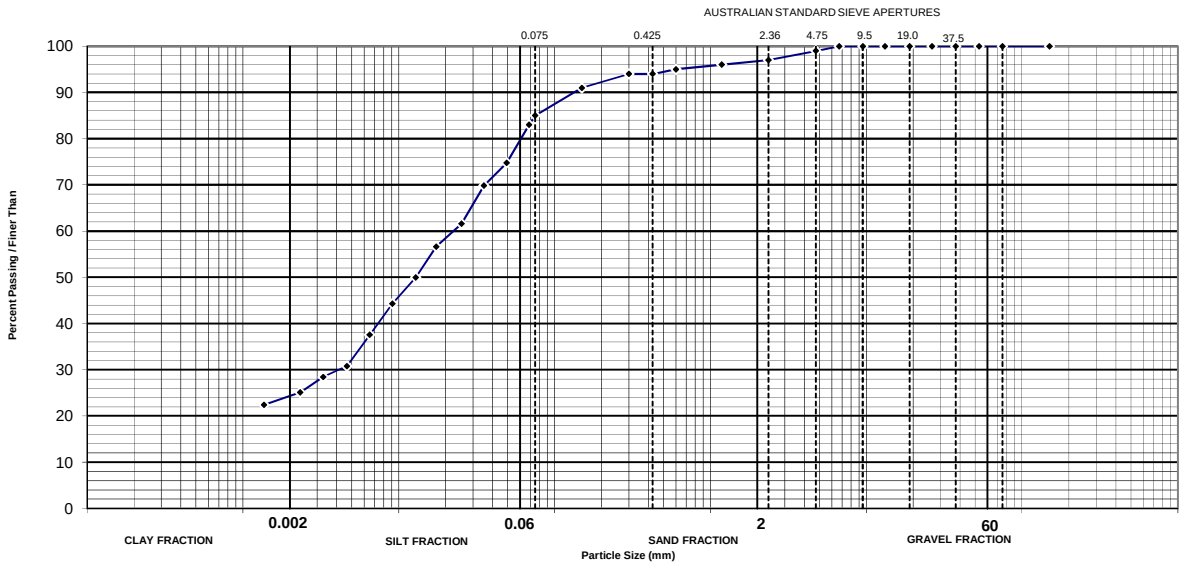
Client:	**Construction Sciences Pty Ltd - Cairns**	Report Number:	**3740/S/227393Hyd**
Clients Address:	**Shed 3, 5 Commercial Place, Earlville QLD 4870**	Project Number:	**3740/P/2508**
Project:	**EQ Resources Ltd - EQ Resources - Supplied Samples**	Lot Number:	**-**
		Internal Test Request:	**3740/T/42488**
Location	**Supplied Sample**	Client Reference:	**11512/S/108921**
Component:	**-**	Purchase Order No:	**11512/CC/782**
Area Description:	**-**	Report Date:	**14/09/2022**
Remarks:	**Some or all of the testing within this report was conducted at our department 25313 located at Kunda Park.**		
Remarks:	**Results apply to the sample as received.**		

Test Procedures: AS1289.3.6.1, AS1289.3.6.3, AS1289.3.5.1

Sample Number:	**3740/S/227393**	Date Tested:	**13/09/2022**	Sample Location:	**TP02**
Sampling Method:	**Tested as Received**	Material Source:	**Supplied Sample**		**0.3 - 1.0**
Date Sampled:	**11/08/2022**	Material Type (Spec):	**Insitu**		
Sampled By:		Material Description:	**Sandy Clay**		
Pre-treatment Loss:	**n/a**	Hydrometer Type:	**grams/Litre**	Dispersion Method:	**mechanical**

Particle Size (mm)	Cummulative Percent Passing	Particle Size (mm)	Cummulative Percent Passing	Particle Size (mm)	Cummulative Percent Passing
		1.180	96	0.0129	50
		0.600	95	0.0091	44
		0.425	94	0.0065	38
		0.300	94	0.0047	31
		0.150	91	0.0033	28
		0.075	85	0.0023	25
		0.069	83	0.0014	22
		0.049	75		
6.7	100	0.035	70		
4.75	99	0.025	62		
2.36	97	0.017	57		

PARTICLE SIZE DISTRIBUTION - HYDROMETER



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Corporate Site Number: 3740

Form Number

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11/07/2022

% Finer than 0.02mm:	58
% Finer than 0.005mm:	32

APPROVED SIGNATORY: Paul Mayes

Construction Sciences

Laboratory: Sunshine Coast Laboratory

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Website:
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Particle Size Distribution-Hydrometer

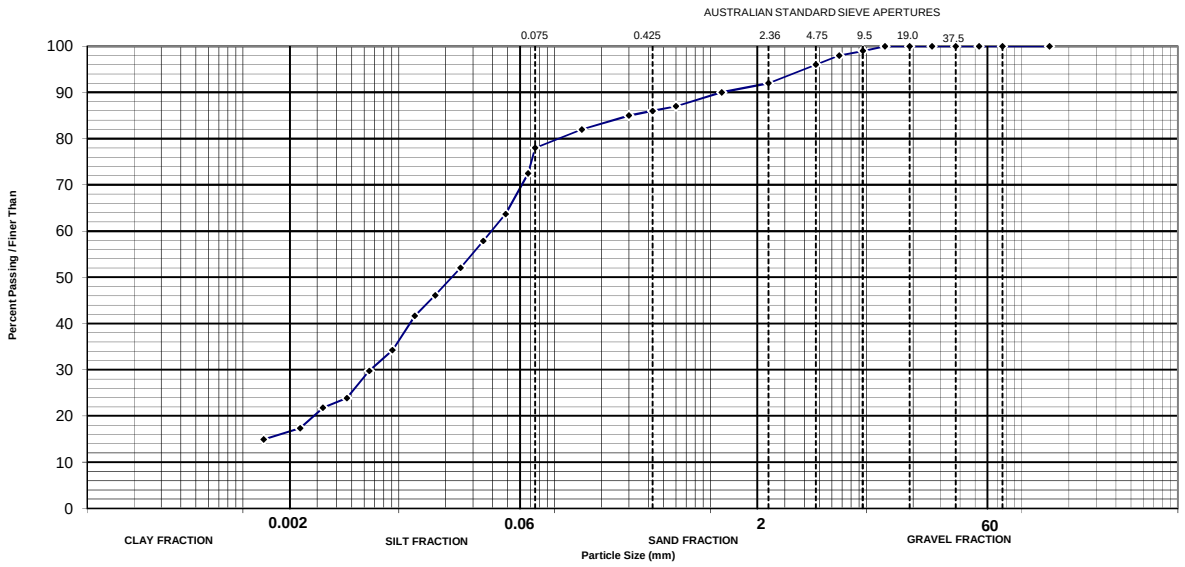
Client:	**Construction Sciences Pty Ltd - Cairns**	Report Number:	**3740/S/227394Hyd**
Clients Address:	**Shed 3, 5 Commercial Place, Earlville QLD 4870**	Project Number:	**3740/P/2508**
Project:	**EQ Resources Ltd - EQ Resources - Supplied Samples**	Lot Number:	**-**
		Internal Test Request:	**3740/T/42488**
Location	**Supplied Sample**	Client Reference:	**11512/S/108922**
Component:	**-**	Purchase Order No:	**11512/CC/782**
Area Description:	**-**	Report Date:	**15/09/2022**
Remarks:	**Some or all of the testing within this report was conducted at our department 25313 located at Kunda Park.**		
Remarks:	**Results apply to the sample as received.**		

Test Procedures: AS1289.3.6.1, AS1289.3.6.3, AS1289.3.5.1

Sample Number:	**3740/S/227394**	Date Tested:	**14/09/2022**	Sample Location:	**TP02**
Sampling Method:	**Tested as Received**	Material Source:	**Supplied Sample**		**1.0 - 2.2**
Date Sampled:	**11/08/2022**	Material Type (Spec):	**Insitu**		
Sampled By:		Material Description:	**Sandy Clay**		
Pre-treatment Loss:	**n/a**	Hydrometer Type:	**grams/Litre**	Dispersion Method:	**mechanical**

Particle Size (mm)	Cummulative Percent Passing	Particle Size (mm)	Cummulative Percent Passing	Particle Size (mm)	Cummulative Percent Passing
		1.180	90	0.0127	42
		0.600	87	0.0091	34
		0.425	86	0.0065	30
		0.300	85	0.0046	24
		0.150	82	0.0033	22
		0.075	78	0.0023	17
13.2	100	0.068	72	0.0014	15
9.5	99	0.049	64		
6.7	98	0.035	58		
4.75	96	0.025	52		
2.36	92	0.017	46		

PARTICLE SIZE DISTRIBUTION - HYDROMETER



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Corporate Site Number: 3740

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11/07/2022

% Finer than 0.02mm:	48
% Finer than 0.005mm:	25

APPROVED SIGNATORY: Paul Mayes

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sunshinecoast@constructionsciences.net

Website:
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Particle Size Distribution-Hydrometer

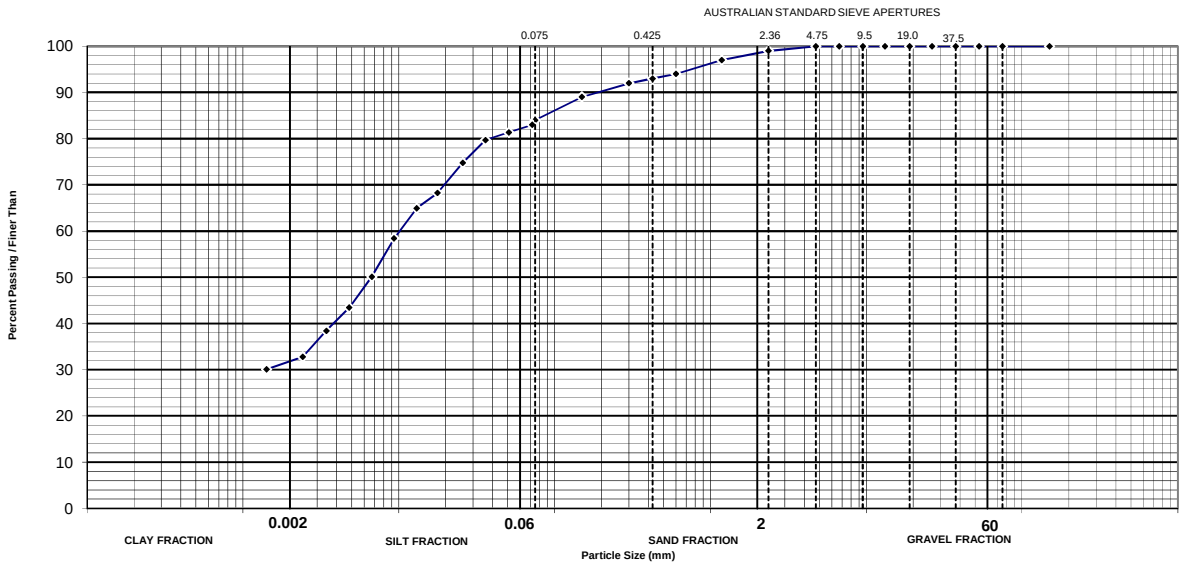
Client:	**Construction Sciences Pty Ltd - Cairns**	Report Number:	**3740/S/227395Hyd**
Clients Address:	**Shed 3, 5 Commercial Place, Earlville QLD 4870**	Project Number:	**3740/P/2508**
Project:	**EQ Resources Ltd - EQ Resources - Supplied Samples**	Lot Number:	**-**
		Internal Test Request:	**3740/T/42488**
Location	**Supplied Sample**	Client Reference:	**11512/S/108923**
Component:	**-**	Purchase Order No:	**11512/CC/782**
Area Description:	**-**	Report Date:	**14/09/2022**
Remarks:	**Some or all of the testing within this report was conducted at our department 25313 located at Kunda Park.**		
Remarks:	**Results apply to the sample as received.**		

Test Procedures: AS1289.3.6.1, AS1289.3.6.3, AS1289.3.5.1

Sample Number:	**3740/S/227395**	Date Tested:	**13/09/2022**	Sample Location:	**TP02**
Sampling Method:	**Tested as Received**	Material Source:	**Supplied Sample**		**2.2 - 3.0**
Date Sampled:	**11/08/2022**	Material Type (Spec):	**Insitu**		
Sampled By:		Material Description:	**Sandy Clay**		
Pre-treatment Loss:	**n/a**	Hydrometer Type:	**grams/Litre**	Dispersion Method:	**mechanical**

Particle Size (mm)	Cummulative Percent Passing	Particle Size (mm)	Cummulative Percent Passing	Particle Size (mm)	Cummulative Percent Passing
		1.180	97	0.0130	65
		0.600	94	0.0093	58
		0.425	93	0.0067	50
		0.300	92	0.0048	43
		0.150	89	0.0034	38
		0.075	84	0.0024	33
		0.072	83	0.0014	30
		0.051	81		
		0.036	80		
4.75	100	0.026	75		
2.36	99	0.018	68		

PARTICLE SIZE DISTRIBUTION - HYDROMETER



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Accreditation No.: 1986
Corporate Site Number: 3740

Form Number

REP HYD-6
11/07/2022

% Finer than 0.02mm:	70
% Finer than 0.005mm:	44

APPROVED SIGNATORY: Paul Mayes

Construction Sciences

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Particle Size Distribution-Hydrometer

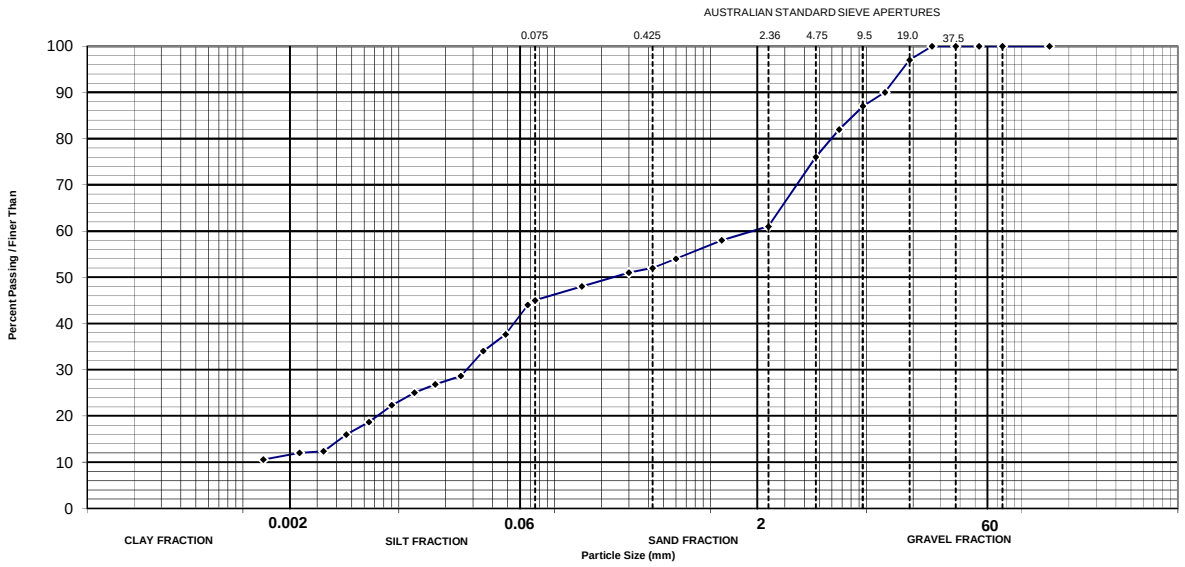
Client:	**Construction Sciences Pty Ltd - Cairns**	Report Number:	**3740/S/227396Hyd**
Clients Address:	**Shed 3, 5 Commercial Place, Earlville QLD 4870**	Project Number:	**3740/P/2508**
Project:	**EQ Resources Ltd - EQ Resources - Supplied Samples**	Lot Number:	**-**
		Internal Test Request:	**3740/T/42488**
Location	**Supplied Sample**	Client Reference:	**11512/S/108924**
Component:	**-**	Purchase Order No:	**11512/CC/782**
Area Description:	**-**	Report Date:	**15/09/2022**
Remarks:	**Some or all of the testing within this report was conducted at our department 25313 located at Kunda Park.**		
Remarks:	**Results apply to the sample as received.**		

Test Procedures: AS1289.3.6.1, AS1289.3.6.3, AS1289.3.5.1

Sample Number:	**3740/S/227396**	Date Tested:	**14/09/2022**	Sample Location:	**TP06**
Sampling Method:	**Tested as Received**	Material Source:	**Supplied Sample**		**1.9 - 2.2**
Date Sampled:	**11/08/2022**	Material Type (Spec):	**Insitu**		
Sampled By:	**Client**	Material Description:	**Gravelly Sandy Clay**		
Pre-treatment Loss:	**n/a**	Hydrometer Type:	**grams/Litre**	Dispersion Method:	**mechanical**

Particle Size (mm)	Cummulative Percent Passing	Particle Size (mm)	Cummulative Percent Passing	Particle Size (mm)	Cummulative Percent Passing
		1.180	58	0.0126	25
		0.600	54	0.0090	22
		0.425	52	0.0064	19
		0.300	51	0.0046	16
26.5	100	0.150	48	0.0033	12
19	97	0.075	45	0.0023	12
13.2	90	0.067	44	0.0014	11
9.5	87	0.049	38		
6.7	82	0.035	34		
4.75	76	0.025	29		
2.36	61	0.017	27		

PARTICLE SIZE DISTRIBUTION - HYDROMETER



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Accreditation No.: 1986
Corporate Site Number: 3740

Form Number

REP HYD-6
11/07/2022

% Finer than 0.02mm:	27
% Finer than 0.005mm:	17

APPROVED SIGNATORY: Paul Mayes

Laboratory: Sunshine Coast Laboratory

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Particle Size Distribution-Hydrometer

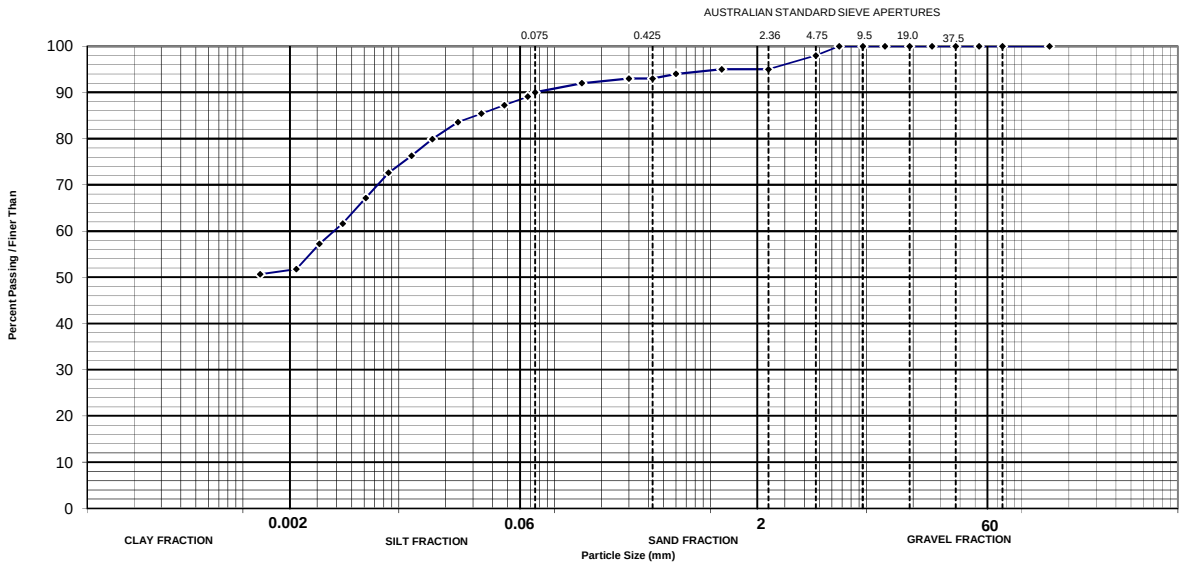
Client:	**Construction Sciences Pty Ltd - Cairns**	Report Number:	**3740/S/227397Hyd**
Clients Address:	**Shed 3, 5 Commercial Place, Earlville QLD 4870**	Project Number:	**3740/P/2508**
Project:	**EQ Resources Ltd - EQ Resources - Supplied Samples**	Lot Number:	**-**
		Internal Test Request:	**3740/T/42488**
Location	**Supplied Sample**	Client Reference:	**11512/S/108925**
Component:	**-**	Purchase Order No:	**11512/CC/782**
Area Description:	**-**	Report Date:	**14/09/2022**
Remarks:	**Some or all of the testing within this report was conducted at our department 25313 located at Kunda Park.**		
Remarks:	**Results apply to the sample as received.**		

Test Procedures: AS1289.3.6.1, AS1289.3.6.3, AS1289.3.5.1

Sample Number:	**3740/S/227397**	Date Tested:	**13/09/2022**	Sample Location:	**TP09**
Sampling Method:	**Tested as Received**	Material Source:	**Supplied Sample**		**0 - 1.0**
Date Sampled:	**11/08/2022**	Material Type (Spec):	**Insitu**		
Sampled By:		Material Description:	**Sandy Clay**		
Pre-treatment Loss:	**n/a**	Hydrometer Type:	**grams/Litre**	Dispersion Method:	**mechanical**

Particle Size (mm)	Cummulative Percent Passing	Particle Size (mm)	Cummulative Percent Passing	Particle Size (mm)	Cummulative Percent Passing
		1.180	95	0.0121	76
		0.600	94	0.0086	73
		0.425	93	0.0061	67
		0.300	93	0.0044	62
		0.150	92	0.0031	57
		0.075	90	0.0022	52
		0.067	89	0.0013	51
		0.048	87		
6.7	100	0.034	85		
4.75	98	0.024	84		
2.36	95	0.016	80		

PARTICLE SIZE DISTRIBUTION - HYDROMETER



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Accreditation No.: 1986
Corporate Site Number: 3740

Form Number

REP HYD-6
11/07/2022

% Finer than 0.02mm:	82
% Finer than 0.005mm:	64

APPROVED SIGNATORY: Paul Mayes

APPENDIX E – BOREHOLE LOGS

TAILINGS.WATER.WASTE.

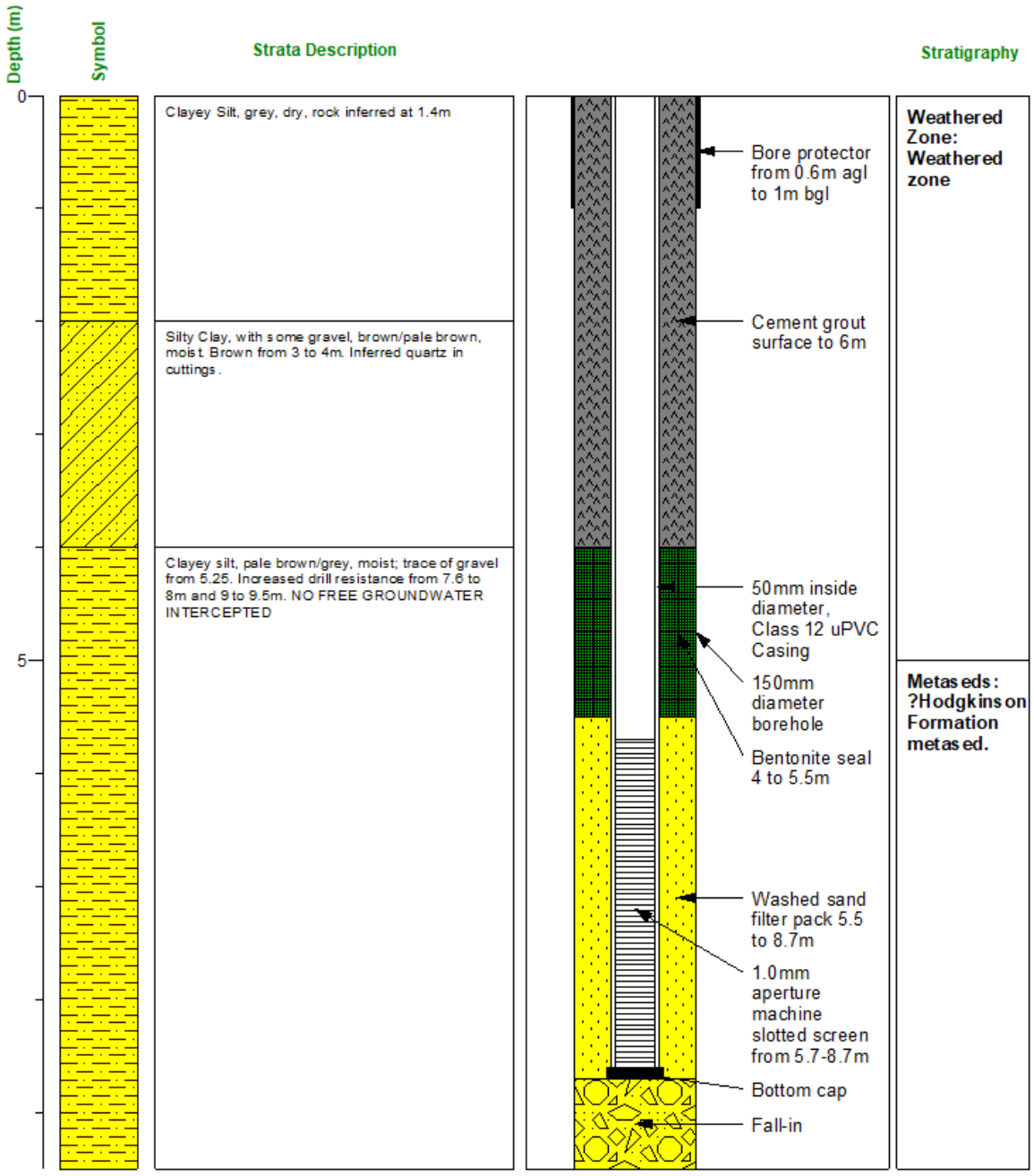
Borehole No: SB02 **Client: EQ Resources**

Location: Mt Carbine **Date Drilled:** 7/12/2021 **Project No:** 222

Easting: 299223 **Northing:** 8171180 **Elevation (m):**

Method: Solid stem auger **Driller:** Geoprobe **Drilling Rig:** Geoprobe 7822DT





Notes:

Datum: AHD/MGA

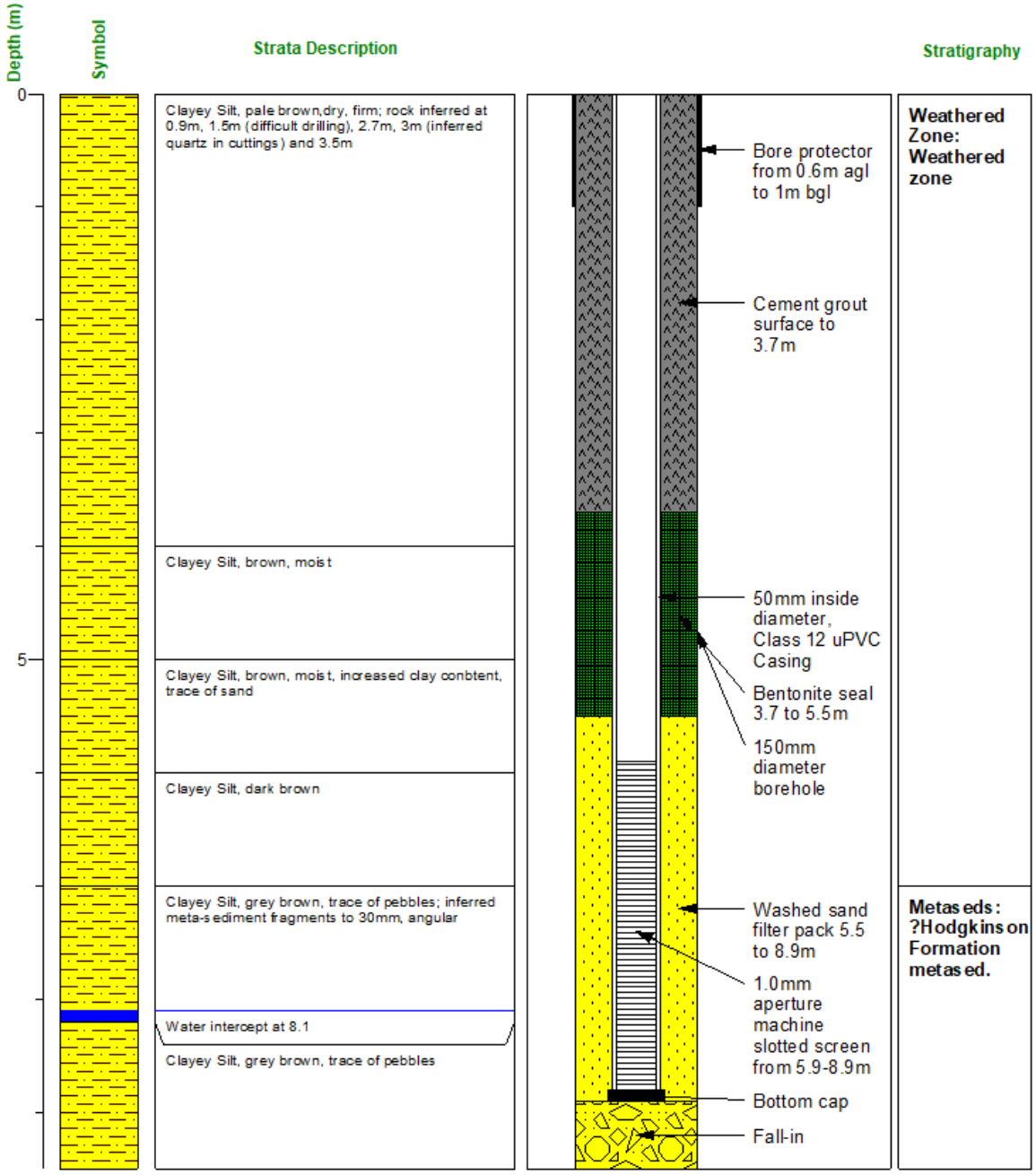
Borehole No: SB03 **Client: EQ Resources**

Location: Mt Carbine **Date Drilled: 7/12/2021** **Project No:** 222

Easting: 299579 **Northing:** 8170803 **Elevation (m):**

Method: Solid stem auger **Driller:** Geoprobe **Drilling Rig:** Geoprobe 7822DT





Notes:

Datum: AHD/MGA

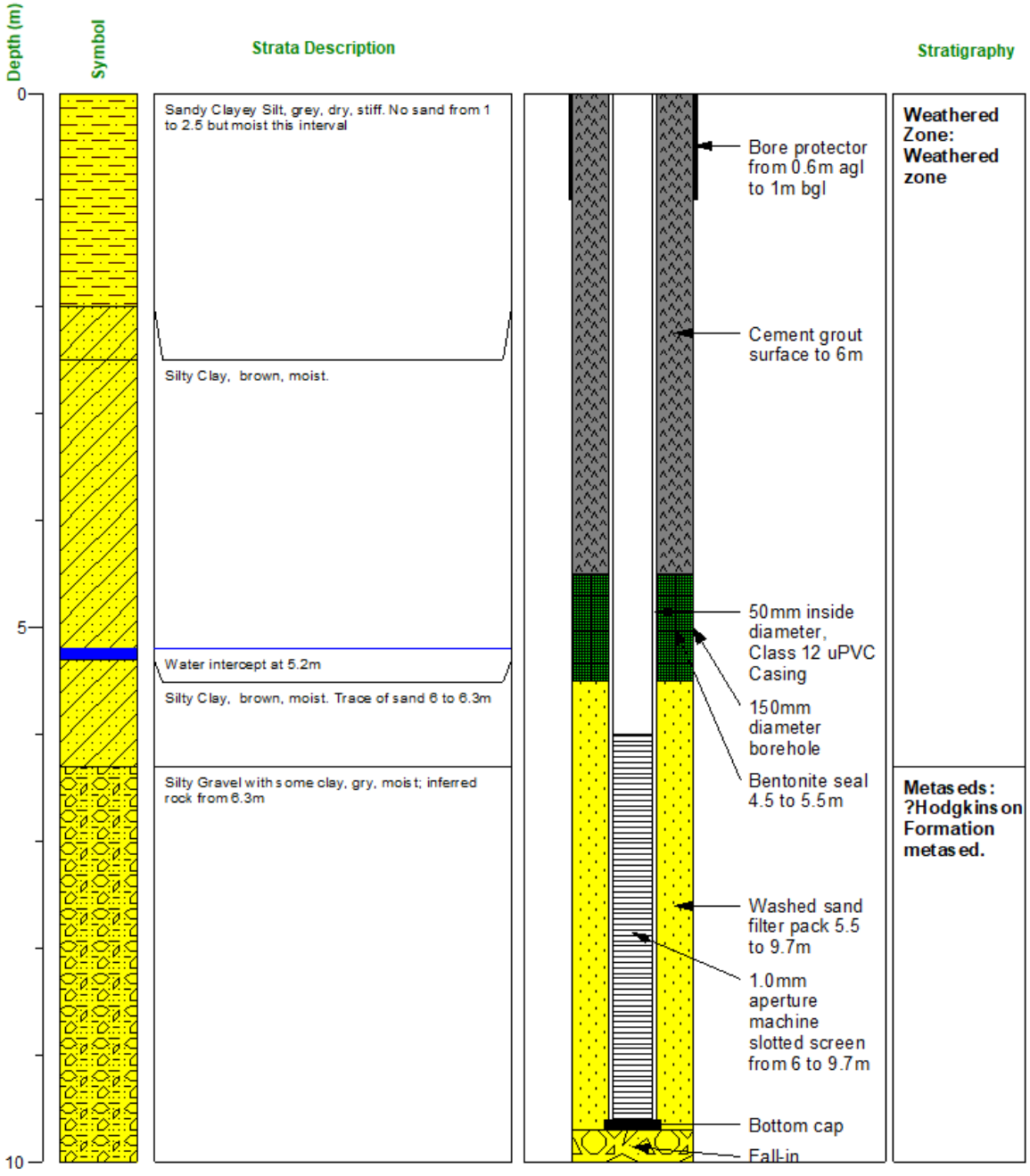
Borehole No: SB04 **Client: EQ Resources**

Location: Mt Carbine **Date Drilled:** 6/12/2021 **Project No:** 222

Easting: 299833 **Northing:** 8170898 **Elevation (m):**

Method: Solid stem auger **Driller:** Geoprobe **Drilling Rig:** Geoprobe 7822DT





Notes:

Datum: AHD/MGA

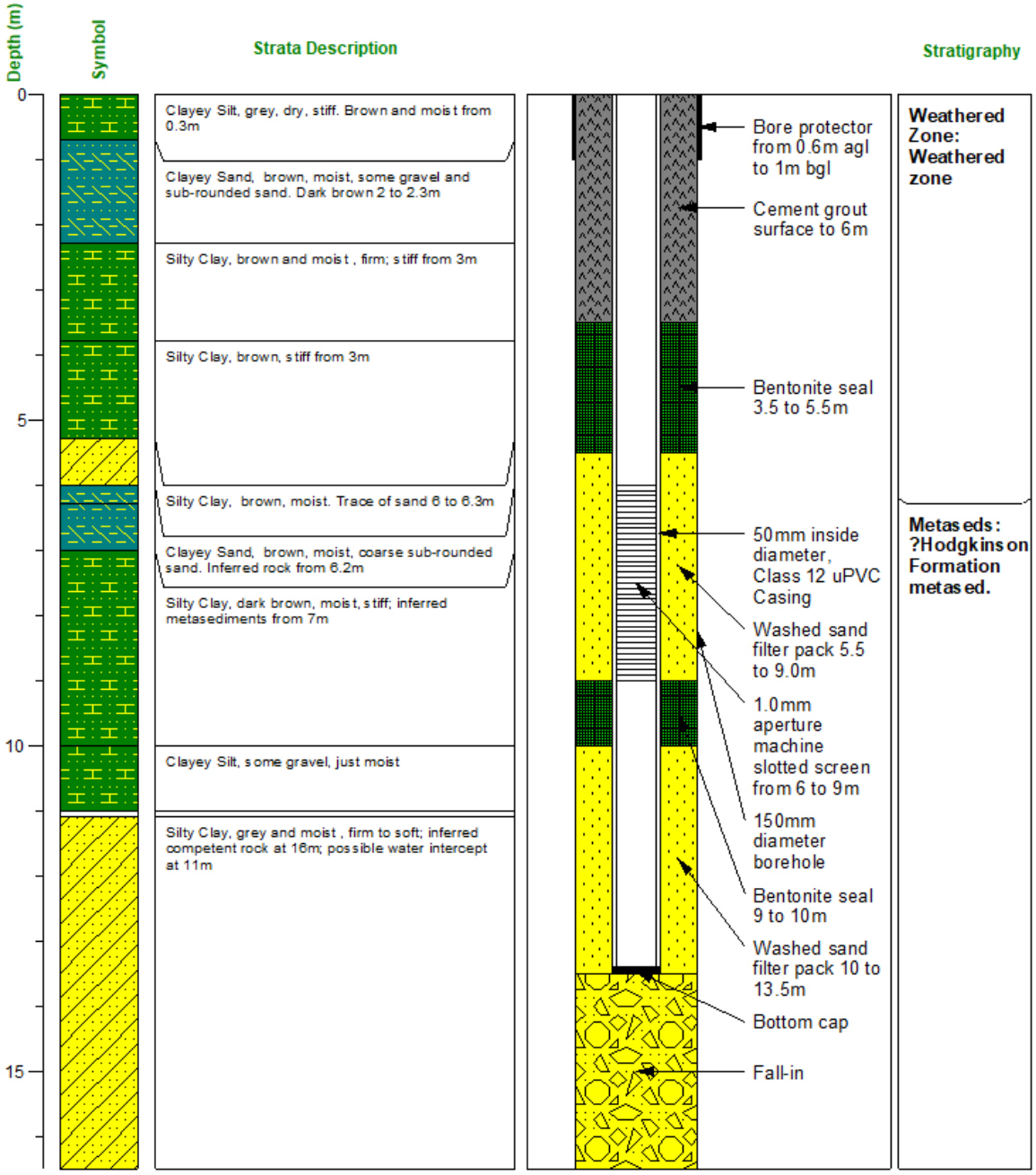
Borehole No: SB05 **Client: EQ Resources**

Location: Mt Carbine **Date Drilled:** 6/12/2021 **Project No:** 222

Easting: 300062 **Northing:** 8171183 **Elevation (m):**

Method: Solid stem auger **Driller:** Geoprobe **Drilling Rig:** Geoprobe 7822DT





Notes:

Datum: AHD/MGA

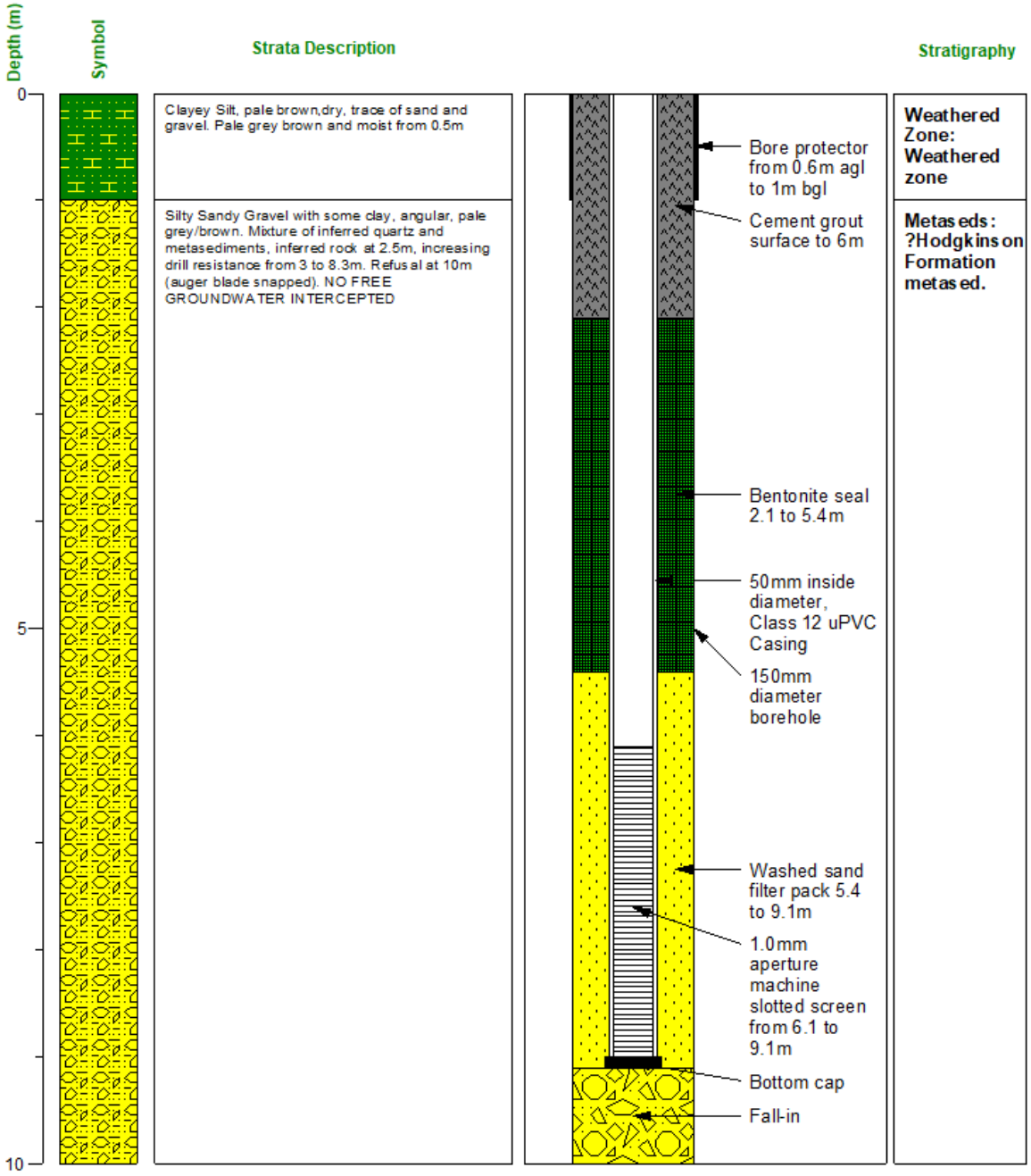
Borehole No: SB07 **Client: EQ Resources**

Location: Mt Carbine **Date Drilled:** 8/12/2021 **Project No:** 222

Easting: 299339 **Northing:** 8172120 **Elevation (m):**

Method: Solid stem auger **Driller:** Geoprobe **Drilling Rig:** Geoprobe 7822DT





Notes:

Datum: AHD/MGA

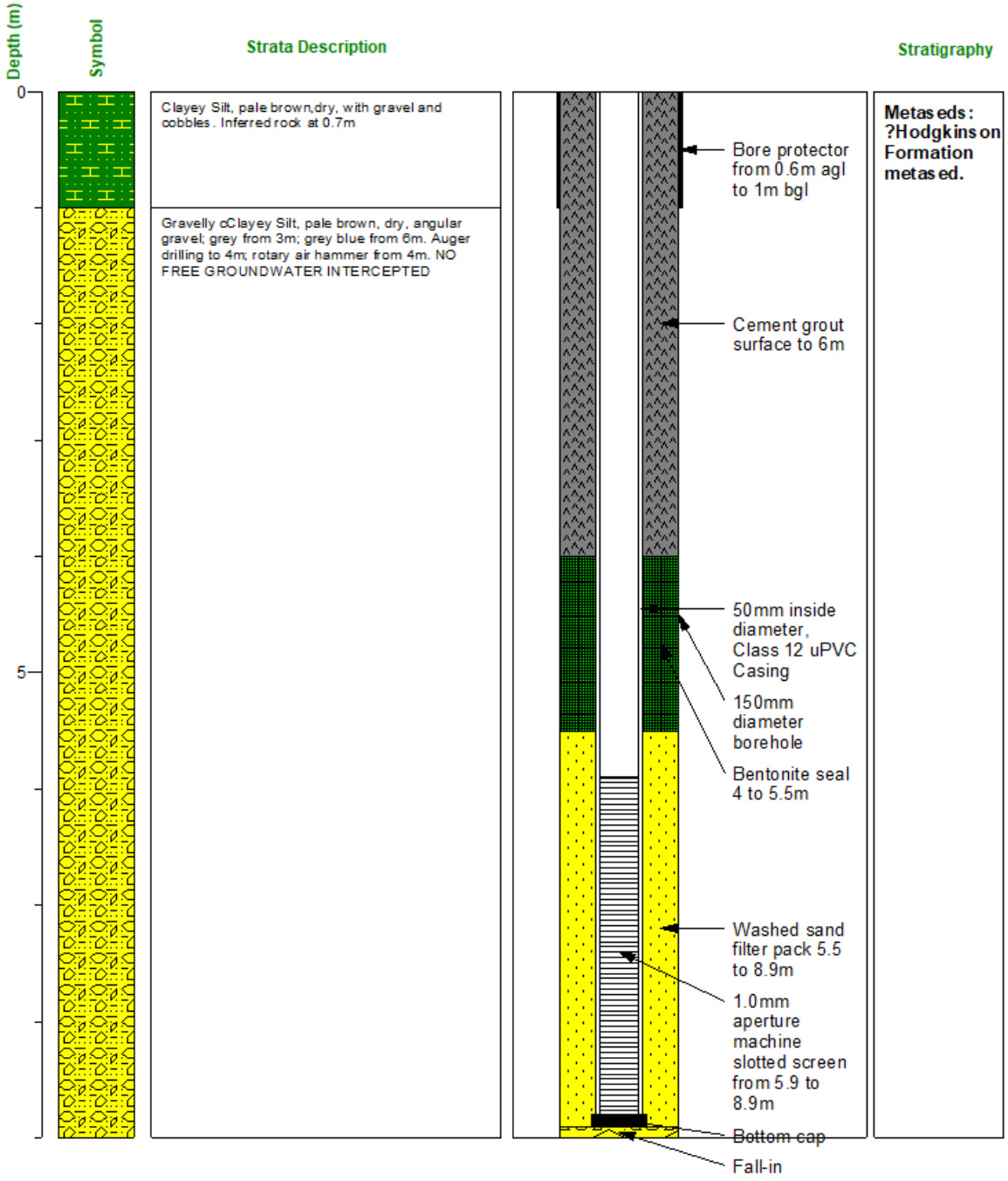
Borehole No: SB08 **Client: EQ Resources**

Location: Mt Carbine **Date Drilled:** 7/12/2021 **Project No:** 222

Easting: 299959 **Northing:** 8171848 **Elevation (m):**

Method: Auger/hammer **Driller:** Geoprobe **Drilling Rig:** Geoprobe 7822DT





Notes:

Datum: AHD/MGA

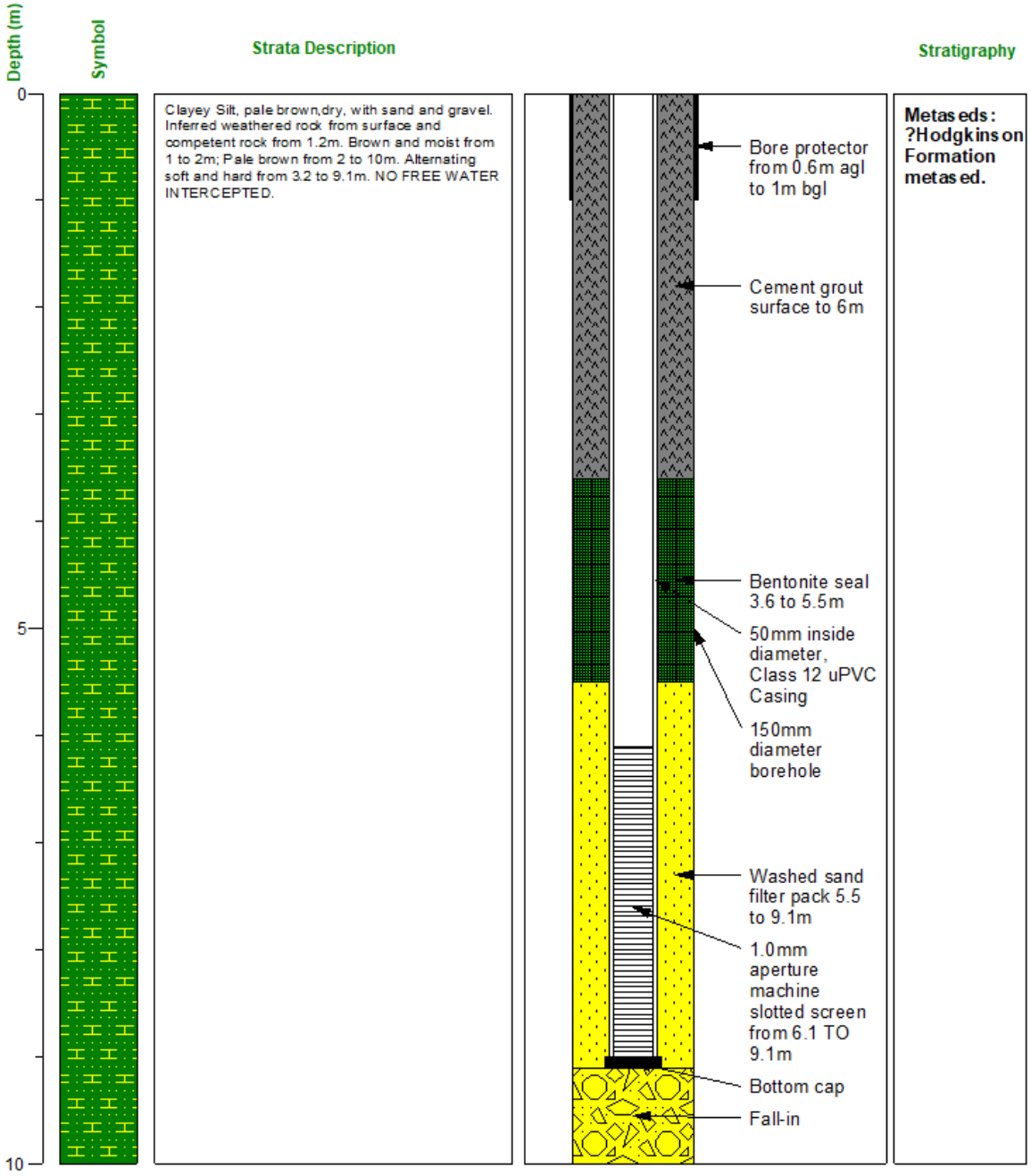
Borehole No: SB09 **Client: EQ Resources**

Location: Mt Carbine **Date Drilled:** 8/12/2021 **Project No:** 222

Easting: 300333 **Northing:** 8171785 **Elevation (m):**

Method: Solid stem auger **Driller:** Geoprobe **Drilling Rig:** Geoprobe 7822DT





Notes:

Datum: AHD/MGA

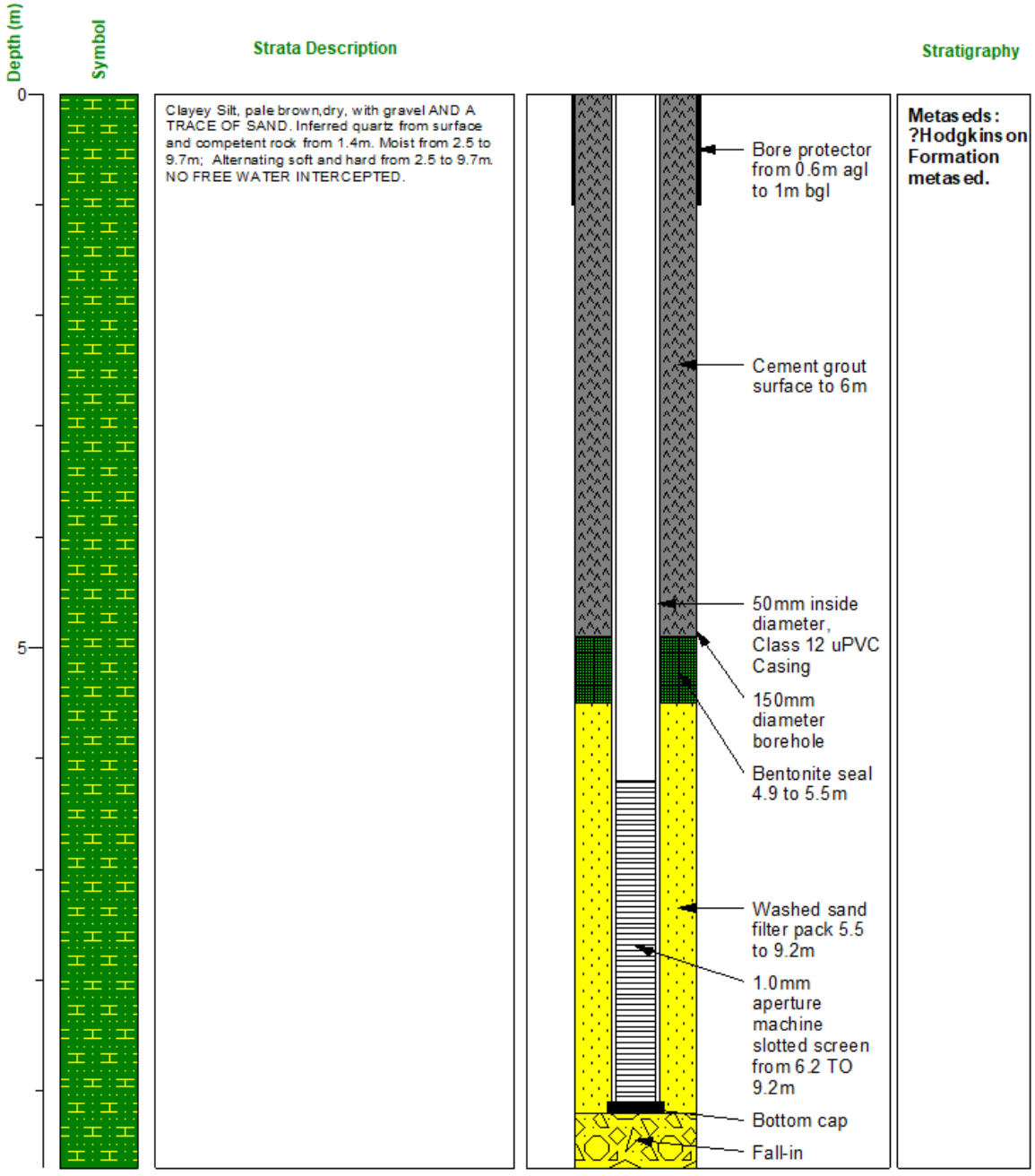
Borehole No: SB10 **Client: EQ Resources**

Location: Mt Carbine **Date Drilled: 7/12/2021** **Project No:** 222

Easting: 299637 **Northing:** 8171923 **Elevation (m):**

Method: Solid stem auger **Driller:** Geoprobe **Drilling Rig:** Geoprobe 7822DT





Page 1 of 1 **Notes:**

Datum: AHD/MGA

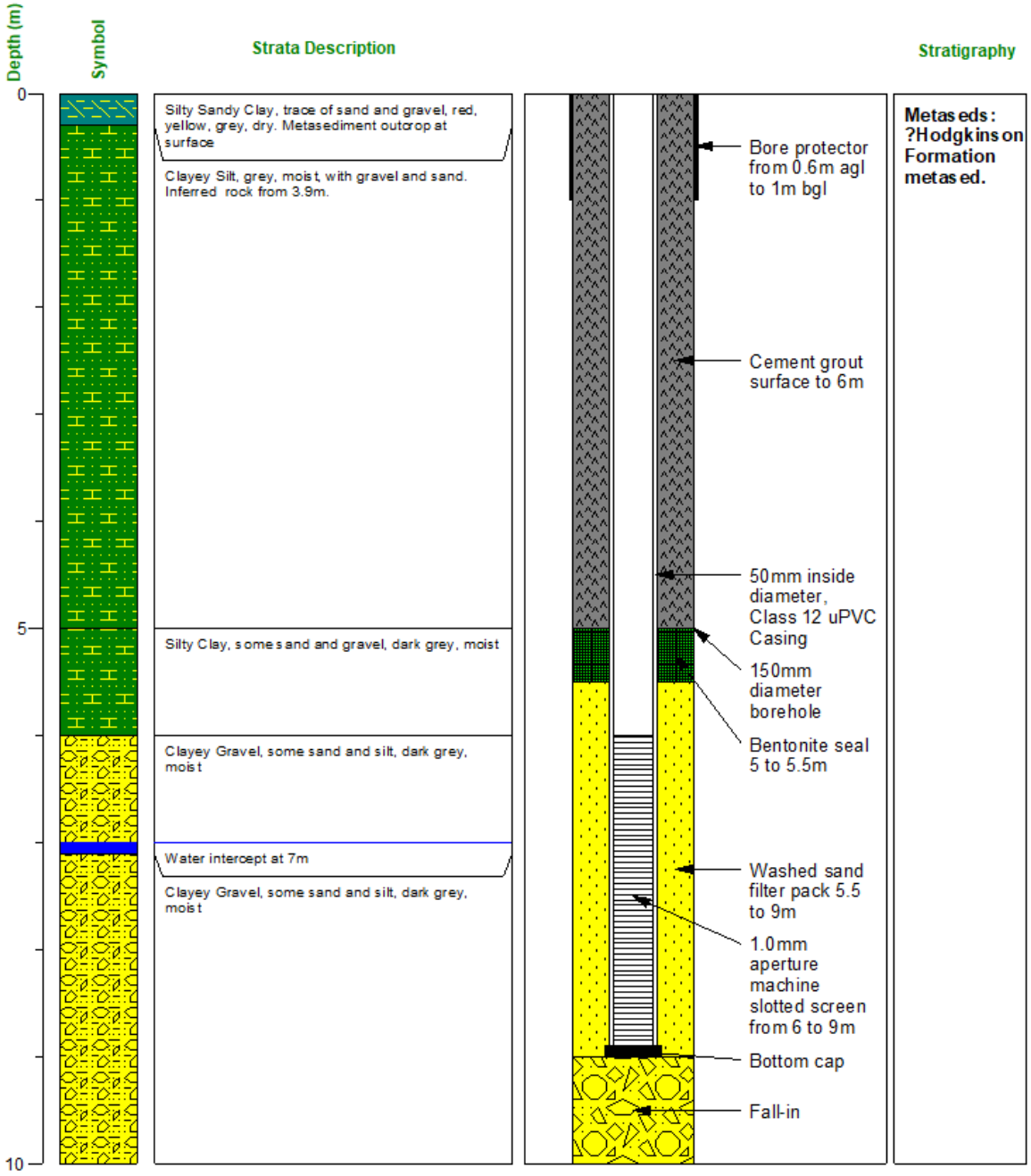
Borehole No: SB11 **Client: EQ Resources**

Location: Mt Carbine **Date Drilled:** 8/12/2021 **Project No:** 222

Easting: 299462 **Northing:** 8173191 **Elevation (m):**

Method: Solid stem auger **Driller:** Geoprobe **Drilling Rig:** Geoprobe 7822DT





Notes:

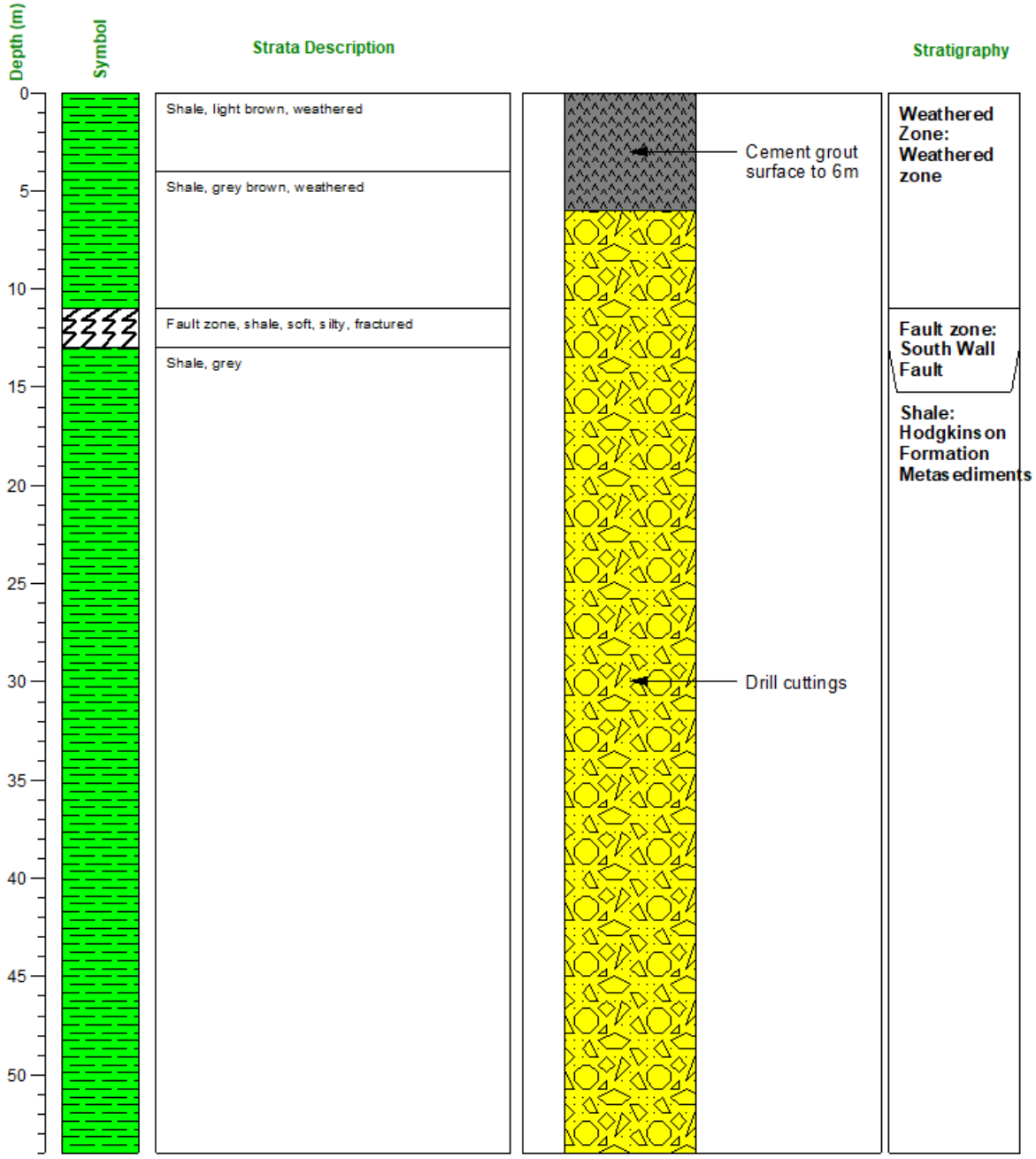
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Borehole No: IB01 test (decomm) **Client: EQ Resources**

Location: Mt Carbine **Date Drilled:** 20/1/2022 **Project No:** 222

Easting: 299455 **Northing:** 8173212 **Elevation (m):**

Method: Rotary **Driller:** M Quinn **Drilling Rig:** Fraste



Notes:

Datum: AHD/MGA

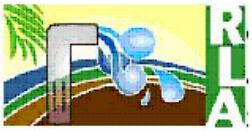
Borehole No: IB01

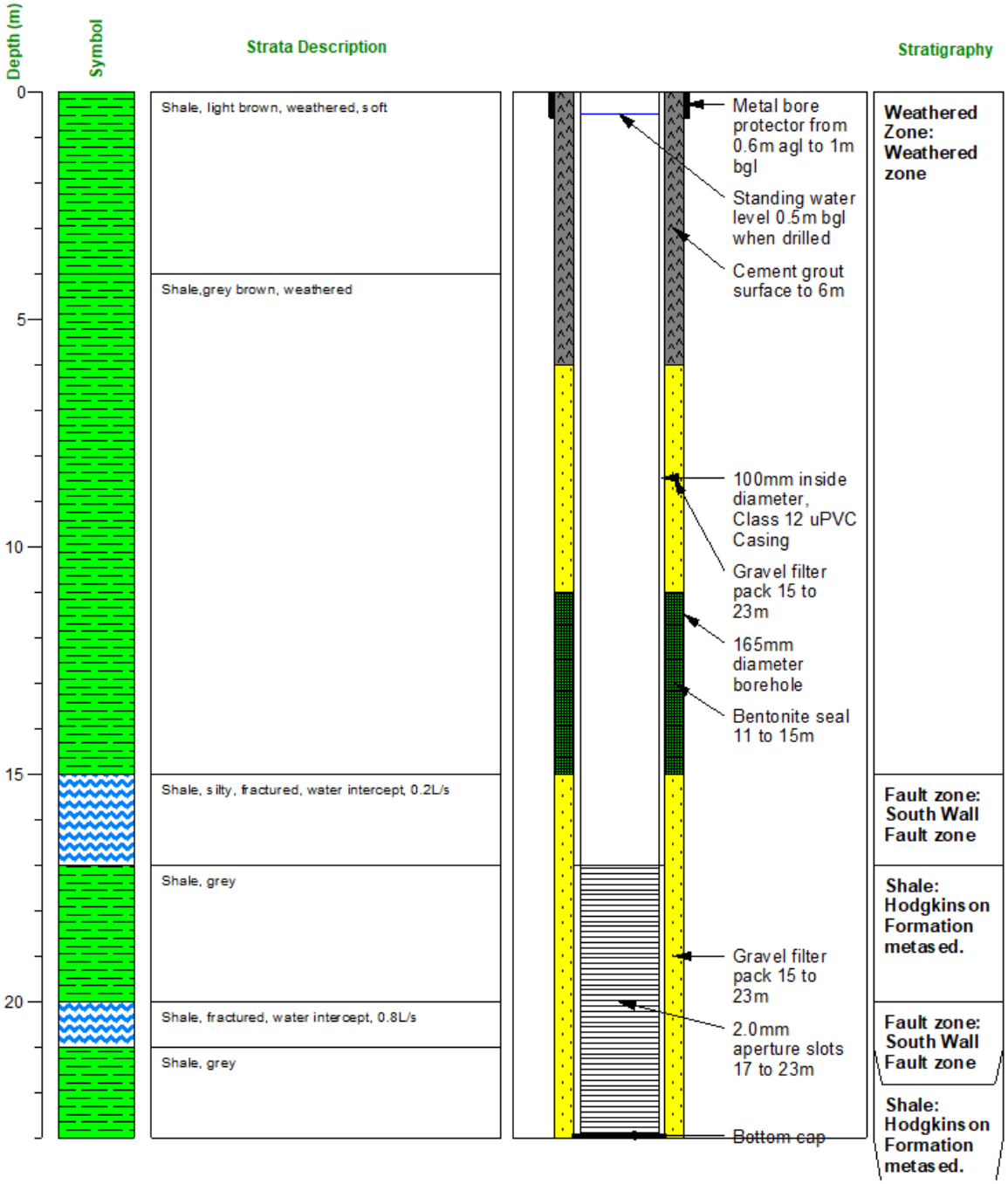
Client: EQ Resources

Location: Mt Carbine **Date Drilled:** 21/1/2022 **Project No:** 222

Easting: 299432 **Northing:** 81173221 **Elevation (m):**

Method: Rotary air **Driller:** M Quinn **Drilling Rig:** Fraste





Notes:

Datum: AHD/MGA

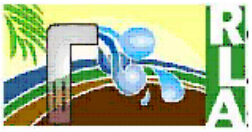
Borehole No: IB02

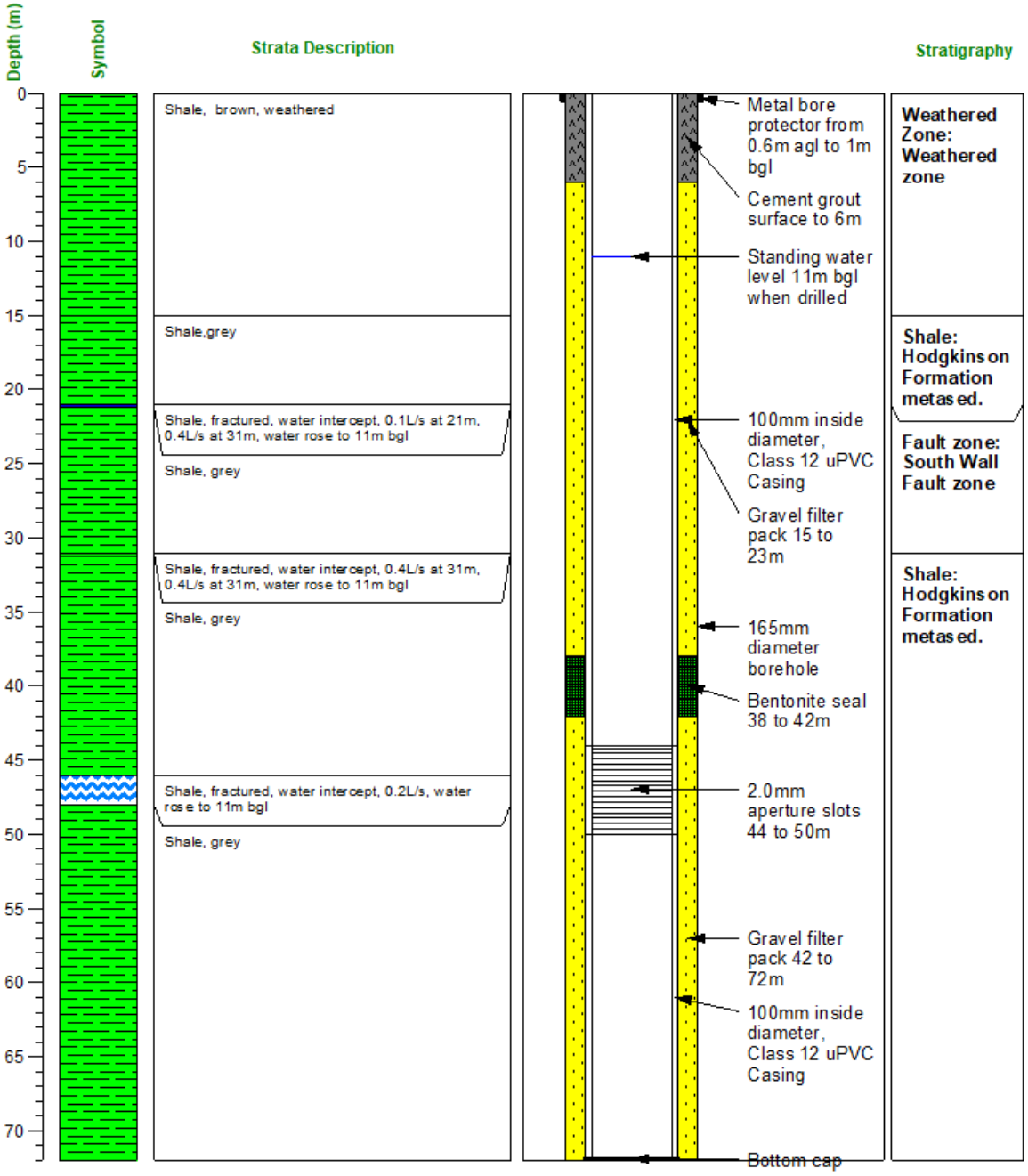
Client: EQ Resources

Location: Mt Carbine **Date Drilled:** 18/1/2022 **Project No:** 222

Easting: 300183 **Northing:** 8172486 **Elevation (m):**

Method: Rotary air **Driller:** M Quinn **Drilling Rig:** Fraste





Notes:

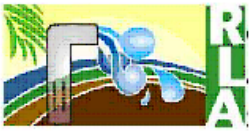
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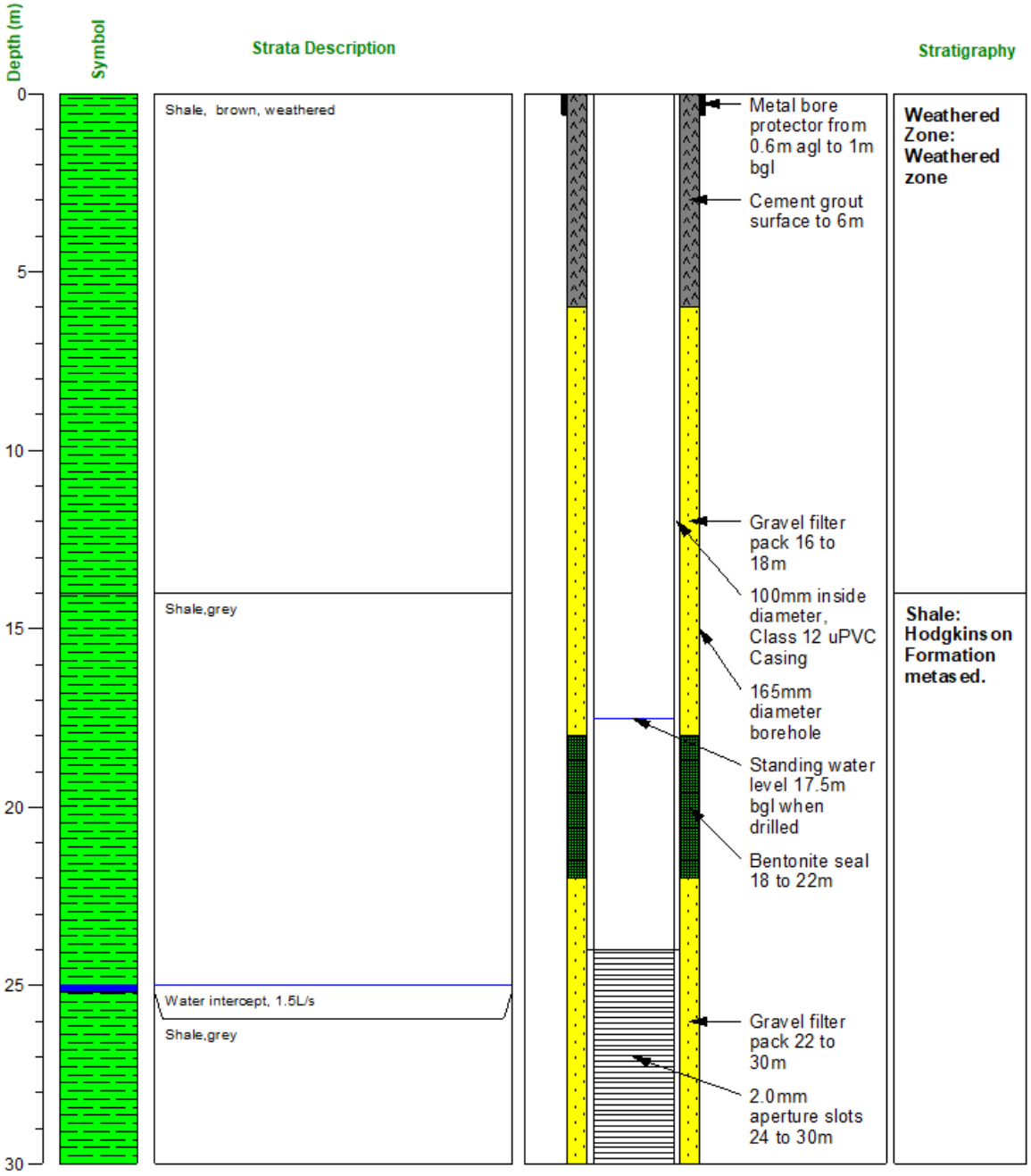
Borehole No: IB03 **Client: EQ Resources**

Location: Mt Carbine **Date Drilled:** 20/1/2022 **Project No:** 222

Easting: 300570 **Northing:** 8171746 **Elevation (m):**

Method: Rotary air **Driller:** M Quinn **Drilling Rig:** Fraste





Notes:

Datum: AHD/MGA

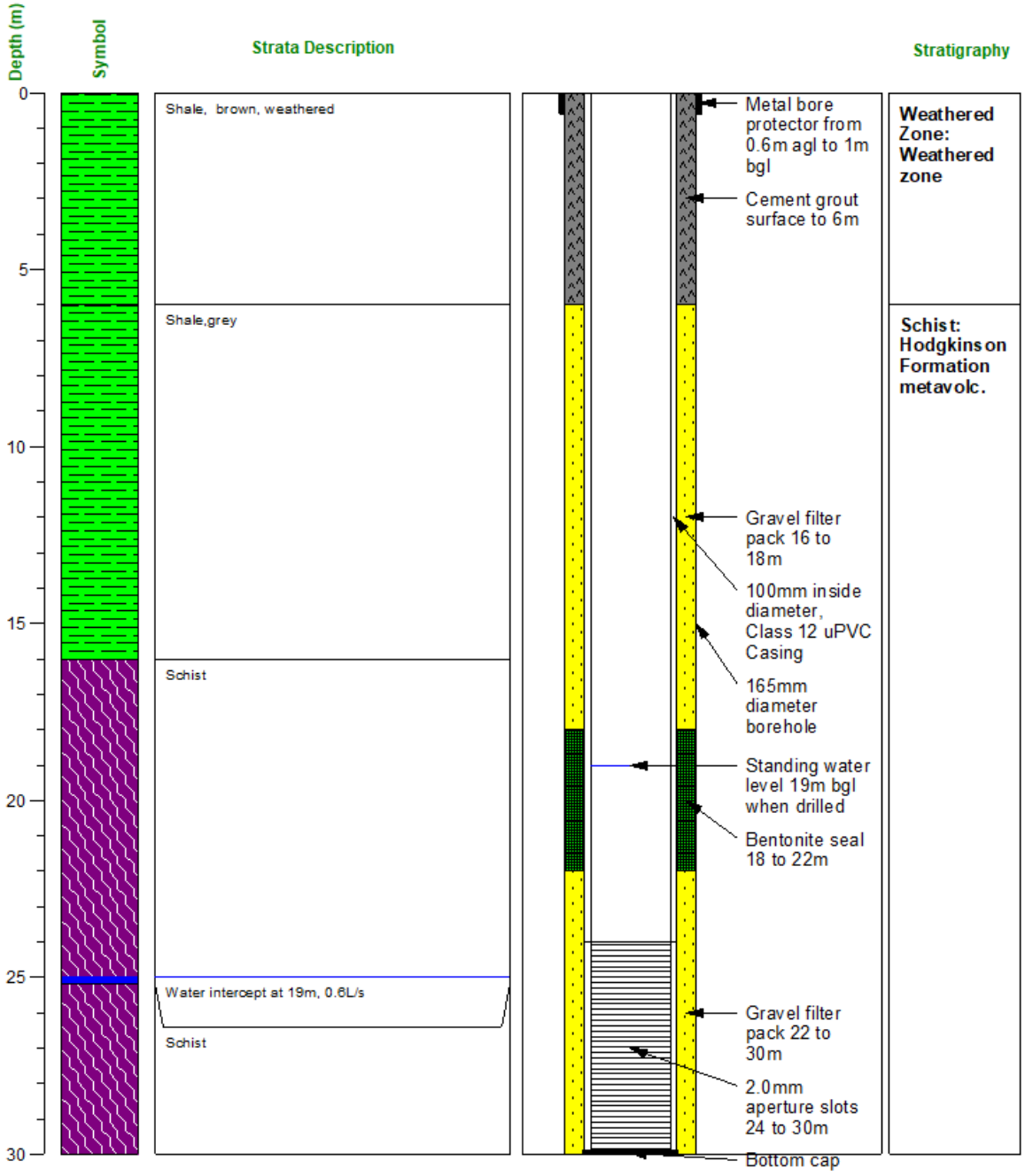
Borehole No: IB04

Client: EQ Resources

Location: Mt Carbine **Date Drilled:** 18/1/2022 **Project No:** 222

Easting: 301032 **Northing:** 8172126 **Elevation (m):**

Method: Rotary air **Driller:** M Quinn **Drilling Rig:** Fraste



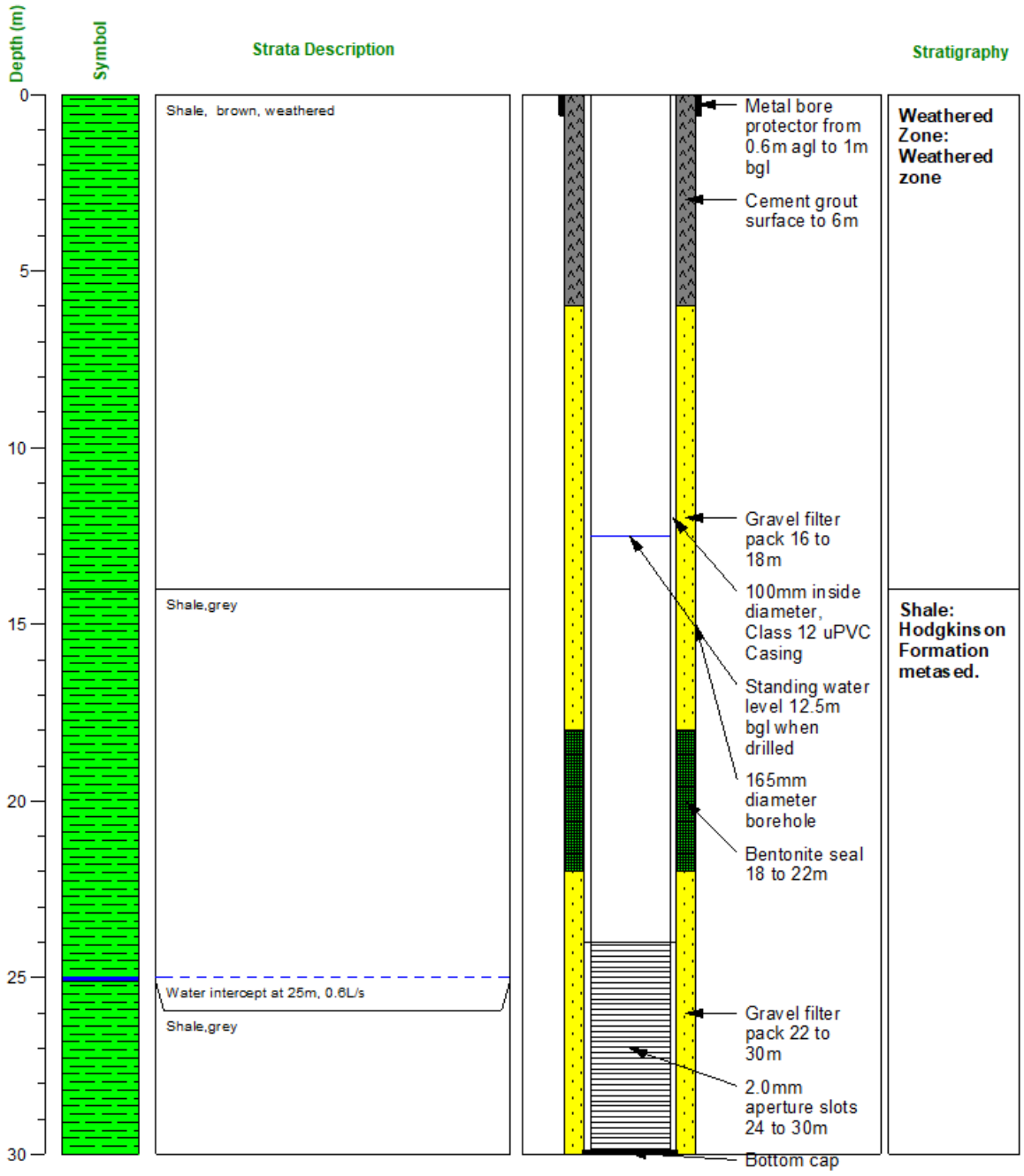
Notes:

Datum: AHD/MGA

Borehole No: IB05

Client: EQ Resources

Location:	Mt Carbine	**Date Drilled:**	19/1/2022	**Project No:**	222
Easting:	299917	**Northing:**	8171749	**Elevation (m):**	
Method:	Rotary air	**Driller:**	M Quinn	**Drilling Rig:**	Fraste



Notes:

Datum: AHD/MGA

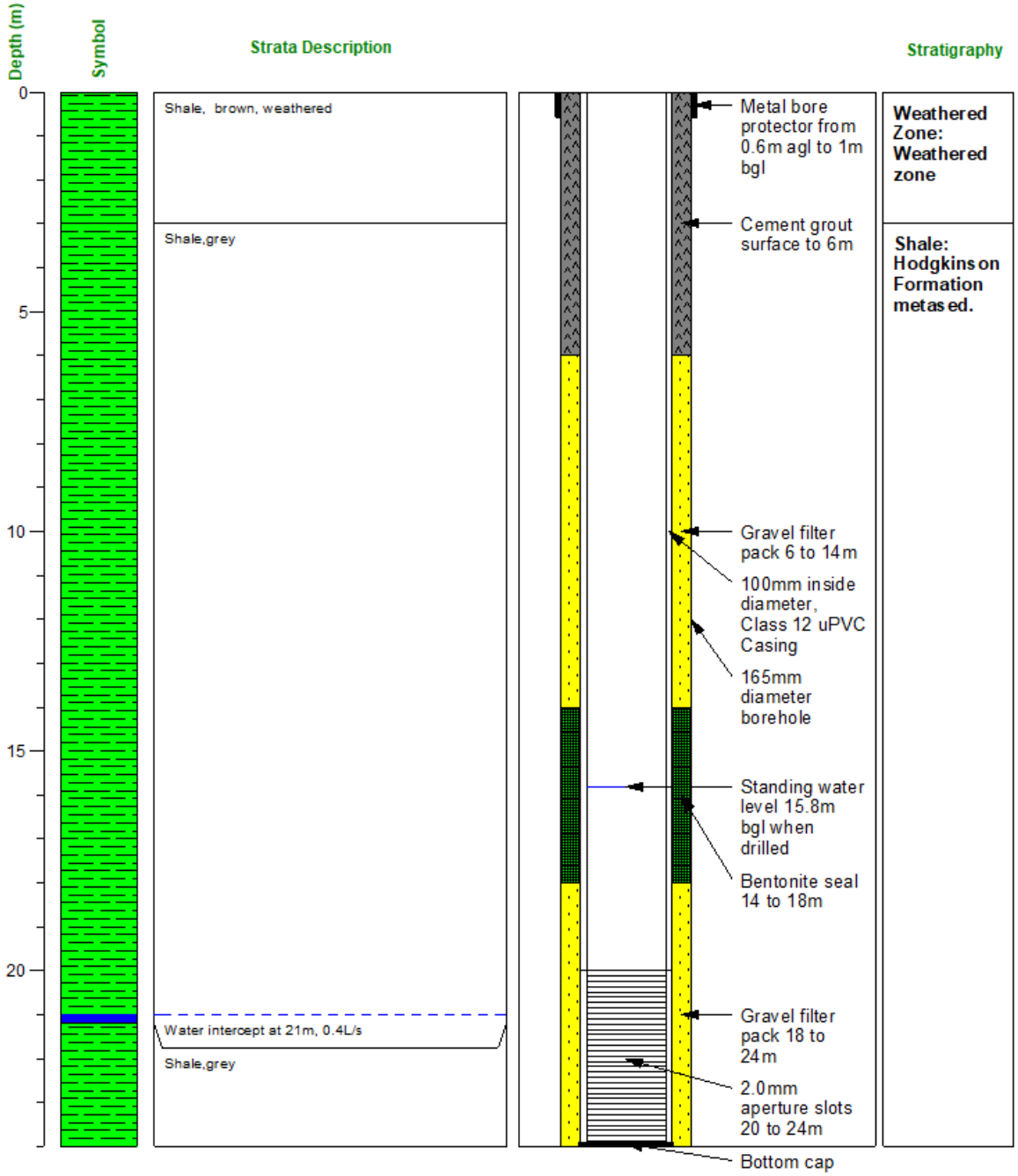
Borehole No: IB06

Client: EQ Resources

Location: Mt Carbine **Date Drilled:** 19/1/2022 **Project No:** 222

Easting: 298746 **Northing:** 8171346 **Elevation (m):**

Method: Rotary air **Driller:** M Quinn **Drilling Rig:** Fraste



Notes:

Datum: AHD/MGA

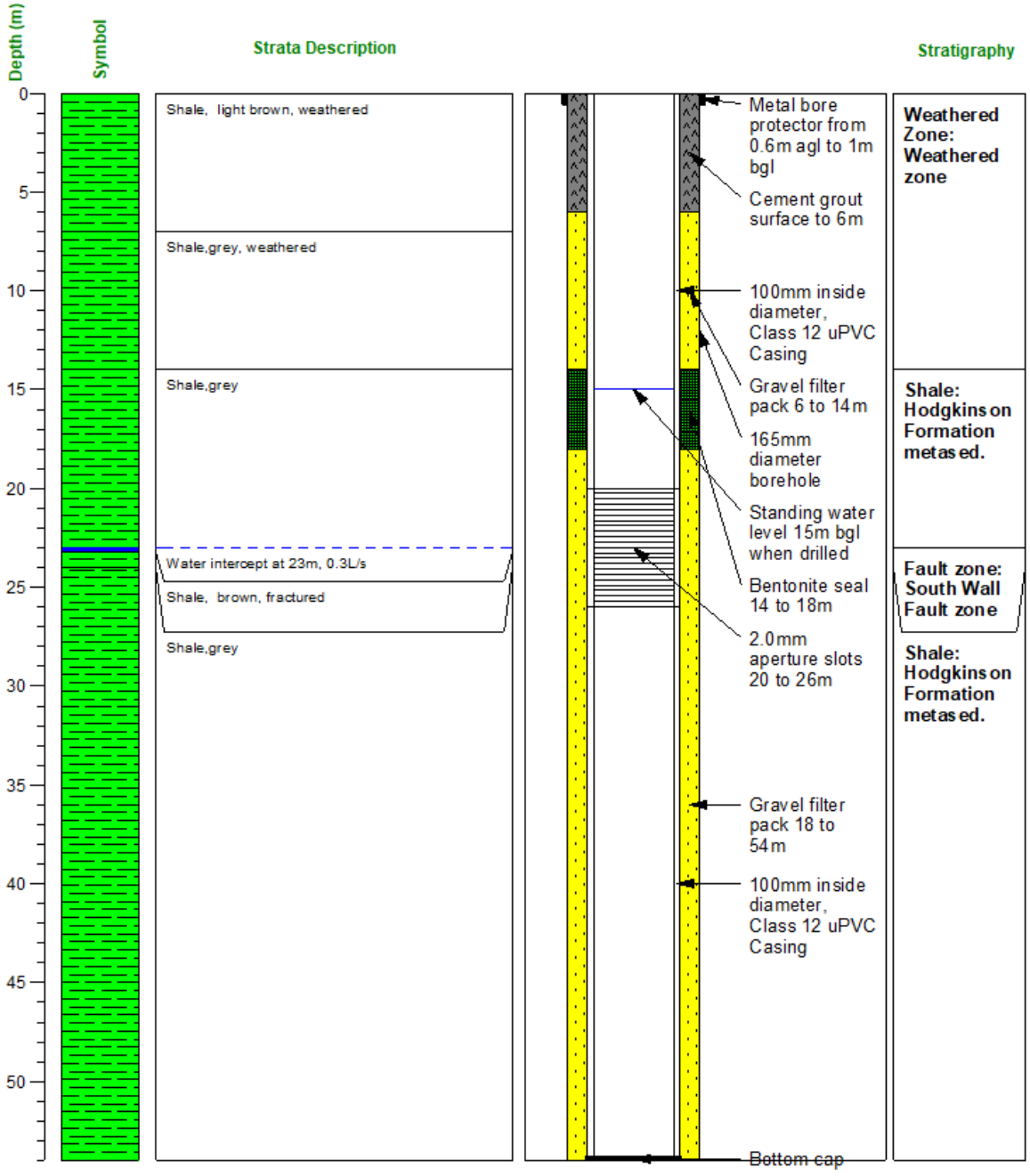
Borehole No: IB08

Client: EQ Resources

Location: Mt Carbine **Date Drilled:** 20/1/2022 **Project No:** 222

Easting: 300893 **Northing:** 8171793 **Elevation (m):**

Method: Rotary air **Driller:** M Quinn **Drilling Rig:** Fraste



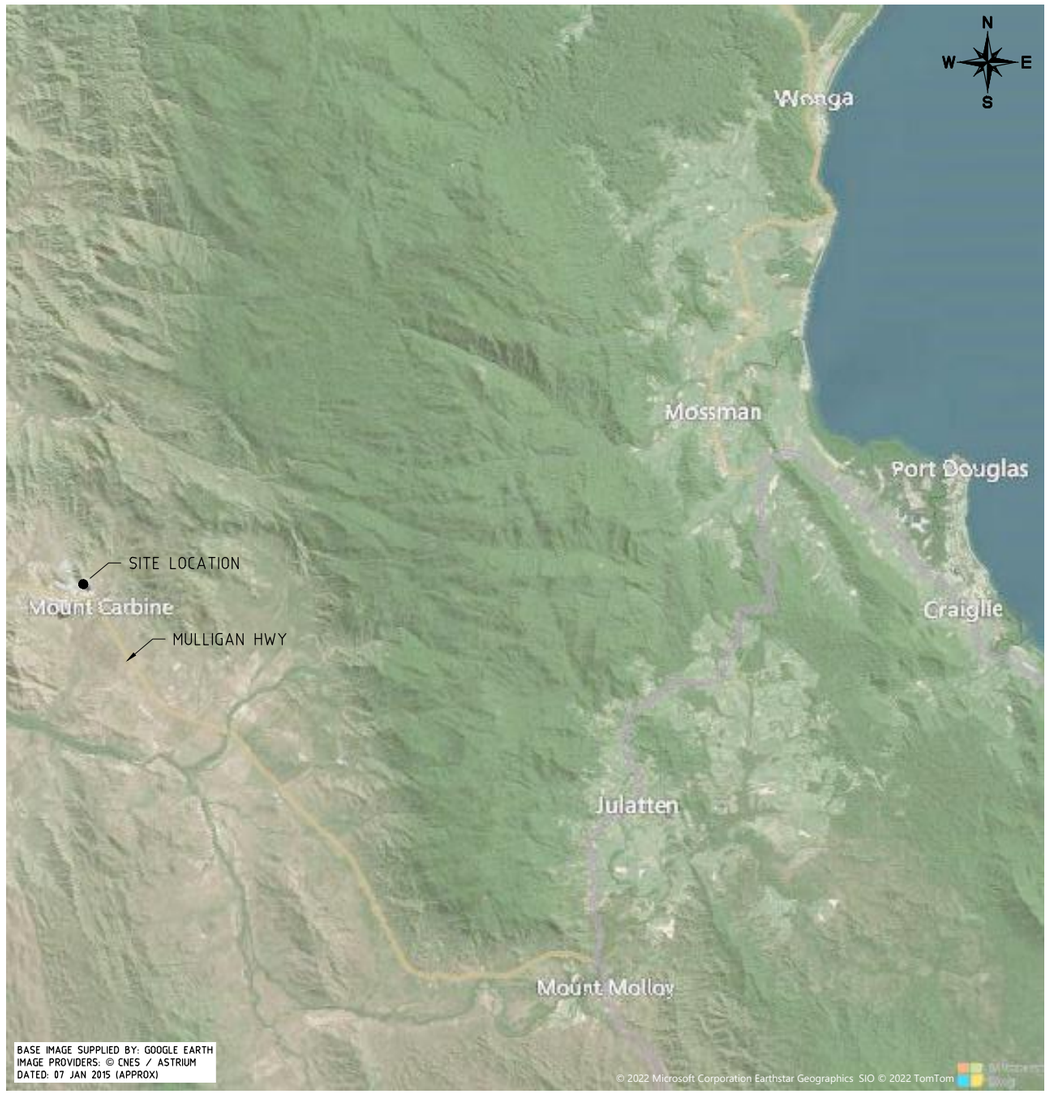
Notes:

Datum: AHD/MGA

APPENDIX F – DRAWINGS

MT CARBINE QUARRIES PTY LTD

TSF3 AND TSF4 SCOPE REPORT



LOCALITY PLAN
SCALE 1:250,000

DRAWING LIST		
NUMBER	DESCRIPTION	REVISION
119190-05-100-001	SITE LOCALITY PLAN AND DRAWINGS LIST	A
119190-05-100-002	EXISTING CONDITIONS	A
119190-05-100-003	SITE LAYOUT	A
119190-05-200-001	TAILINGS STORAGE FACILIITY 3 - GENERAL ARRANGEMENT	A
119190-05-200-002	TAILINGS STORAGE FACILIITY 3 - CROSS SECTIONS	A
119190-05-300-001	TAILINGS STORAGE FACILIITY 4 - GENERAL ARRANGEMENT	A
119190-05-300-002	TAILINGS STORAGE FACILIITY 4 - CROSS SECTIONS	A
119190-05-400-001	WASTE ROCK DUMP - GENERAL ARRANGEMENT	A
119190-05-400-002	WASTE ROCK DUMP - CROSS SECTIONS AND DETAILS	A

GENERAL CONSTRUCTION NOTES

1. THESE NOTES APPLY TO ALL PROJECT DRAWINGS IN THE SET UNLESS NOTED OTHERWISE AND SHALL BE READ IN CONJUNCTION WITH THE SPECIFICATION.
2. ALL LEVELS ARE IN METRES TO AUSTRALIAN HEIGHT DATUM (AHD).
3. ALL COORDINATES ARE IN METRES TO MAP GRID AUSTRALIAN (MGA-94).
4. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.
5. DIMENSIONS AND LOCATIONS OF EXISTING STRUCTURES SHALL BE CONFIRMED ON SITE BY THE CONTRACTOR PRIOR TO COMMENCEMENT OF WORKS.
6. LOCATION AND DEPTH OF ALL SERVICES TO BE VERIFIED BY THE CONTRACTOR PRIOR TO THE COMMENCEMENT OF WORKS.
7. DIMENSIONS SHALL NOT BE SCALED OFF DRAWINGS.
8. DISREGARD GDA 94, MGA ZONE 55 AND USE GRID LOCATION FROM MINE SITE.

ISSUED FOR REPORTING
NOT FOR CONSTRUCTION

No.	DESCRIPTION	DATE	DRAWN	CHECK'D	APPR'D
A	ISSUED FOR REPORTING	08/11/22	JC	KT	RH

SCALE: 1:20,000	
JOB No.	119190-05
DATE	JUL 2022
DESIGN	RH
DRAWN	HPN
CHECKED	KT
APPROVED	RH

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MT CARBINE QUARRIES PTY LTD
TSF3 AND TSF4 SCOPE REPORT

SITE LOCALITY PLAN AND DRAWINGS LIST

DWG. No. 119190-05-100-001

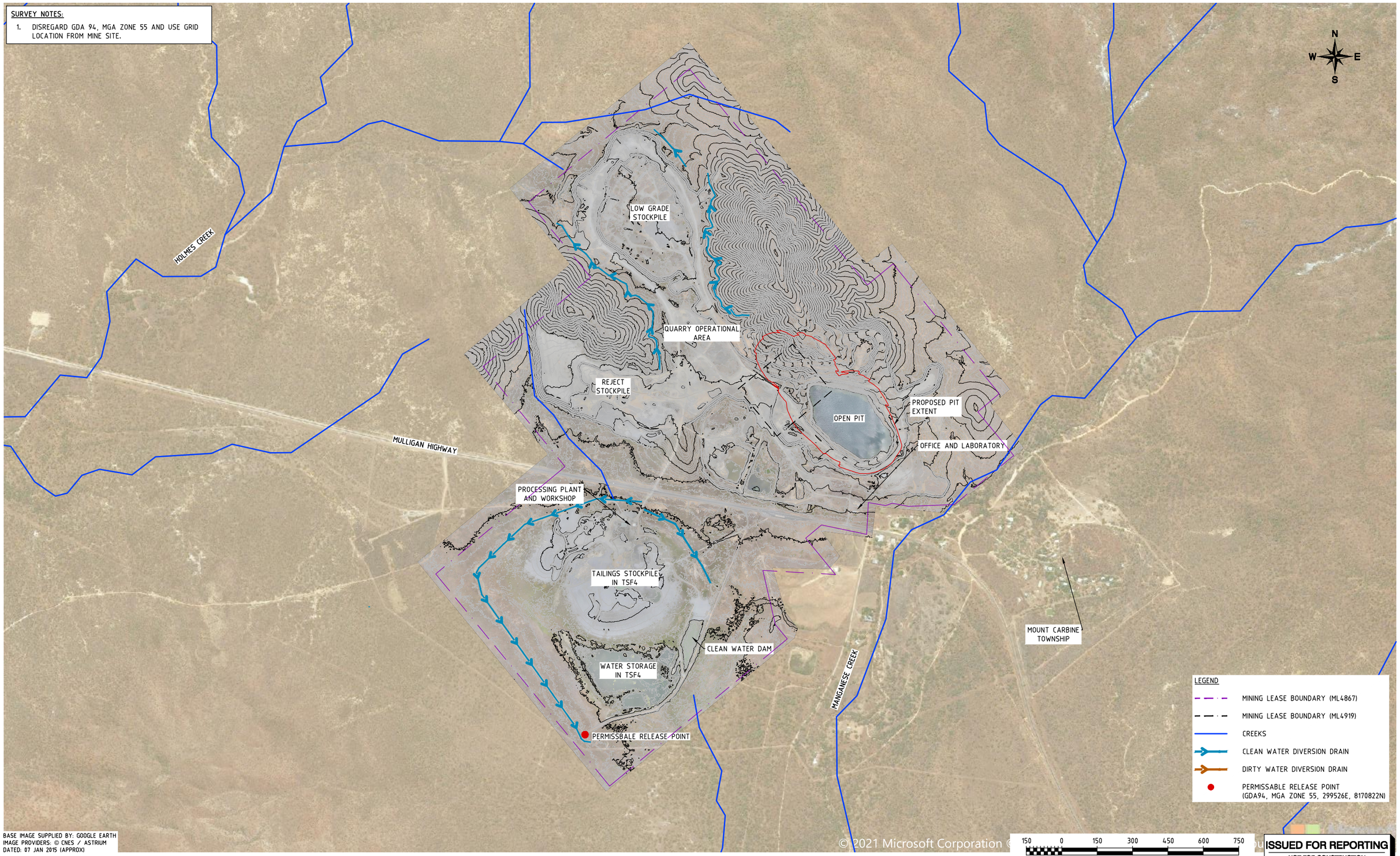
SHEET SIZE A3 | Rev. A

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SHEET 1 OF 1

SURVEY NOTES:

1. DISREGARD GDA 94, MGA ZONE 55 AND USE GRID LOCATION FROM MINE SITE.



BASE IMAGE SUPPLIED BY: GOOGLE EARTH
IMAGE PROVIDERS: © CNES / ASTRIUM
DATED: 07 JAN 2015 (APPROX)

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No.	DESCRIPTION	DATE	DRAWN	CHECK'D	APPR'D
A	ISSUED FOR REPORTING	08/11/22	JC	KT	RH

SCALE:	1:15,000
JOB No.	119190-05
DATE	JUL 2022
DESIGN	RH
DRAWN	HPN
CHECKED	KT
APPROVED	RH

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MT CARBINE QUARRIES PTY LTD
TSF3 AND TSF4 SCOPE REPORT

EXISTING CONDITIONS

DWG. No. 119190-05-100-002

SHEET SIZE A3 | Rev. A

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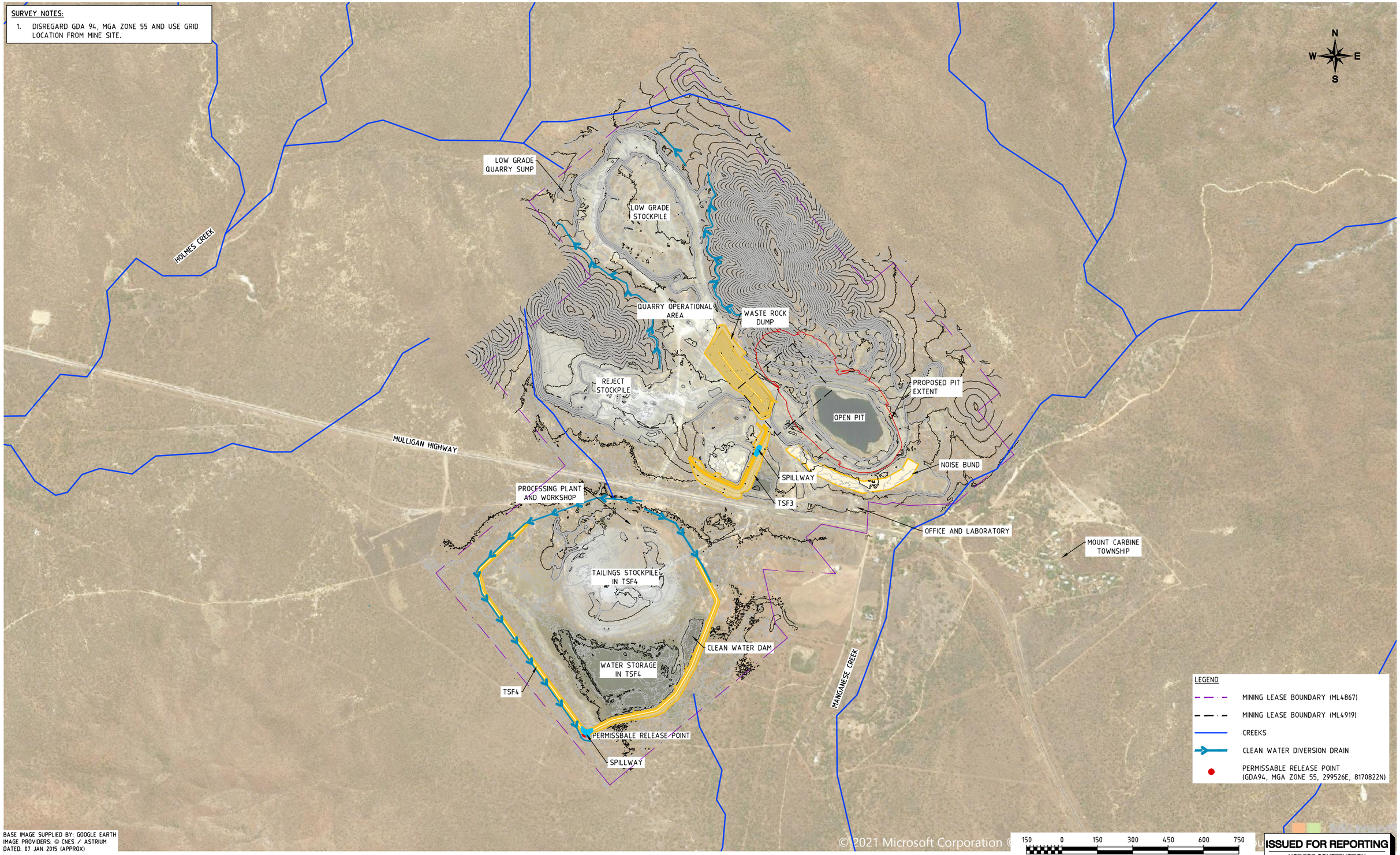
SHEET 1 OF 1

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Printed on: Thursday, 10 November 2022 01:49:17 PM By: James Camille

SURVEY NOTES:

1. DISREGARD GDA 94, MGA ZONE 55 AND USE GRID LOCATION FROM MINE SITE.



BASE IMAGE SUPPLIED BY: GOOGLE EARTH
IMAGE PROVIDERS: © CNES / ASTRIUM
DATED: 07 JAN 2015 (APPROX)

150 0 150 300 450 600 750
SCALE OF METRES 1:15,000 @ A3

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No.	DESCRIPTION	DATE	DRAWN	CHECK'D	APPR'D
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A	ISSUED FOR REPORTING	10/11/22	JC	KT	RH

SCALE:	1:15,000
JOB No.	119190-05
DATE	JUL 2022
DESIGN	RH
DRAWN	HPN
CHECKED	KT
APPROVED	RH

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MT CARBINE QUARRIES PTY LTD
TSF3 AND TSF4 SCOPE REPORT

SITE LAYOUT

DWG. No. 119190-05-100-003

SHEET SIZE A3 | Rev. B

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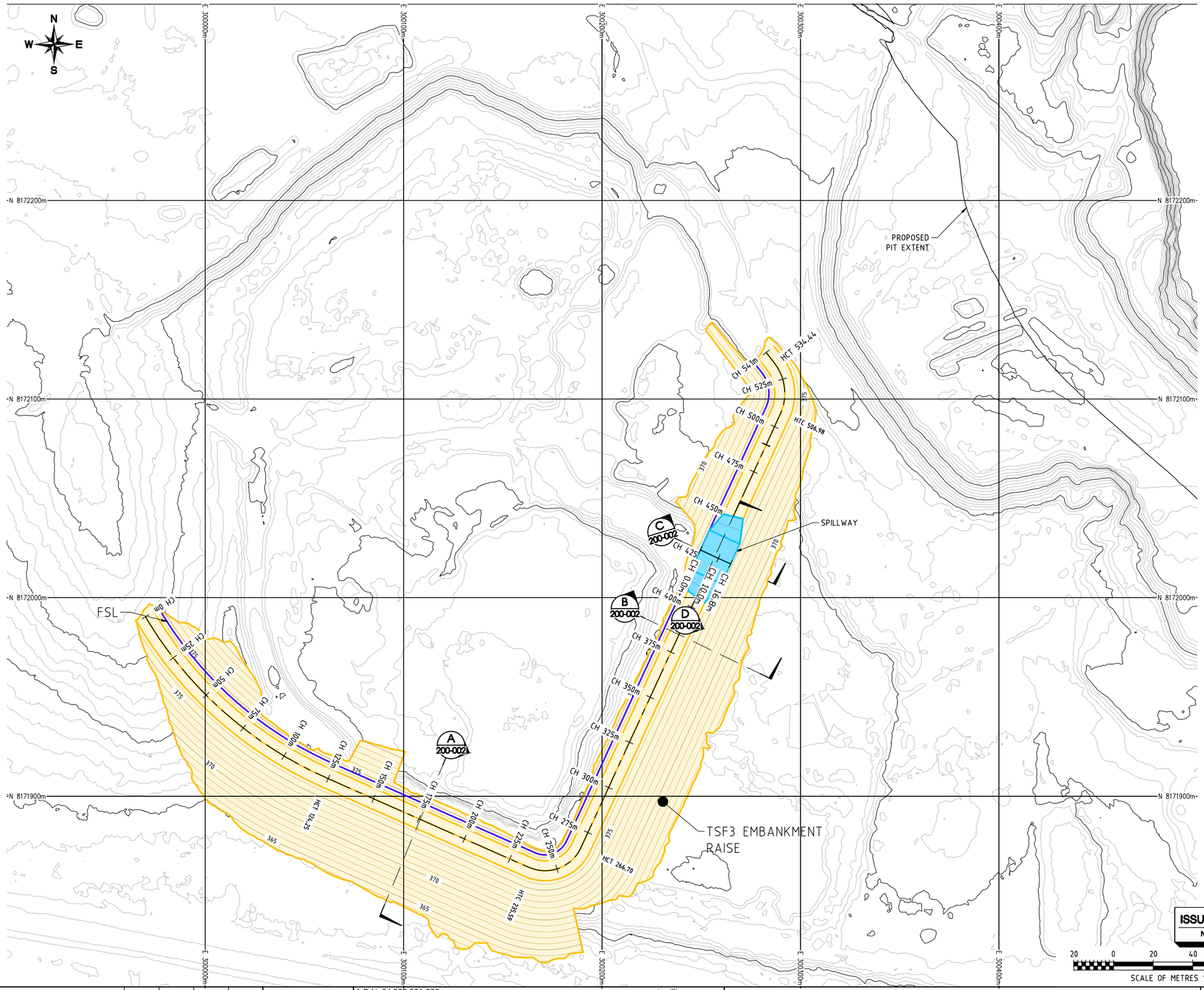
SHEET 1 OF 1

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Printed on: Wednesday, 30 November 2022 10:27:00 AM By: Micheal Lane

SURVEY NOTES:

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SCALE:	1:2000
JOB No.	119190-05
DATE	JUL 2022
DESIGN	RH
DRAWN	HPN
CHECKED	KT
APPROVED	RH

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MT CARBINE QUARRIES PTY LTD
TSF3 AND TSF4 SCOPE REPORT

TAILINGS STORAGE FACILITY 3
GENERAL ARRANGEMENT

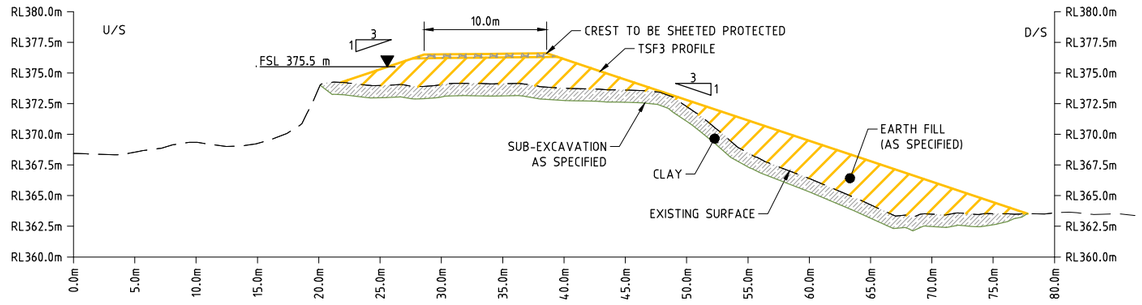
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SHEET SIZE A3 Rev. A

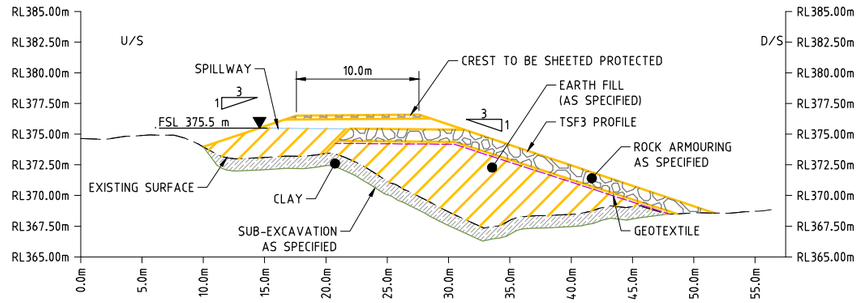
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SHEET 1 OF 1

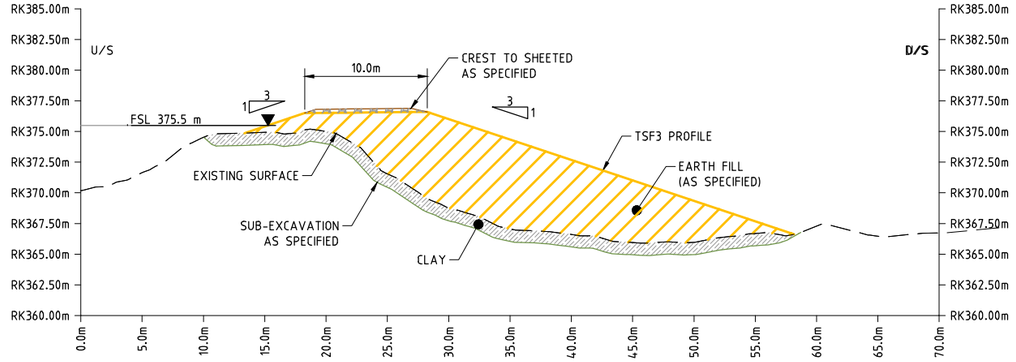
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1. EXISTING SURFACES TO BE PREPARED AS SPECIFIED.



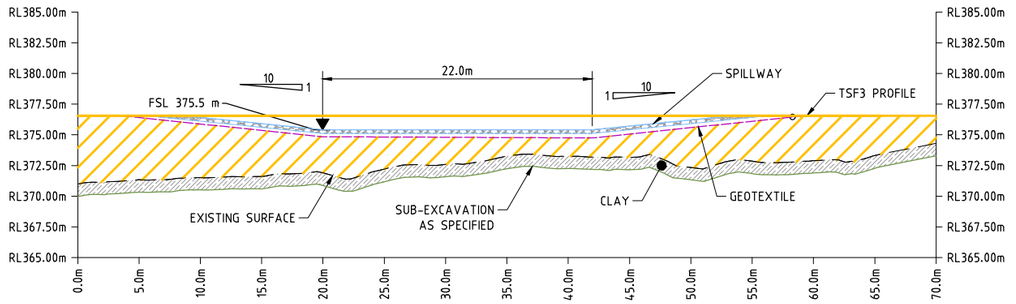
SECTION A
1:500 200-001



SECTION C
1:500 200-001



SECTION B
1:500 200-001



SECTION D
1:500 200-001

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SCALE OF METRES 1:500 @ A3

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No.	DESCRIPTION	DATE	DRAWN	CHECK'D	APPR'D
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SCALE: 1:250	
JOB No.	119190-05
DATE	JUL 2022
DESIGN	RH
DRAWN	HPN
CHECKED	KT
APPROVED	RH

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MT CARBINE QUARRIES PTY LTD
TSF3 AND TSF4 SCOPE REPORT

TAILINGS STORAGE FACILITY 3
CROSS SECTIONS

DWG. No. 119190-05-200-002

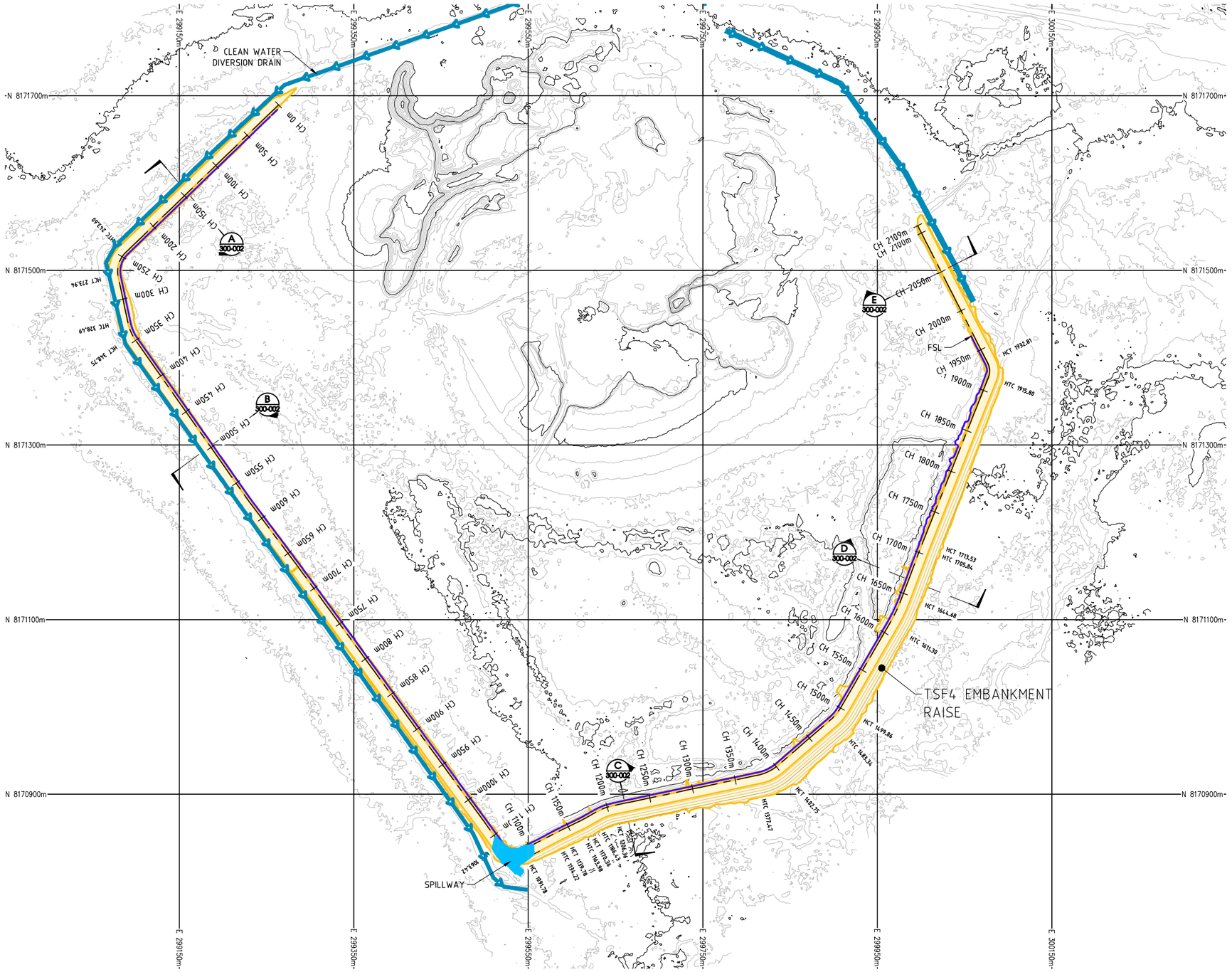
SHEET SIZE A3 | Rev. A

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SHEET 1 OF 1

NOTES:

1.- CLEAN WATER TO BE DIVERTED OUTSIDE OF TSF4 AS DIRECTED.



50 0 50 100 150 200 250

SCALE OF METRES 1:5000 @ A3

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No.	DESCRIPTION	DATE	DRAWN	CHECK'D	APPR'D
A	ISSUED FOR REPORTING	08/11/22	JC	KT	RH

SCALE:	1:15,000
JOB No.	119190-05
DATE	JUL 2022
DESIGN	RH
DRAWN	HPN
CHECKED	KT
APPROVED	RH

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MT CARBINE QUARRIES PTY LTD
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TAILINGS STORAGE FACILITY 4
GENERAL ARRANGEMENT

DWG. No. 119190-05-300-001

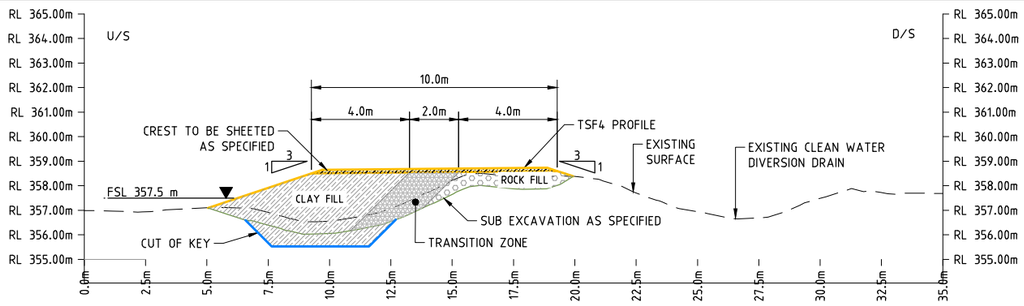
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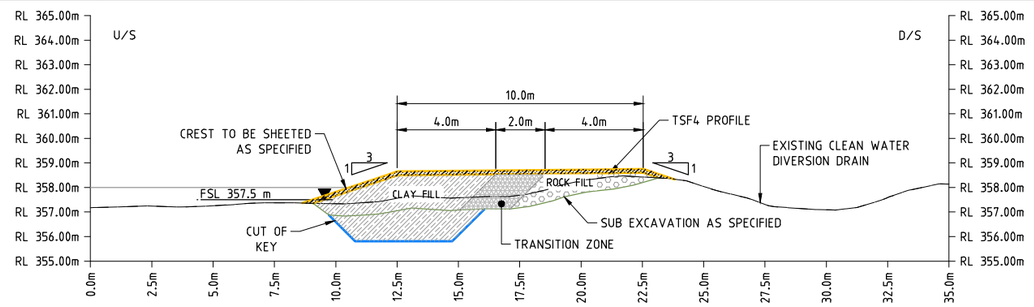
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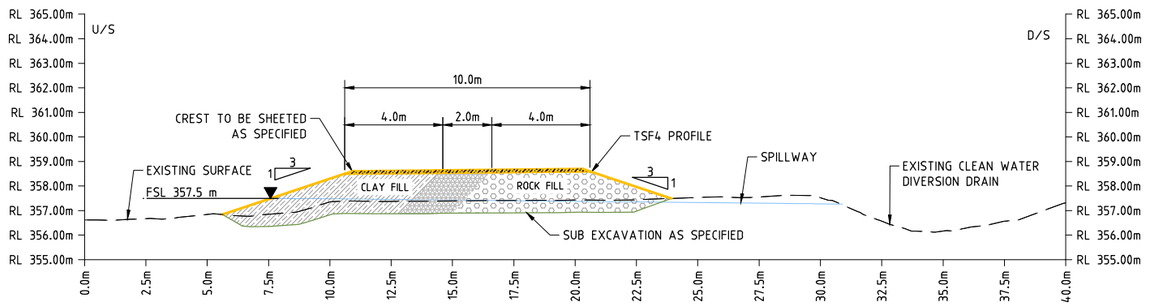
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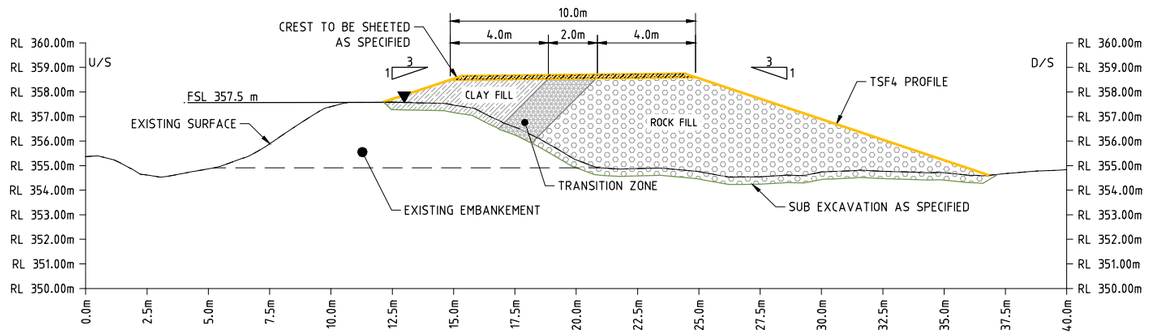
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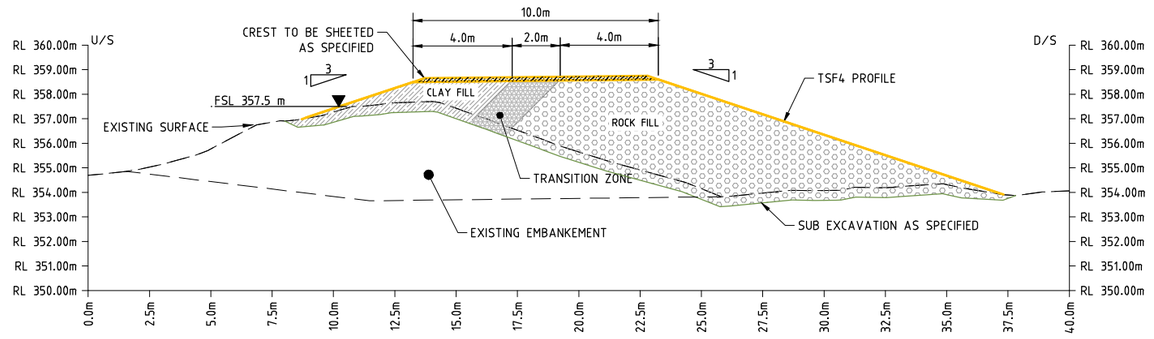
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SECTION C 1:250 300-001



SECTION D 1:250 300-001



SECTION E 1:250 300-001

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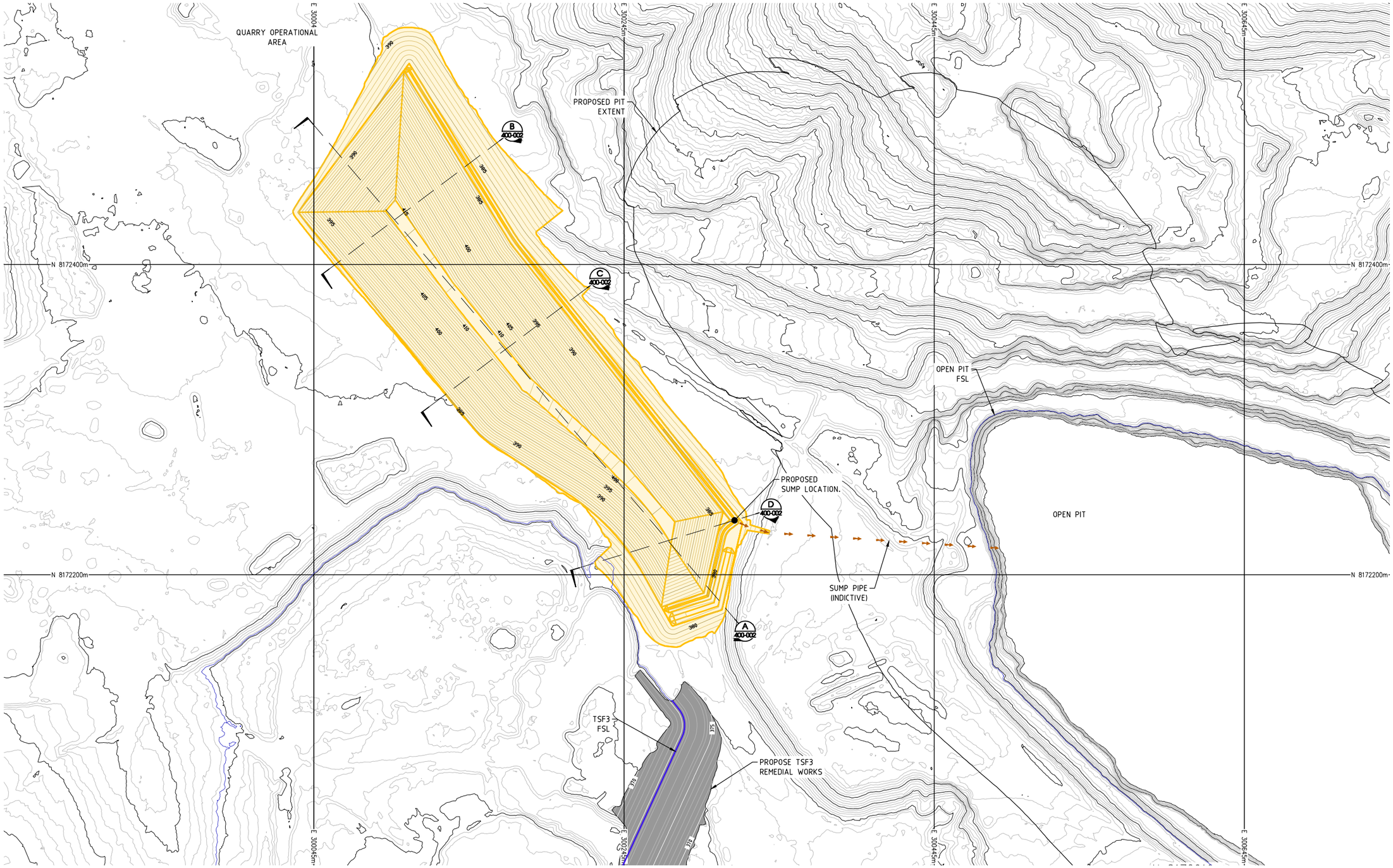
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WASTE ROCK DUMP GENERAL ARRANGEMENT

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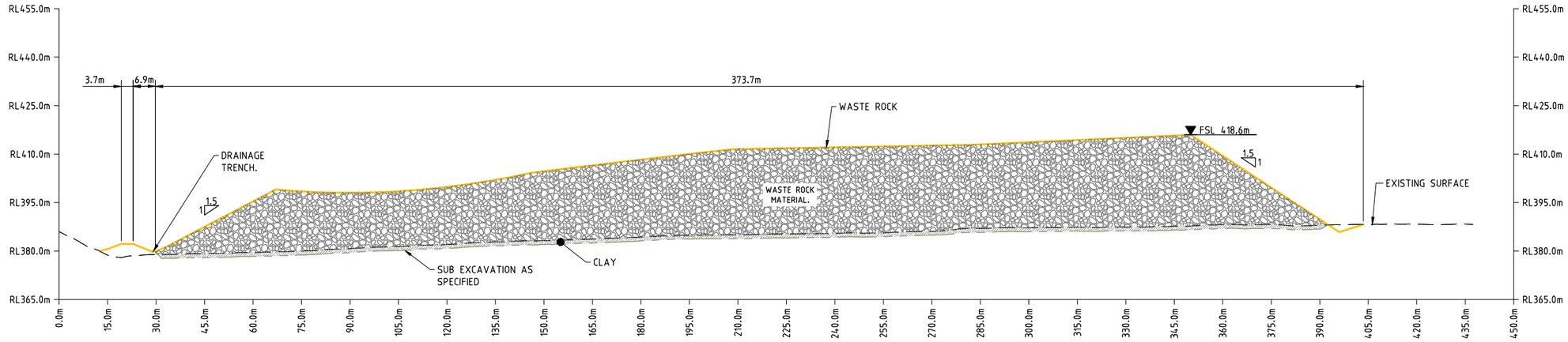
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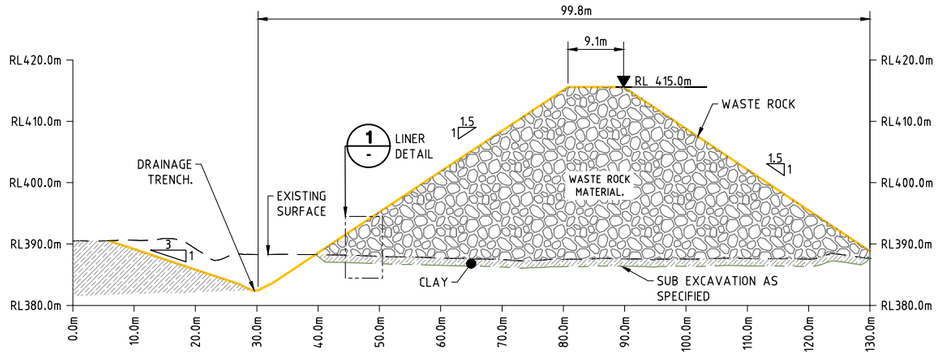
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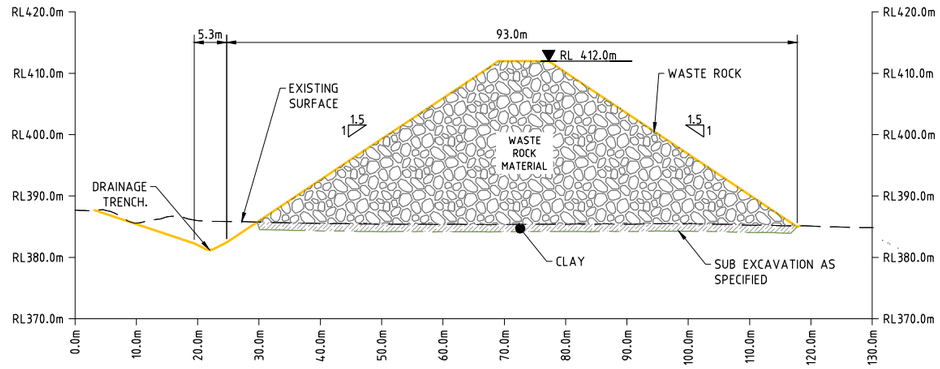
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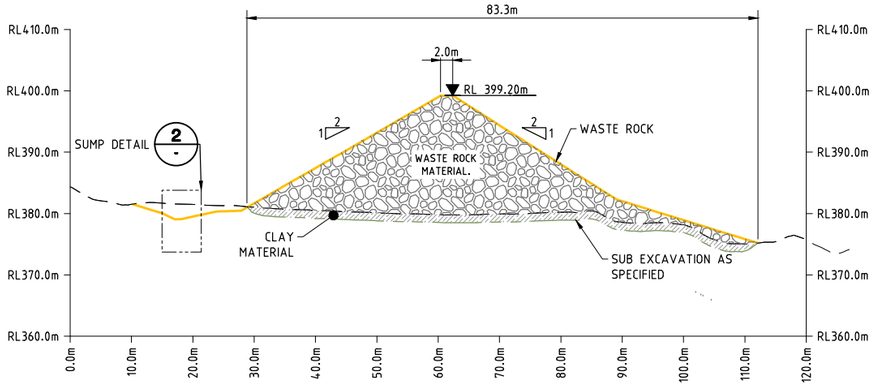
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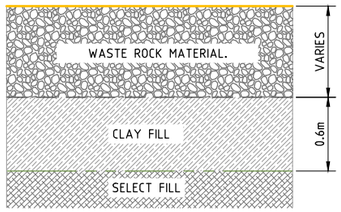
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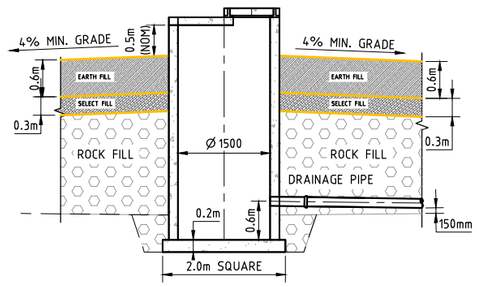
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DETAIL 1 LINER LAYOUT SCALE: 1:50 -



DETAIL 2 SUMP DETAIL SCALE: 1:50 -

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Appendix F:
Brief Review and Structural Assessment/Scoping of Iron Duke–Petersens, Mt Carbine EPM14872 (HCOVGlobal 2020)





Brief review and structural assessment/scoping of Iron Duke – Petersens - Mt Carbine
EPM 14872

Nick Oliver

Director and Principal consultant, HCOVGlobal (trading as HCO Associates PL)

11/06/2020

This report (Phase 1) is based on two days site visit and one day reporting in early June, 2020. Nick Oliver nor HCO Associates (and the umbrella consortium HCOVGlobal) makes no representation or warranty, express or implied, in relation to the accuracy or completeness of this report or of any other information provided. The conclusions and recommendations expressed here are the opinion of the author based on the materials described and should not be taken as a commercial recommendation. The limited time available means the interpretations were rushed and the ideas expressed are premature.

HCO Associates PL accepts no responsibility or liability for any decisions taken by any Recipient or its advisers based on the information, statements or opinions provided in this report. The results presented here remain confidential to Specialty Metals. For information, contact Kevin MacNeill <kmacneill@spmetals.com.au>

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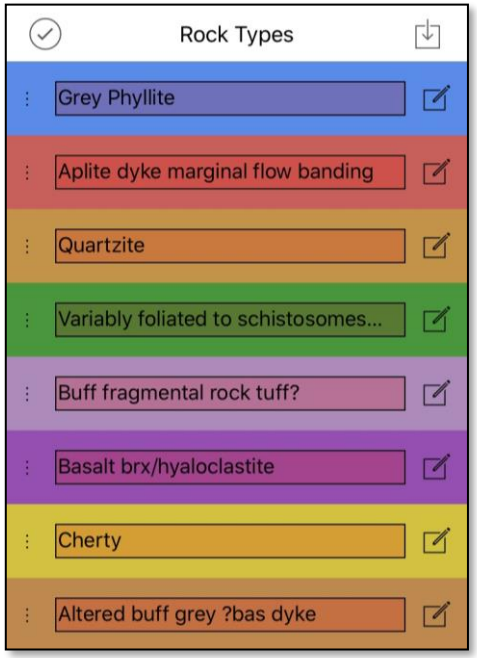
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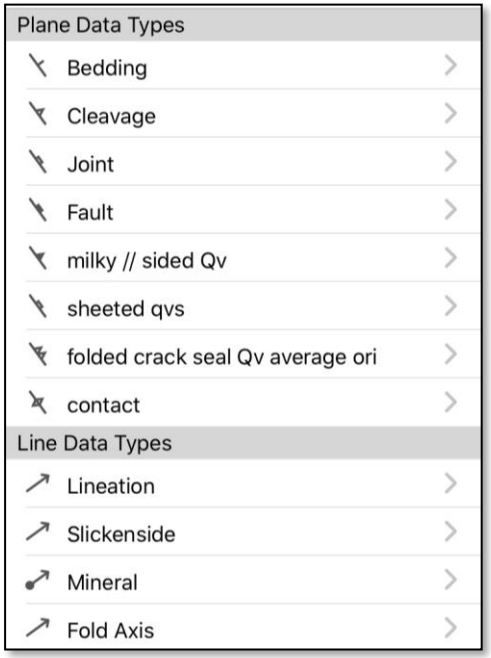
Speciality Metals International Limited

Phase 1: Summary of progress

- 2 days observations around pit and parts of Iron Duke EL
- Checked on and made observations of:
  - Lithologies
  - Vein orientations, continuity, style, timing, mineralogy and implications of these
  - Faults – South Wall (SWF), Iron Duke (IDF), ?Central, minor in footwall of South Wall fault
  - Structural timing of veins, faults and ductile fabrics relative to each other
  - Attempts at identifying shear sense indicators on South Wall Fault from pit walls and drill core
- Brief review of data sets, publications and reports as provided by Dean Krak









This preliminary field dataset will be added to the later mapping (and has not been ported yet to QGIS). The main metamorphic (pre-dyke) rock types are (in abundance according to the observational points shown):

1) laminated grey phyllite (main ore host),
2) strongly foliated pale green metabasalt (mostly/?all in SWF footwall),
3) dark blotchy weak- to moderately foliated, locally ?peperitic/hyaloclastitic metabasalt,
4) cherty units, some discrete. Others as bands within metabasalts, and
5) A finely fragmental unit, possibly a tuff, adjacent to and locally intercalated with chert and metabasalt

STRUCTURES: pre-fault ductile fabrics

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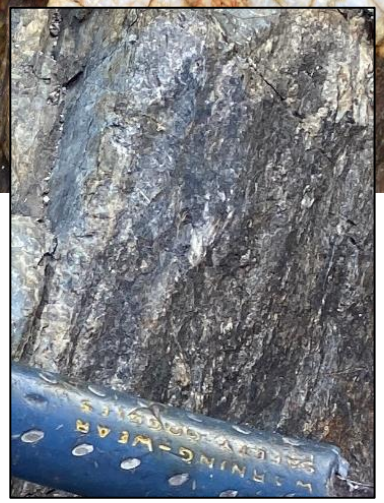
Plane Data Types

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- Cleavage
- Joint
- Fault
- milky // sided Qv
- sheeted qvs
- folded crack seal Qv average ori
- contact

Line Data Types

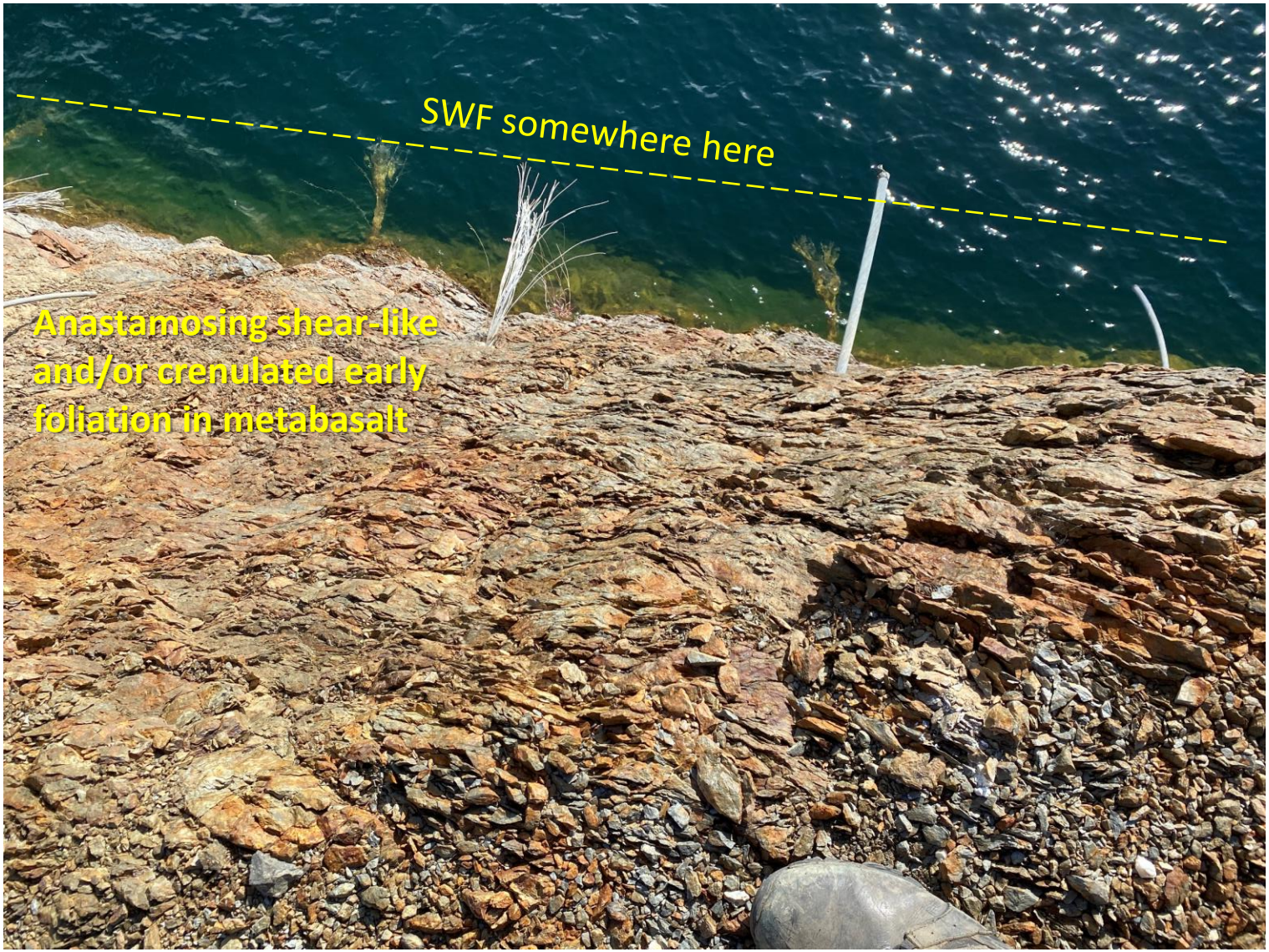
- Lineation





This is a composite crenulation cleavage, locally tightly folding bedding and early regional metamorphic(W-poor) veins

The main foliation in the phyllite and metabasalt is a composite S1/S2 crenulation and/or shear cleavage (S1 of DeRoo). Rigorous form surface mapping of this cleavage, combined with previous workers datasets, will assist in trying to constrain the ductile component of movement on the SWF



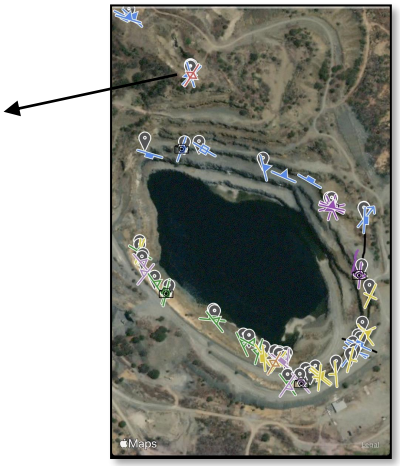
Looking down and NE at the fabrics in the South Wall. This greeny-grey foliated schist is interpreted as the metabasalt, as it contains no obvious internal bedding and is dominated by chlorite. Locally it contains cherty segments, probably inter-flow sediments. There are at least two fabrics that correlate with DeRoo's "S1", and we found only one example of his F2 kink-like folds with steep axial planes that he infers to be related to the veining. The main point is that this strong composite foliation is sharply truncated by the mineralized veins.



I'm not sure of orientations here, but the ore veins (quartz-wolframite-scheelite) cut two previous, strongly ductile foliations. I don't think the second fabric here (let's call it Ss to note its shearing) is DeRoo's S2 or S3 – it's a strong, ductile shearing feature that we also saw in the footwall of the SWF (but unrelated to this fault – different style – anastomosing and ductile shearing, rather than planar with gouge/cataclasite/fault breccia).

STRUCTURES: later ductile fabrics

Small sub-pit on elevated northern wall of main pit



Looking south, steep dipping wolframite-bearing quartz veins and the earlier S1 fabric are overprinted by shallow partly kink-like folds, DeRoo's F3. There are also some later generation quartz veins (yellow arrows) running along the locally prominent fracture cleavage associated with these folds (probably unmineralized?). DeRoo interprets the main veins as being syn-S3 in this case, but I suspect they're earlier and haven't folded harmonically with the adjacent S1 cleavage in the phyllites. The distribution of the zones of strong F3 folding is patchy around the pit, and this distribution, and/or the specifics of S3 orientations, may also help to constrain movement on the later faults.

STRUCTURES: Faults

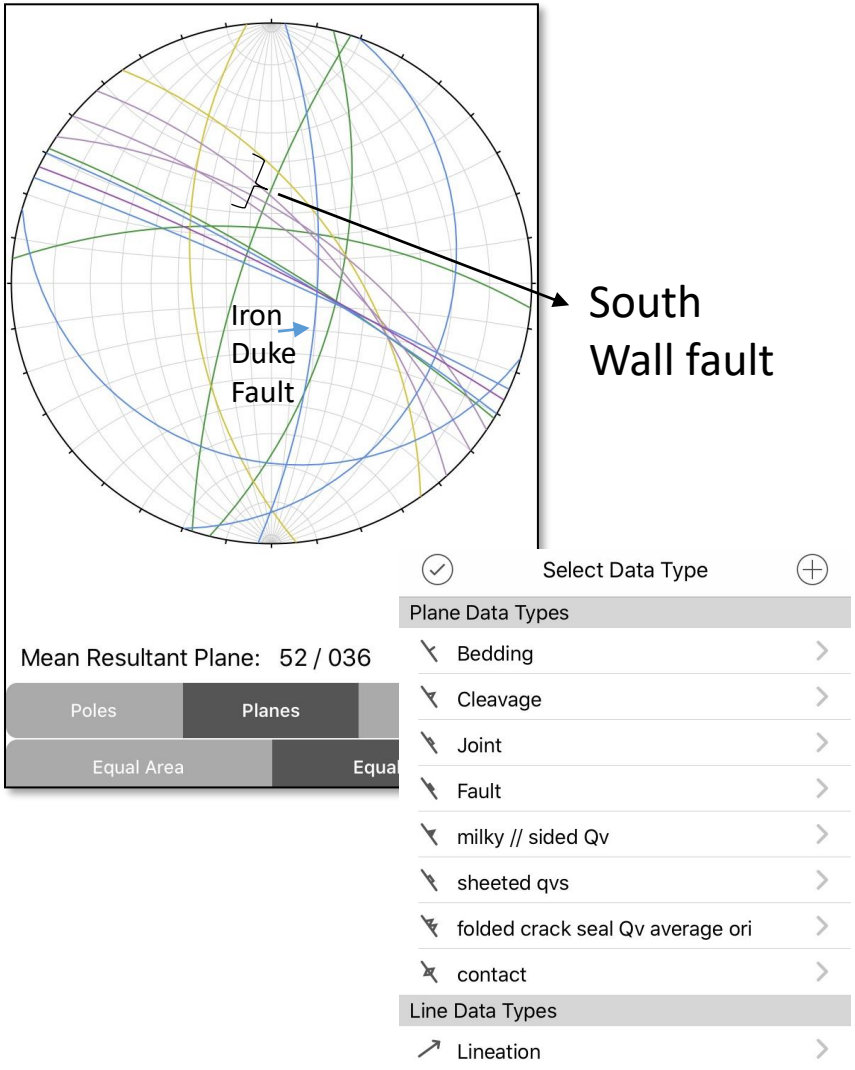
All orientations here are relative to magnetic north, not mine grid.

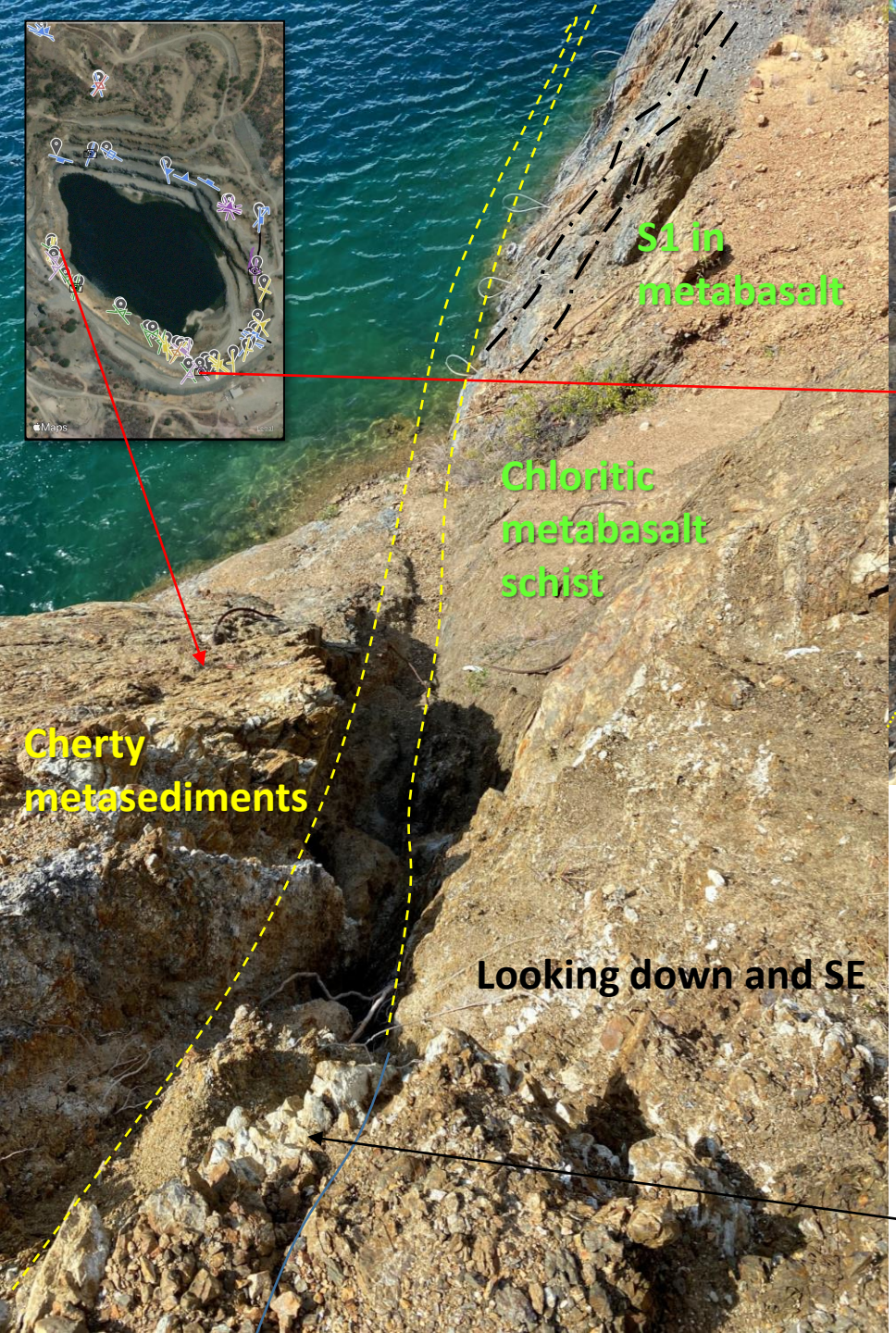
All the faults we saw seemed to post-date the ductile fabrics, and the W-bearing ore veins. The main faults examined were the South Wall Fault and Iron Duke Fault. The Iron Duke Fault is apparently a major steeply east-dipping N-S striking fault (based on its damage zone) north of the eastern pit wall, and shows evidence for oblique east-block-south-and-down movement based on curved quartz veins and internal shear bands (see below). However, it could not easily be tracked into the projected position on that eastern pit wall, where an irregular zone of fractured dark metabasalt lies adjacent to (and possibly faulted from) cherts. It should be possible to resolve movement on this fault with further mapping. It overprints quartz veins that are probably part of the mineralized set.

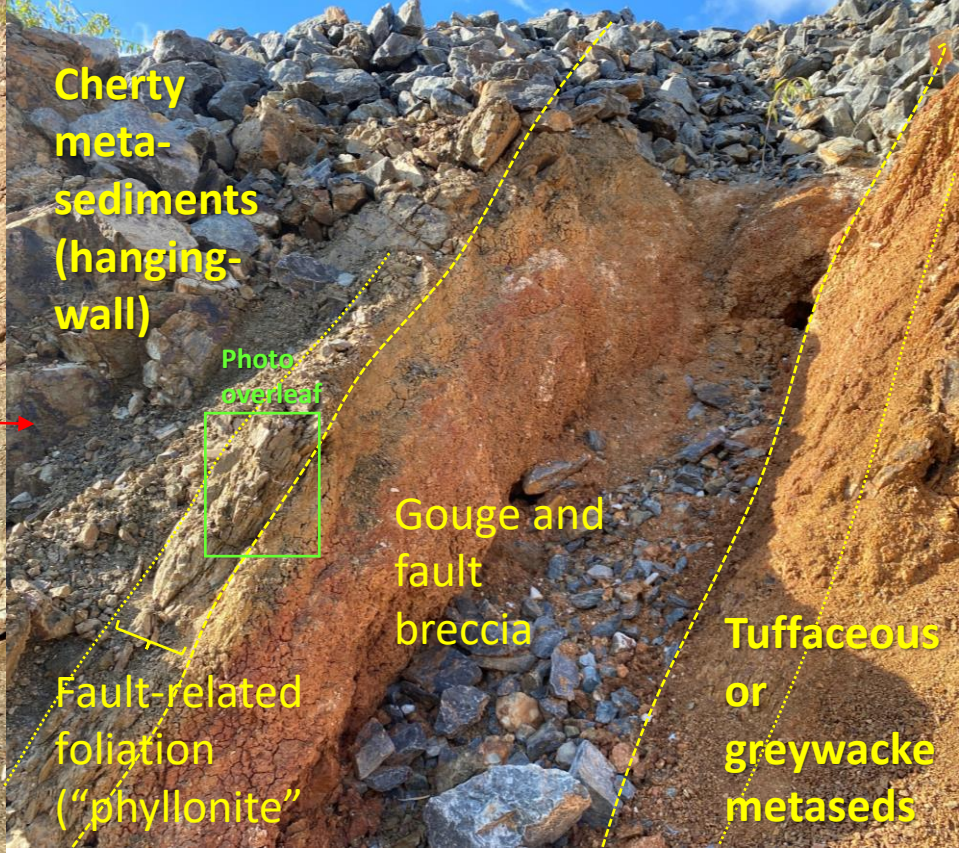
The SWF is relatively easy to trace but determining the shear sense is really tough (to date) and will require closer examination of the drill core as well as an attempt to try to access more exposure in the lower benches near the waterline. Determining the offset across this fault will also be assisted by better recognition of lithologies in the HW and FW, and careful tracing of curvatures or offsets in the pre-fault cleavage. The fault is one of the very youngest features observed, and clearly separates a veined hanging-wall from an effectively unveined footwall. The fault is fairly planar, especially on the HW contact. Strong, curved, foliation arrays in the footwall metabasaltic package appear to be related to the earlier ductile foliations, but its possible that these foliations may assist with recognizing drag effects on the SWF.

A number of conjugate faults were found in the footwall of the SWF, sharply jostling meta-basaltic schist with tuffaceous and cherty metasediments, with metre-scale apparent dip-slip or oblique-slip offsets, which in turn do not appear to truncate the adjacent South Wall fault. The Central Fault was 'found' (only 5 to 10cm wide) but did not have the orientation expected from the previous mapping and will require further checking.

Stereographic projection of great circles of faults, coloured by the host and/or adjacent lithology







Looking S/SE

The South Wall fault is fairly distinctive, with a 20-100cm core of gouge and fault breccia surrounded by a relatively narrow brittle-ductile foliation zone that appears fault related. The footwall has a moderate to strongly developed earlier foliation that is truncated by the SWF at a low angle. Mineralized quartz veins appear absent in the FW, but are found in the HW and locally (partly dismembered) in the fault zone itself



I try not to rely on slicken-line striations unless desperate, as they can provide an unreliable indication of the latest, and potentially insignificant fault movement. The more ductile indicators such as these shear bands are more reliable, and these were the best ones I could see. There were also similar features in core, but the best examples were in unoriented core where the shear sense was equivocal due to uncertainty of the core orientation. The ones shown here (looking SE, above the ramp) were the only moderately good ones I could find quickly that could be measured, with a shear-sense confidence of > 75%. However, it is highly desirable to get more data to strengthen the interpretation. Depending on the magnitude of offset (seems big from the magnetics), this apparent reverse movement would imply the potential for more ore at depth, unless the SWF was a 'master' for the mineralization (i.e. controlling fault that never had mineralization underneath it). It looks like the fault could also be accessed safely by boat on the western edge of the pit (see previous slide, photo at left)

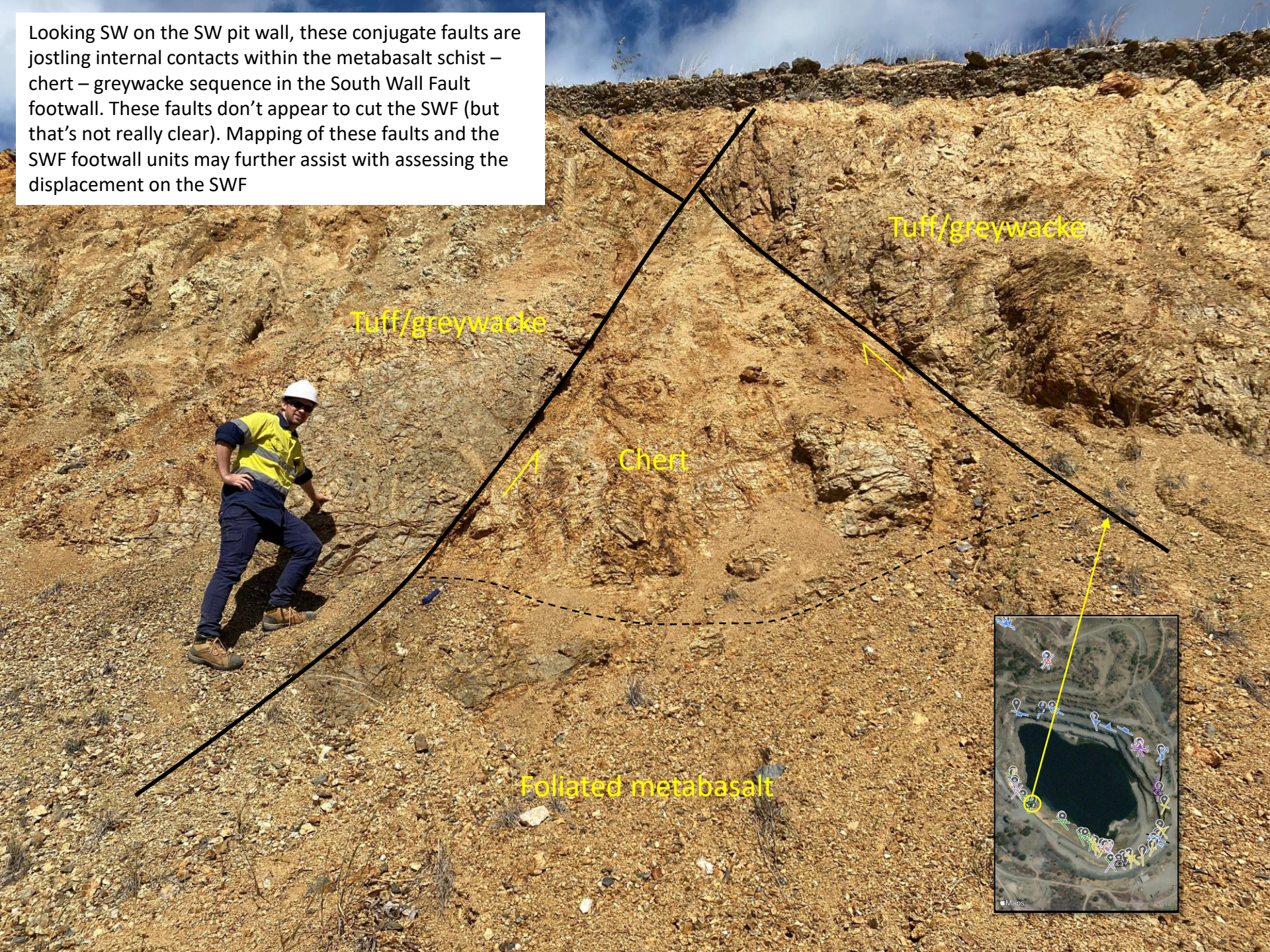


Where the oriented core hits the SWF, core/barrel spin at the fault edge is apparent in some holes, other holes are not oriented, and others are defined by rubble at the interface, as seen in these examples (oriented to imagine you are looking at the steep-east dipping fault zone). With careful work there is some potential to generate some reasonable shear sense interpretations but there were no easy solutions with a short inspection of the ~ 10-odd holes that we looked at with SWF intersections.

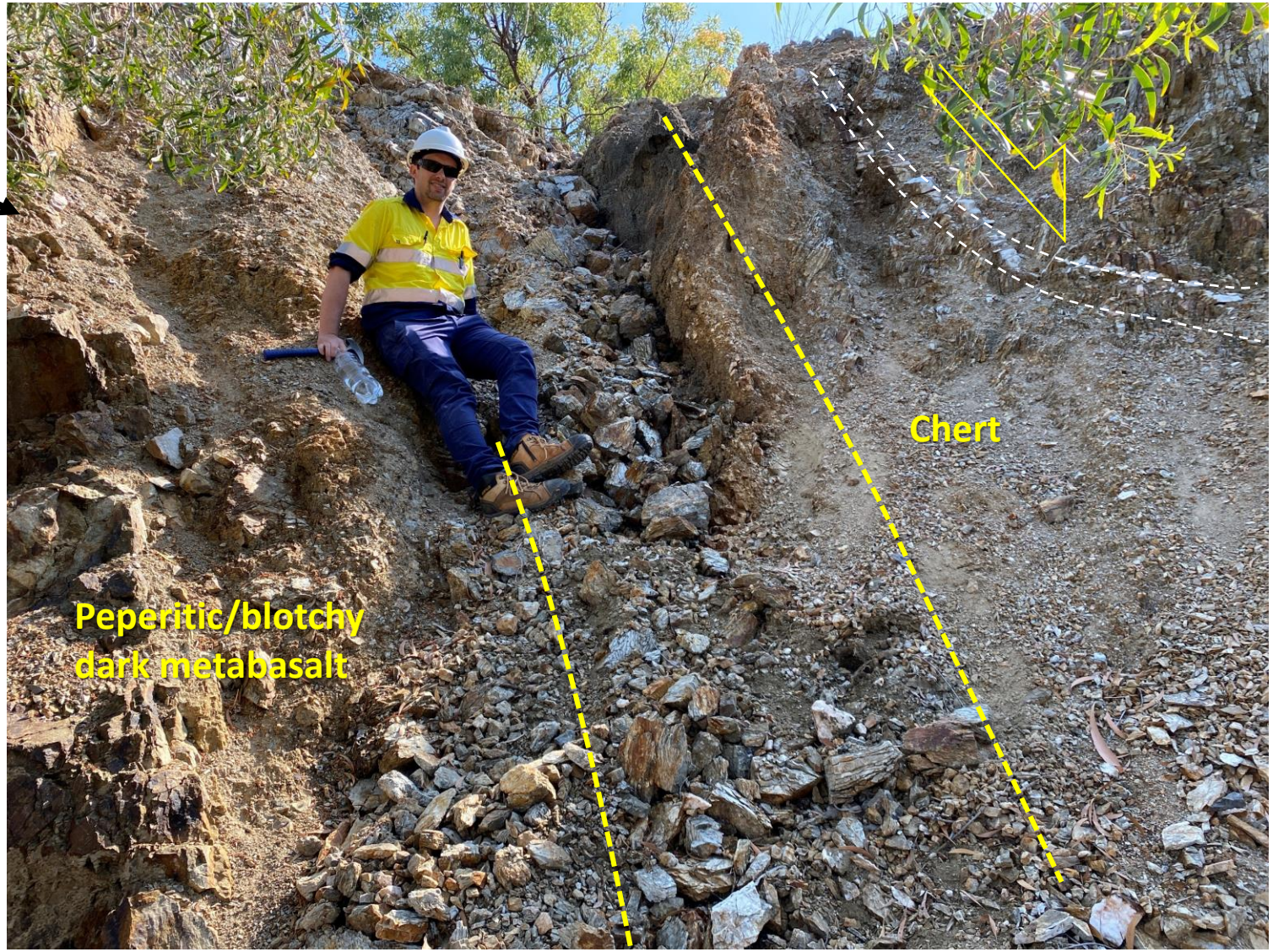


Hopefully we will get further with the SWF movement sense, by carefully examining the core, and/or successfully repeating some shear sense observations if we can access the lower pit walls. A case could be made for trying to resurrect the old core saw, or buying another one, if we cannot get adequate information from the existing core. It may also come to the point of committing to a first HQ drill hole that is carefully oriented, and targets both the SWF as well as deeper ore not fully drilled out, e.g. at the northern extension of the existing open cut (drilling SW through ore to hit the fault, similar to many of the earlier holes). That's a $30K to $60K ask though, for a ~ 150 to 350m hole.

Looking SW on the SW pit wall, these conjugate faults are jostling internal contacts within the metabasalt schist – chert – greywacke sequence in the South Wall Fault footwall. These faults don't appear to cut the SWF (but that's not really clear). Mapping of these faults and the SWF footwall units may further assist with assessing the displacement on the SWF







Iron Duke fault

Looking north, the Iron Duke Fault is broader than the SWF at this location, and juxtaposes distinctive dark blotchy metabasalts from cherts as shown. Curvature of normally very straight ore-bearing quartz veins defines an apparent oblique slip vector on this fault, with the eastern block down and to the south along ~ 50 →130. Its extension into the eastern pit wall was not so clear, however, it might curve off or branch. So it's a post-vein fault with an as-yet unclear relationship to the Central or South Wall Faults.

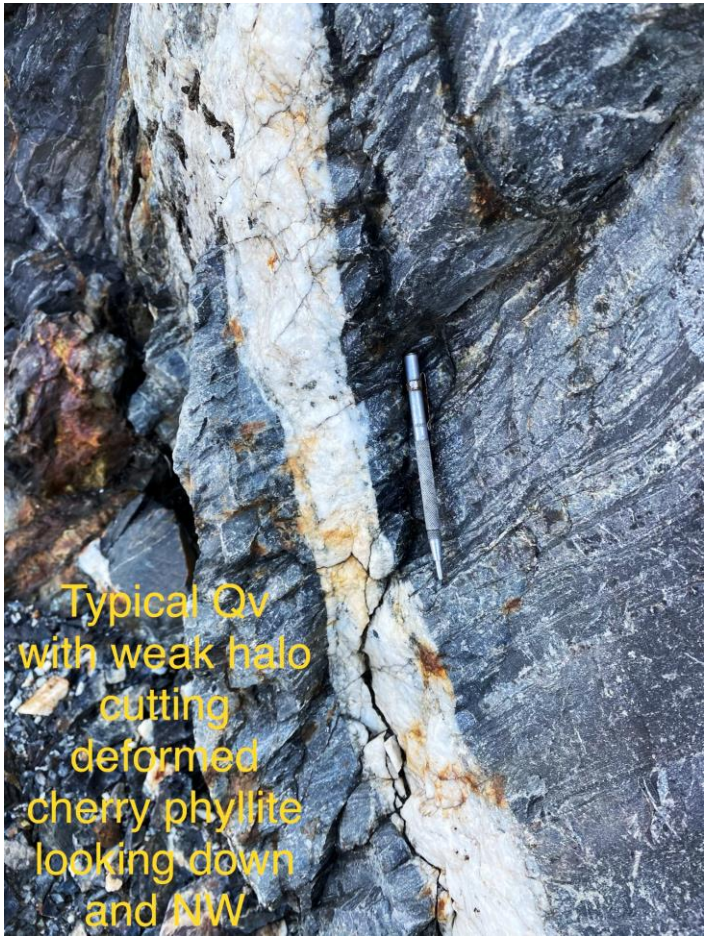


There are some later, very brittle shallow faults with up to m-scale displacements and we will continue to monitor these in case the displacements potentially affect ore envelope thoughts.

Observations on the veins and magnetics

The EGRU and earlier work noted ‘illite-chlorite’ around the wolframite-bearing veins. Dean found this beaut piece at left (below) that casts doubt on a low temperature origin for the tungsten-bearing veins. This is garnet-pyrite-quartz (not sure if any W), and the predominant haloes around the other veins are combinations of biotite, silica, tourmaline and muscovite. The presence of garnet in particular implies high temperatures (> 400°C) and thus there is a possibility that the orebody lies proximal to either a source granitoid, or potentially to another style of mineralization (e.g. W-skarn). Andy White’s report also notes clinopyroxene at Mt Carbine deposit, and abundant clinopyroxene and cordierite hornfels (and local garnet-clinopyroxene skarn) along the flank of the Mt Carbine granite to the east. The magnetic high running straight into the pit needs to be understood in this context: Andy White proposed the magnetic highs closer to the Mt Carbine granite were a signal of the contact metamorphism. All of this is consistent with hot, contact metamorphic-related fluids driving the tungsten mineralization system, and overprinting the earlier, lower temperature chlorite-dominant greenschist facies regional metamorphism.





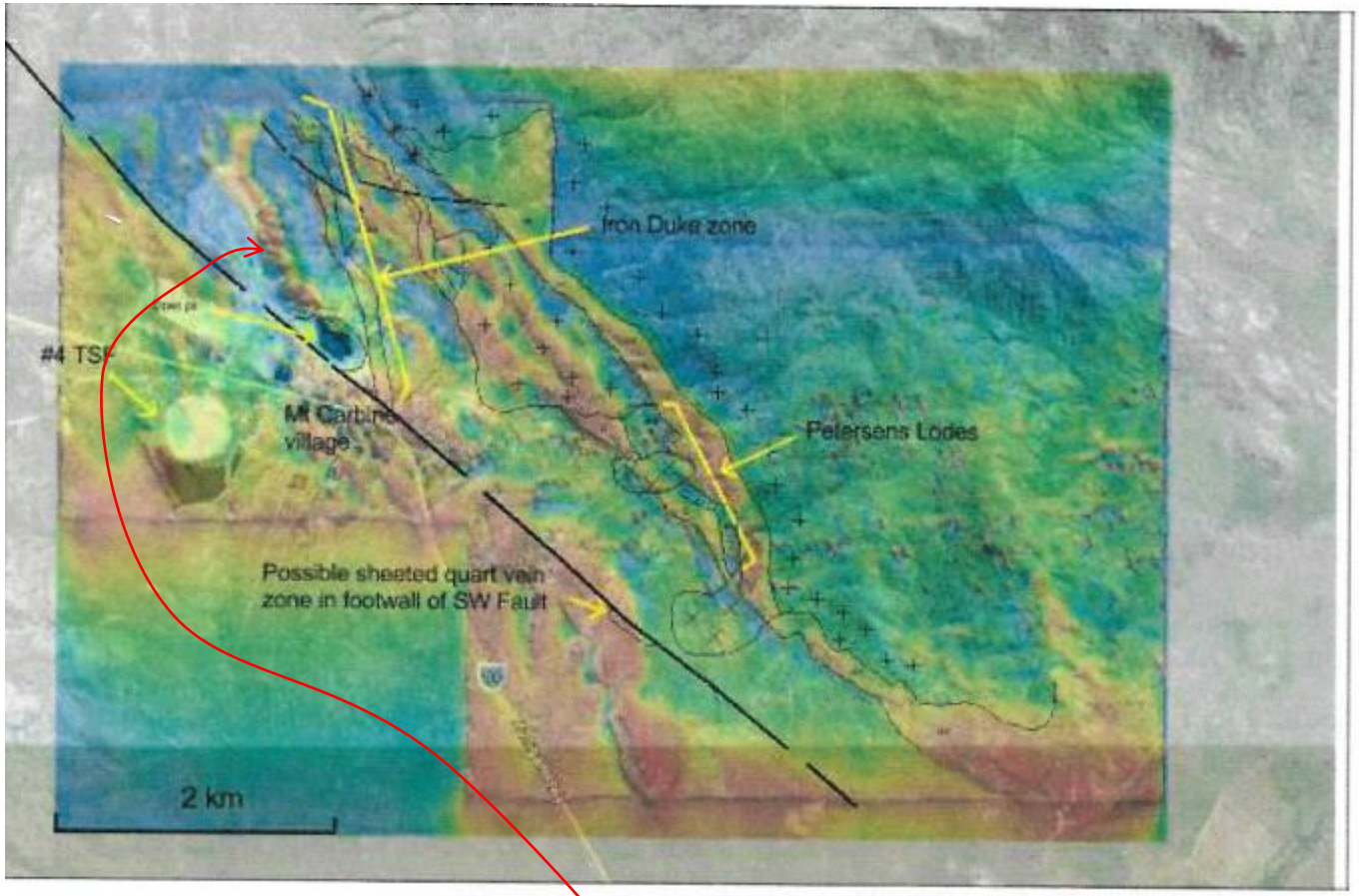


Figure 16. Geological map on Google image, draped on high resolution airborne (helimag) magnetic image.

From Andy White's 2013 report. As he notes, the different magnetic units need to be mapped out and interpreted (e.g. this one!), and combined with whatever kinematic information is available from the SWF.

Proposed approach to structural study

Items requiring consideration for work plan or costing by the Specialty metals team (outside the specific proposed workplan for Nick Oliver consult) are indicated

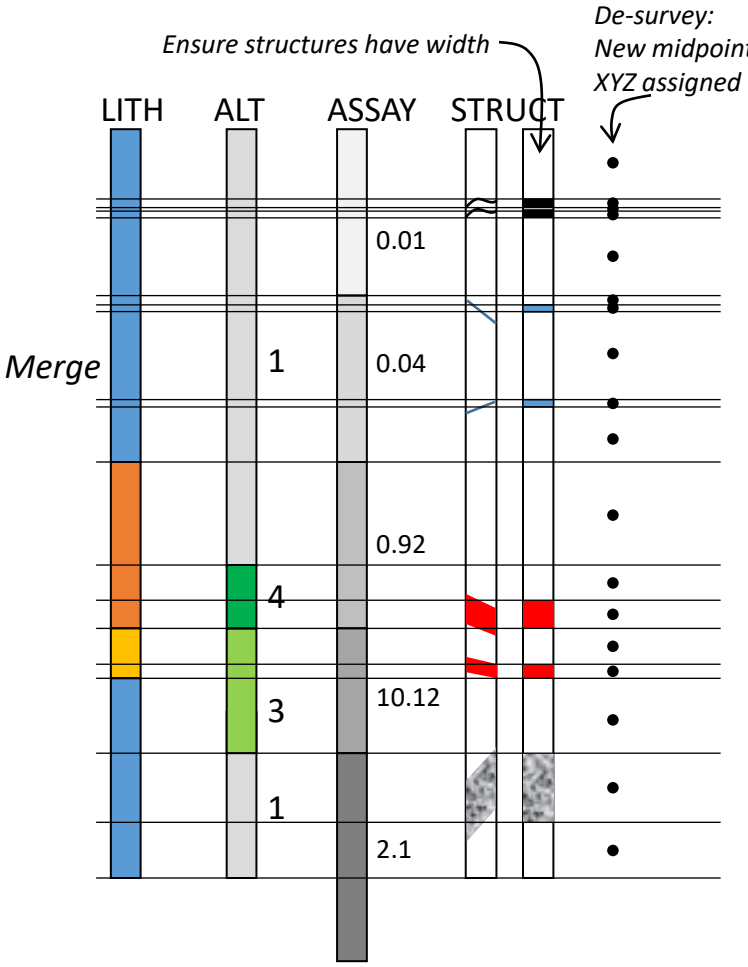
1. Preparatory and Field work
   - Prep: Negotiate/discuss what Dean and Tony might be able to do in advance of or during the proposed fieldwork (and afterwards as results get assembled). This might include firmly establishing all possible access tracks and points, seeing if there is a digital and/or printable version of the magnetics, locating any missing datasets, working out the best way to get the core sorted for examination and/or photography, and continuing to work on the Leapfrog model as results are produced (would possibly need Dean/Tony to get a licence on demand. If the final intent is to shift everything into Surpac then the question should be whether or not to purchase a separate full Leapfrog licence or just do it through me and Tony on a licence-on-demand)
   - Field/pit: Mapping units and fabrics with main view to potentially assist with determining offset on South Wall fault. Contacts and foliations, even mineralized veins, all have potential to show fault-related curvature that may assist reconstructing the offset. The broader distribution of the lithologies (to be combined with previous mapping) may also assist with this. The extent to which this mapping should be broadened into the general EL can be resolved during the site visit. I have the necessary mapping softwares (Clino) and QGIS, which I fully recommend to Dean and Tony. Dean and/or Tony to accompany as required.
   - Specific targeting of the South Wall fault: there are exposures in the pit walls that require further examination, along with the other faults that appear to bound or truncate in some way the mineralization. This will require some logistical effort.
   - Verifying aspects that can be inferred from the magnetics – what mappable rock units correspond with the magnetic patterning identified in Andy White's report?
   - Assemble all the above in QGIS using the appropriate Australian Map Grid that allows subsequent transformation into/out of mine grid as required

2. Drill core analysis

- If the core can be re-stored and later laid out adequately to ensure rapid progress while I'm on-site in July/August, it may be worthwhile trying to quickly log key holes to see if any key litho-boundaries can assist with the geometric reconstruction. This might also be possible with core photographs if this can happen in a reasonable time-frame, i.e. Dean/Tony and/or myself depending on timing etc
- Assess the geochemical database to assist with drill-hole selection and with logging of same
- Examine/determine the nature of the vein width/grade/spacing distributions from select holes, as a means to be able to constrain how the rest of the database is approached.
- Continue and persist with attempts to determine the specific movement vector on the SWF (and other faults as pertinent)
- There will be logistical core-handling needs during the time I'm on site, depending on what work (layout, photography, logging) can be achieved in advance of my visit)

3. Data analysis (there may be several bits-and-pieces of information transfer requirements during this stage)
   - Fuller assessment of previous data and reports to see what else needs to be considered
   - Try to determine the extent to which the previous recording of the mineralized zones in the pit and the drilling can best be used to identify trends, clusters, parcels of more mineralized material (continuing on from our on-line discussion of 2nd June)
   - Merge the structural database within the pit floor mapping and the drilling with the available assays (see method overleaf), to try to identify the specific orientation and extent of higher and lower grade parcels in 3D
   - Examine the details of the drilling intercepts with the known faults and logged rock boundaries (if any are useful and can be determined), and prepare to project/interpret/merge with the results from (and compilation of prior) field mapping
   - Work with Dean and his leapfrog models (using my licence on demand, USD$140/day) to bring in key surfaces, model new ones, and work out the best way to present and/or infer details within the 3D detail of the W orebody
   - Leapfrog outputs will be arranged in such a way that products can be ported into Surpac or Vulcan etc when it comes to that point. Leapfrog is the obvious tool for this given we will also be wanting to drape on the mapping results etc, and also because Dean already has made significant progress using Leapfrog.
   - We will need to find, or establish, a fool-proof way to ensure that UTM/MGA can be easily shuffled back-and-forth with the mine grid, and in 3D. For example, the traces of the strikes of the digitised veins are in mine grid and would have to be manually measured off the old maps in order to generate new data to fuse with newly-gathered field data

This procedure of “merge-and-desurvey” is a way to link together the structural measurements of veins with the grade information. This is easily done in Leapfrog, so that the results can then be examined (in ioGAS, I have licence) with stereographic projections and attributed structural data. The final processed product can then be ported back into Leapfrog to assist with the overall geometry and understanding of the tungsten.



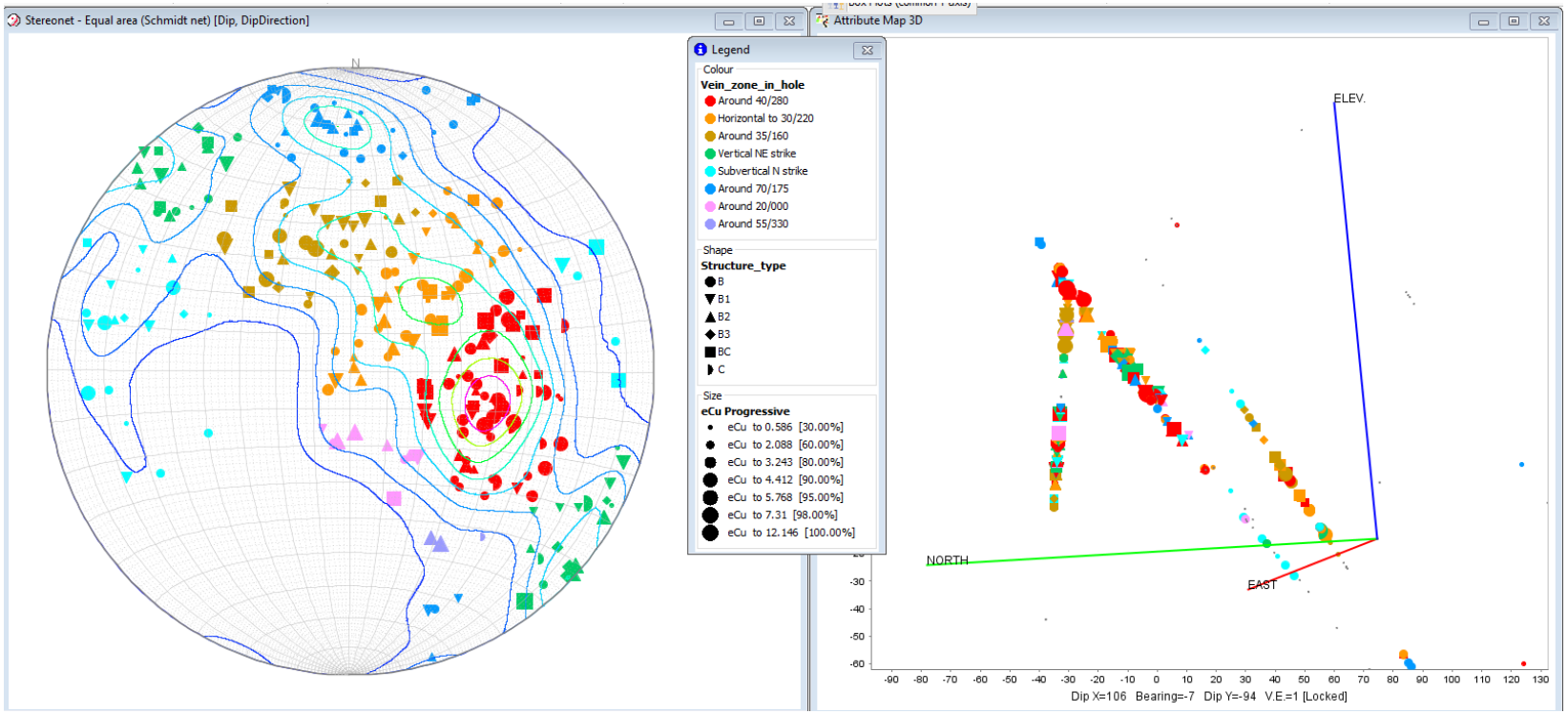
Structures now have assays, alt, lith assigned

DIP	DIR	ASSAY	ALT	LITH	X	Y	Z
		0.01	1	B	....	....	....
42	**102**	**0.01**	**1**	B	....	....	....
		0.01	1	B	....	....	....
45	**105**	**0.01**	**1**	B	....	....	....
		0.01	1	B	....	....	....
		0.04	1	B	....	....	....
24	**189**	**0.04**	**1**	B	....	....	....
		0.04	1	B	....	....	....
62	**298**	**0.04**	**1**	B	....	....	....
		0.04	1	B	....	....	....
		0.92	1	R	....	....	....
		0.92	4	R	....	....	....
31	**201**	**0.92**	**4**	R	....	....	....
		10.12	3	Y	....	....	....
41	**234**	**10.12**	**3**	Y	....	....	....
		10.12	3	B	....	....	....
12	**152**	**2.1**	**1**	B	....	....	....
		2.1	1	B	....	....	....

Merging diverse down-hole datasets

- Assign a width to all structural data (artificially if necessary, e.g. thin faults become 1cm thick, make “from” and “to” from downhole point depth for structures with no width assigned)
- Extract numerical data relevant to the cross-comparison: in particular here, vein width, vein orientation
- Can also include logged mineralogy, magnetic susceptibility down-hole, terra-spec point data etc
- Merge and desurvey all data intended for cross-comparison
- Then each defined piece of XYZ-space has attributes from all of the datasets
- Micromine, Leapfrog are two examples of programs that can do this

Example of outputs from another project



The grade is indicated by the dot size; the colours are then allocated based on their orientational clustering on the stereographic projection. Shapes can reflect something else, e.g. vein width, spacing etc and these shapes/sizes/colours can be swapped around for easy visualisation

The output then becomes a way of identifying different parcels of vein attributes (including orientation) in 3D. All of the points shown are all ‘tagged’ back to their specific location in 3D so they can be built into revised shapes in the orebody

4. Reporting

- Ppt presentation in similar style to this (unless you want formal word/pdf report, please specify)
- QGIS surface model combining all the surface datasets
- Selected parts of that ported into Leapfrog 3D model
- Leapfrog model with derived csvs and dxfs of new surfaces as defined by the work, suitable for export to Vulcan/Surpac
- on-line webinar etc to go through the results

5. Timing and scope

- If the bid for government funding is not successful, I would suggest a cut-back version of the plan that focusses on resolution of the SWF offset, with lesser focus on the database assessment and 3D model construction, e.g. for 7-9 days total, centred around a single site visit of perhaps 4 to 6 days (you decide on days/$)
- If the bid for funding is successful (21 days, i.e. in addition to this Phase 1 completed), I would propose something like this (not greatly different to earlier proposal):
  - 4 days reviewing the data prior to site visit (late July)
  - 9 days fieldwork and drill core inspection incl travel time (early August)
  - 8 days analysis, building 2D & 3D products, reporting, some of this might be usefully be on site/during fieldwork (August)
- Happy to adjust this back to 17 days total if you want to lump the 4 days completed work retrospectively into a 21-day total
- Happy also to consider two field stints if it makes more sense logistically, although the drive is reasonably gruelling (might consider flights if they get easier/cheaper, perhaps Dean could drop down from Kuranda to pick me up from Cairns in this case, to save on a rental)

Regards, *Nick Oliver*

11th June, 2020

Appendix G:
Report to RB Mining Pty Ltd on Mount Carbine Review of Rock Mechanics (Golder 1984)

R.B. MINING PTY. LTD. Copy 2

THE MT. CARBINE MINE
REVIEW OF
UNDERGROUND MINING PROPOSAL

APRIL 1984

HD034

GOLDER ASSOCIATES
CONSULTING GEOTECHNICAL & MINING ENGINEERS

No.7

Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

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REPORT

TO

R.B. MINING PTY. LTD.

ON

THE MT. CARBINE MINE

REVIEW OF

UNDERGROUND MINING PROPOSAL

APRIL, 1984

8361-0024

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SUMMARY

This report presents an independent review of underground mining proposals for the Mt. Carbine mine, with the objective of confirming the feasibility of underground mining and the cost estimates for financing purposes.

CONCLUSIONS AND RECOMMENDATIONS

1. Geology and Ore Reserves

1.1 The method of ore reserve estimation at Mt. Carbine, while unconventional, is well suited to the ore type and known structure of the deposit and has successfully predicted grade and tonnage for the present open pit operation. With minor qualifications, it should predict the grade and tonnage of the underground resource.

1.2 In the current ore reserve estimate, certain geological complications, namely the en echelon geometry, pitch, and vein mineralogy of the depth and eastern extensions of the Johnson-Wayback Zone, combined with lack of drilling, make the estimation of ore in this zone less certain than elsewhere.

1.3 Ore estimated between RL245m and RL145m and sections 22800E and 22925E in the Johnson-Wayback Zone or "North Stope" area of the present mine plan is less certain than in the remainder of the orebody This area comprises about 2 million tonnes or about 30 percent of the total ore reserve estimate (Ref. 3), and should be classified as Inferred Ore (not reserves). By conventional definition, the remainder would be of "Indicated" classification or unconventionally as "Drill Measured".

1.4 To upgrade this "Inferred Ore" of the Johnson-Wayback Zone, a diamond drilling program of five holes of aggregate depth about 1500 metres is necessary. Such a program would define the structure

and dimensions of ore reserves within the limits of the "North Stope" of the present mine plan. A study of vein mineralogy to establish any empirical relationship between ore grade and low grade mineralization is also necessary to enhance confidence in the ensuing interpretation.

2. Mining Methods and Layout

2.1 The proposed underground mining method is sound in concept and has a high potential for low unit mining costs because of the full use of gravity for ore extraction from stopes, use of conveyors to transport crushed ore to surface and the minimal labour requirement. When implemented, it will represent a significant breakthrough in underground mining technology.

2.2 Because of ground control considerations, some modifications to stoping layout are recommended. However, these modifications will not significantly alter the recoverable tonnes or grade of ore, change the basic concepts of the proposal or significantly increase capital and operating cost estimates. It is considered that further optimisation of the mine plan will be possible during the detailed design stage.

2.3 The types of equipment proposed for mine development and ore production are, in the main, well proven in practice. Some minor modifications to the equipment list are proposed. High standards of equipment operation and maintenance will be required to obtain the budgetted performances from the equipment since there will be no spare units available.

2.4 The anticipated costs and performances are the result of implementing a continuous mining system. Such systems have been applied for some time to underground coal mining but not, until now, to underground hard rock mining. These systems have high potential but require a

high degree of technical and operational control. Thus, highly skilled operators and a continuous input from qualified and experienced technical personnel will be essential, particularly in the early years of operation.

2.5 The recommended modifications to the basic proposal arising from the current review require to be detailed for approval by the relevant statutory authorities, before the project is finally implemented.

3. Cost Estimates

3.1 Estimated capital costs have been increased by $1.1 million, from $9.5 million originally estimated to $10.6 million. This arises mainly from additional equipment costs and underground development costs.

3.2 Estimated direct mine operating costs have been increased by $0.59 per tonne of ore delivered to the treatment plant, from $1.73 per tonne to $2.32 per tonne. This arises mainly from increases in stope development costs, stope ground support and a contingency factor of 15 percent on the basic unit cost.

3.3 Operating costs will be most sensitive in the areas of labour and explosives:

- a 20 percent increase in labour costs, due to increased manning or a significant rise in earning rates, will increase the overall operating cost by approximately 6 percent,

- a 50 percent increase in explosive costs, due to increased usage of watergel explosives, will increase the overall operating cost by approximately 6 percent.

3.4 Individual operating cost estimates have been averaged over a life of mine basis and are considered to have an order of accuracy of ± 25 percent. In order to obtain more accurate cost estimates, it will be necessary to prepare detailed development and production schedules, together with manning charts, on at least an annual basis, in order to determine the variation in operating costs over the life of the mine.

3.5 The proposed modifications to the stoping layout will not influence the capital costs and are estimated to increase the operating cost by not more than $0.24 per tonne. It is considered that this cost could be reduced by further optimisation of stope design in the detailed planning stage.

4. Possible Risks

The principal areas of risk in the project and the approaches necessary to minimise such risks are as follows:

4.1 The proposed mining system is a series operation and delays or breakdowns in any one area could stop production temporarily. High standards of operation and maintenance will be required to minimise this risk. (Note that the mining operation is scheduled for only five shifts per week and there is ample scope for rapidly replenishing stockpiles when mining recommences after delays).

4.2 Because of the required high standards of operation and technical control, it may be necessary to pay premium rates to attract suitable personnel. Such people also tend to attract higher than average wage escalation rates.

4.3 There is considerable flexibility in production rate but little flexibility in mined grade to counter future depressed metal prices.

4.4 The scheduled development rates for the decline and underground development, particularly the relatively complex stope extraction system, may not be achieved. This again highlights the need for

high quality engineering and supervision.

4.5 The stability of the extraction development beneath the stopes will be critical and production could be halted for significant periods if instability were todevelop in these areas. Thus, the excavations must be carefully designed and securely supported before stoping commences.

4.6 The proposed open stopes are very large and premature wall failures could prejudice production. For this reason, wall support and mass blasting have been recommended in the modified design. However, the mass blasts will require precise engineering and supervision since each blast will represent a significant proportion of the ore reserve.

GOLDER ASSOCIATES PTY. LTD.
per:

L. K. Walker

L.K. Walker

KJR/KEM/dg

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1. INTRODUCTION

1.1 Background Information

The Mt. Carbine mine is located some 140km north of Cairns in north Queensland, Australia. The mine has been operating as an open pit continuously since 1974, with a proven average recovered grade of 0.07 percent WO_3. The successful mining of such low grade ore has been achieved by an innovative approach to ore treatment, using photometric and X-ray ore sorters to upgrade the ore.

Due to the dramatic fall in tungsten prices since July 1981, the original open pit plan has become economically untenable. The plan has been modified to eliminate overburden removal and ore reserves in the reduced pit are scheduled to be exhausted by 1986 given a continuation of the current low price.

In response to this situation, S.B. Management Pty. Ltd., on behalf of R.B. Mining Pty. Ltd., have devised an underground mining system, with an innovative approach. It is planned to mine an underground ore reserve of 6.5 million tonnes over 7 years at a rate of 900,000 tpa. Predicted capital and operating costs are sufficiently low to permit operations to continue beyond the completion of the open pit. Because of the unusually low underground mining costs, it was considered necessary by R.B. Mining to obtain an independent review of the proposal.

1.2 Scope and Responsibilities of Review

The review has been carried out in four principal areas, with responsibilities as follows:

- geology and ore reserves
  - Dr. D.M. Ransom (D.M. Ransom and Partners)
- mining methods and layouts
  - Mr. K.E. Mathews and Dr. K.J. Rosengren (Golder Associates Pty. Ltd.)
- drilling and blasting requirements
  - Mr. J.K. Mercer (I.C.I. Australia Operations Pty. Ltd.)
- capital and operating cost estimates
  - Mr. A.J. Murphy (A.J. Murphy and Associates).

The review has been co-ordinated, and the final report prepared by Golder Associates Pty. Ltd.

All relevant reports, drawings, work sheets and records used in the feasibility study were made freely available by S.B. Management and R.B. Mining. A three day visit to the Mt. Carbine mine was made by Messrs Ransom, Mathews and Rosengren, during which time the existing mine and plant were inspected, drill cores were examined and detailed discussions were held with the mine staff.

In addition to reviewing the proposal submitted, various modifications are recommended to improve the feasibility and efficiency of the underground mining system. Further detailed planning will be required to incorporate these modifications into the mine plan. An estimate of the cost variations likely to result from the modifications is included and this will also require confirmation when the modified mine plan is completed.

2. GEOLOGY AND ORE RESERVES

2.1 Introduction

The Mt. Carbine Mine, North Queensland, is an open pit tungsten mine which has been operated by R.B. Mining Pty. Ltd. since 1976. It is the lowest grade hard rock producer in the world. Planning is currently in progress for an underground extension to the mine, employing a unique low cost mass mining method. It is planned to mine down dip extensions of orebodies exposed in the open pit. Central to this plan is an underground ore estimation report by Forsythe (Ref. 3) wherein a grand total of 6 452 500 tonnes in two stopes is calculated at an average recovered grade of .102 percent WO_3.

In this section, the method of ore reserve estimation and its geological basis is reviewed.

2.2 General Geology

The Mt. Carbine orebody is composed of two north-westerly striking wolframite and scheelite-bearing quartz-feldspar vein zones, 20 to 50 metres in width and 850 metres in length. These are the Johnson-Wayback Zone to the north and Bluff Zone to the south. The veins themselves are steep, tending to north-easterly dipping and average about 0.2 metres in width. They compose about 10 percent of the host rock by volume. Vein density defines "zones" which in turn comprise the ore. The orebody is truncated to the south-east by the north-west striking, north-east dipping South Wall Fault.

2.3 Previous Ore Reserve Practice

The nature of the vein mineralization at Mt. Carbine, that of coarse wolframite irregularly developed within narrow veins, causes significant problems in ore reserve estimation. Conventional sampling procedures, including diamond drilling, cannot be satisfactorily applied, hence ore reserve estimation has tended to be based on assumptions of structural

continuity and the relationship of quartz content and WO_3 grade.

Potential for bulk mining of the vein zones was recognized first by North Broken Hill Ltd.(Refs 4, 5). Previously, all hard rock production had been by underground mining of individual veins. North Broken Hill undertook a program of assessment involving vein quartz measurement in cross-cuts, which concluded that quartz composed 10 percent of rock in the main mined areas at an average grade-of-quartz of 2 percent WO_3. Three diamond core holes were drilled subsequently, which were assayed at 1.5m intervals. These showed large discrepancies between quartz and WO_3 grade, but WO_3 grade (recovered) was estimated at 0.12 percent, quartz percentage 10 percent and grade-of-quartz as 1.0 percent or 1.2 percent WO_3.

Taylor (Ref. 6), reviewing the data of North Broken Hill and previous mining for the ANZ Banking Group in 1971 concluded that there were no criteria for accurate grade calculations using drill core, and hence that a bulk test and further diamond drilling was required. He conceded that the vein quartz volume is an important indicator of whether a zone will be payable and that there was no reason for the vein concentrations to change with depth.

Forsythe (Ref. 3, Appendix I) summarized the open cut ore reserve estimates of R.B. Mining Pty. Ltd. These were based on the three original North Broken Hill drill holes, and six newly drilled holes which showed that the main quartz vein zones continued vertically below their previously mined positions. Ore grade was estimated from previous mining records, visual estimation of wolframite in two drill holes and grade obtained from the early stages of the current open pit operation. Estimates of 10 percent quartz averaging 0.90 percent WO_3 grade-of-quartz (0.072 percent WO_3 recovered) were applied to 15 million tonnes of "drill measured" and 13 million tonnes of "indicated" ore reserves in the proposed open pit area.

Campbell (Ref. 7) in a report to Australian Consolidated Minerals Ltd. in 1976, generally endorsed the ore reserve estimates of R.B. Mining Pty. Ltd.

The ore reserve was estimated as 13.2 million tonnes at 0.07 percent WO_3 recovered. Campbell estimated that the tonnage would be better than ± 10 percent accurate but noted that the grade figure was something of a "guesstimate".

These figures have been substantially verified in the present mining operation wherein 8 million tonnes of ore has been treated for a recovered grade of approximately .07 percent WO_3.

2.4 Present Ore Reserve Estimation

For the present ore reserve, the following procedure has been followed (Ref. 3):

(i) application of geostatistical techniques to recovered grade and tonnage from the open pit;

(ii) remeasurement of quartz veining in the nine original and ten further diamond drill cores;

(iii) revision of subsurface geology;

(iv) development of a subsurface orebody pattern and superposition of geostatistically estimated WO_3 values derived from the pit data on the pattern.

The application of geostatistics to the pit quartz volume and WO_3 recovered grade first by Mintec (Ref. 8) (two-dimensional kriging) and later by E. Brachmanski of R.B. Mining Pty. Ltd. (three-dimensional kriging) had a number of important ramifications for the conventional view of the orebody. Most importantly it showed that the relationship between quartz volume and grade-of-quartz was not, as previously assumed, constant. A large low grade but quartz-rich area in the north-west of the pit was shown to be present, reflecting a primary change in the

grade of WO_3. This had the effect of eliminating (as ore) the north-westerly (mine grid) extremity of the northernmost of the two major vein zones of the orebody. The three-dimensional kriging also illustrated a generally vertical trend of WO_3 values in the pit longitudinal projection, sensibly following structure.

Average percentage quartz contents were calculated for RL's 145m, 195m, 245m, 295m below the pit and ore blocks calculated by computer. The calculation was based on:

- the general pattern of kriged quartz percentage, grade-of-quartz, and WO_3 grade (recovered) from the RL355m bench;
- re-measured drill hole data to provide localized information on quartz content below the pit;
- the assumption of vertical dip of the vein zones, the low grade zone and the extremities of the vein system;
- interpretation of quartz vein concentration patterns from drill information and vertical projection.

A grand total, above and below RL295m, the maximum proposed pit depth, of 6 452 500 tonnes at an average pit recovered grade of .102 percent WO_3 was estimated.

2.5 Assessment

2.5.1 Method

The writer has no argument with the method of estimation described above. The use of geostatistical data has graphically illustrated the nature of grade distribution in the open cut, which provides a rigorous model for interpretation of the ore zones and estimation of ore reserves at depth. The method employed is more sophisticated but not dissimilar in principle to that employed by R.B. Mining

Pty. Ltd. prior to commencement of the open pit mine. The successful operation of the open pit during the past eight years clearly favours this type of analysis, albeit unconventional. The bulk sample provided by the open pit and the density of drilling allow confidence in the method of structural projection and grade estimation above RL245m.

However, below RL245m, i.e. 100m below the present pit floor, the density of drilling falls off. While not of great importance for the Bluff Zone, which is truncated by the South Wall Fault at approximately this RL, there are no drill holes in the Johnson-Wayback Zone between RL245m and RL145m and sections 22800E and 22950E. The structure is projected virtually from the pit floor to RL145m on section 22850E without drill confirmation of its continuity in the area of the eastern and depth extension of the "North Stope" of the current mine plan. Variograms from the Johnson-Wayback Zone in the open pit (Refs 3, 8) show ranges of recovered WO_3 and quartz percentage of 15m and 21m compared with 123m and 82m respectively in the Bluff Zone. These parameters indicate that considerably less certainty can be attached to projections of the Johnson-Wayback Zone and it is in this zone that the drilling is lacking. The respective estimation variances of the Bluff and Johnson-Wayback Zones lead to a similar conclusion. Further, since the current mine plan requires that initial production come from the "North Stope" area, the ore outlines in this area are fundamental to the successful commissioning of the underground mine.

2.5.2 Geological Uncertainties in the Ore Reserve Estimation

(i) Vein and Vein Zone Geometry

It is evident from Forsythe (Ref. 3, Plan 2) that the Bluff and Johnson-Wayback zones are composed of a set of veins of

en echelon geometry striking slightly north of mine east and also the strike of the zones which they define. Viewed at a low angle, the geometry is well illustrated in Forsythe (Ref. 3, Plan 2). Whether the en echelon array is defined by thickenings of through going veins or vein terminations, they exhibit the geometry of shear zone-generated tension gashes. The tendency of the veins to form en echelon arrays is quite prominent in the Ruby Zone, which is about 350m north of the open pit.

The en echelon veins in the Bluff Zone as indicated in the old workings are characterized by a regular periodicity within the vein zone itself. On the other hand, the Johnson and Wayback Zones are en echelon components of a larger vein zone of similar geometry to the Bluff Zone. This larger zone is characterized by a less regular periodicity of vein development which gives rise to the splayed character of the level interpretations of Forsythe (Ref. 3, Plan 10). This may be the fundamental geological reason for the low ranges in the variograms and high estimation variances in the Johnson-Wayback Zone, and the "spottier" quartz content and wolframite grades described by Mintec (Ref. 8).

Following from recognition of the geometric properties of the vein zones, the nature of the terminations of the vein zones at their eastern extremity (mine grid) bears on the ore reserve. The kriged quartz content and the old mine data suggest that the ore-bearing structure terminates by thinning of quartz veins in the vicinity of section 22950E in both the Bluff and Johnson-Wayback Zones. Kriged grade-of-quartz data show no significant decline in value. Hence it is clear that the ore-bearing structure essentially dies out at approximately this section. Drill holes east of the Johnson-Wayback Zone on section 22950E exhibit quartz contents in the

range of 3 percent, consistent with this interpretation. The structural termination of the Johnson-Wayback ore zone is undefined by the current drilling data. The zone may pitch vertically or steeply to the west - the low quartz content in drill hole CB22 on section 22975E suggests a pitch to the east is unlikely. Longitudinal sections of kriged wolframite in the open pit are ambiguous but a westerly pitch might be inferred from the blocks containing >.08 percent in sections 26350N and 26375N.

(ii) Mineral Zoning

A further geological factor bearing on the ore reserve is the nature of the low grade boundary defined in the kriged grade-of-quartz data which in turn defines the western limit of the ore zone in the pit. Observations of mineralogy of the veins on either side of this boundary are described by Forsythe (Ref. 3, Appendix III) as:

- having a high wolframite:scheelite ratio;
- containing significant potash feldspar;
- lacking prominent white mica selvedges.

These changes, which on present indications are transitional, are typical of mineral zoning phenomena which characterize vein-type tin-tungsten deposits. They may have a structural cause or represent phase changes related to a physico-chemical condition. In the west of the vein system, drilling suggests the boundary is effectively vertical in disposition, and from approximately section 22700E in the Bluff Zone and 22750E to section 22900E in the Johnson-Wayback Zone feldspar is prominent. West of 22700E and east of 22900E as shown in the drill cross-sections in Forsythe (Ref. 3, Plan 4) scheelite is more prominent. These observations are qualitative only.

However the reappearance of mineral assemblages similar to the western low grade zone in drill holes CB22 and CB7 west of the ore zone at 22900E suggests a mineralogical complication at the eastern end of the ore zone is a possibility. Although kriged grade-of-quartz data in the pit does not show a decline in grade similar to the western end of the ore zone, it is considered that the present drilling data are inadequate to define the situation at depth.

2.5.3 Definition of Ore Reserves

To summarize the above, three geological complications compromise the ore reserve estimation in the Johnson-Wayback Zone below RL 245m, as follows:

- the en echelon structural relationship of the Johnson and Wayback Zones;
- the pitch of the eastern termination of the Johnson-Wayback Zone;
- the presence of mineral assemblages indicative of low grade mineralization east of section 22900E.

These geological factors result in uncertainty in the ore reserve estimation in the Johnson-Wayback Zone below RL245m between sections 22800E and 22950E. This uncertainty is a result of lack of drilling in this zone. Without being precise, this area contains about 2 million tonnes or about 30 percent of the estimated ore reserve of Forsythe (Ref. 3).

By conventional definition (Aus.I.M.M., Ref. 9), the ore reserve at Mt. Carbine in the Bluff Zone and the Johnson-Wayback Zone above RL245m can be classified as "indicated". Unconventionally it might be referred to as "drill measured" in keeping with

previous practice at Mt. Carbine. The approximately 2 million tonnes of uncertain classification should be classified as an inferred ore (not reserves).

2.6 Further Work

To upgrade the classification of the approximately 2 million tonnes of inferred ore in the eastern and depth extremity of the Johnson-Wayback Zone, further diamond drilling is required. A program of five holes to test the area below RL245m and between sections 22800E and 22900E is proposed as follows:

Section	RL of Centre of Vein Zone Intersection	Approximate Total Depth (m)
22825E	195m	325m
22850E	245m	275m
22850E	145m	350m
22900E	195m	275m
22900E	145m	300m
	TOTAL say	1500m

Holes should be sited so as to intersect the vein zone as a whole as close as possible to the section and RL nominated, hence accurate location and survey of the holes is essential.

Concurrent with the proposed drilling program, a study is proposed to provide semi-quantitative data on vein mineralogy. The aim is to establish an empirical relationship between ore and vein mineralogy, and to map the interpreted low grade zone. Some petrographic work may be

required, but most data can probably be compiled by hand-specimen observation of drill core.

At the conclusion of such a drilling program, a reinterpretation of the structural geology and reassessment of the ore reserves in the Johnson-Wayback would be undertaken.

2.7 Conclusions

1. The method of ore reserve estimation at Mt. Carbine, while unconventional is well suited to the ore type and known structure of the deposit and has successfully predicted grade and tonnage for the present open pit operation. With minor qualifications, it should predict the grade and tonnage of the underground resource.

2. In the current ore reserve estimate certain geological complications namely the en echelon geometry, pitch, and vein mineralogy of the depth and eastern extensions of the Johnson-Wayback Zone, combined with lack of drilling make the estimation of ore in this zone less certain than elsewhere.

3. Ore estimated between RL245m and RL145m and sections 22800E and 22925E in the Johnson-Wayback Zone or "North Stope" area of the present mine plan is less certain than the remainder of the orebody. This area comprises about 2 million tonnes or about 30 percent of the total ore reserve estimate of Forsythe (1984), and should be classified as inferred ore (not reserves). By conventional definition, the remainder would be of "indicated" classification or unconventionally as "drill measured".

4. To upgrade this "inferred ore" of the Johnson-Wayback Zone, a diamond drilling program of five holes of aggregate depth about 1500 metres is necessary. Such a program would define the structure and dimensions of ore reserves within the limits of the "North Stope" of

the present mine plan. A study of vein mineralogy to establish any empirical relationship between ore grade and low grade mineralization is also necessary to enhance confidence in the ensuing interpretation.

2.8 Recommendations

It is recommended that:

1. A five hole 1500m diamond drilling program should be undertaken to test the depth extension and eastern extremity of the Johnson-Wayback Zone.

2. A study of vein mineralogy and its relationship to ore and low grade mineralization should be undertaken concurrently with the drilling program.

D.M. Ransom

D.M. Ransom
Consultant Geologist

DMR/dg

3. MINING METHODS AND LAYOUTS

3.1 Proposed Method and Layout

The proposed underground mining layout is shown, in general terms in Drawing No. 300.0.002 F. This layout envisages two large open stopes which would daylight in the bottom of the open pit. Access to the various mining levels is by a 1 in 6 gradient decline and ore is brought to surface by a conveyor system installed in this decline.

Features of the proposed mining system include:

(i) The decline would be mined using an hydraulic drilling jumbo, with a Haggloader mucking, by means of a short mobile conveyor, on to the permanent conveyor which is progressively installed as the decline advances.

(ii) Stope blasting would utilise large diameter (165mm and 200mm) vertical blastholes drilled from the pit bottom and from an intermediate drilling level at approximately mid stope height.

(iii) Broken ore would be drawn by gravity from pyramidal undercuts through chain controls and a Ross chain feeder to an underground crusher and thence to the decline conveyor system. Oversize rocks would be retained on a grizzly and broken before entering the crusher.

The proposed system is sound in concept. It is effectively a continuous mining system and has a high potential for low unit mining costs because of:

- selective mining of the higher grade zones only
- use of large diameter blastholes in stope blasting
- full use of gravitational energy in moving broken rock from the stope to the decline conveyor
- elimination of underground mobile loaders

- use of conveyors for transport of ore to surface
- extensive use of electric power
- minimal labour requirements.

When implemented, it will represent a significant breakthrough in underground mining technology. Some modifications of detail are recommended in the following paragraphs but these do not affect the overall mining concept which is considered to be technically feasible.

3. Ground Control Aspects

The open stopes are large by current standards. The main stope has dimensions of 160m high x 190m long x 70m wide above the undercut level, while the western stope has dimensions 120m high x 95m long x 60m wide. Because of the large wall exposure, some slabbing from the walls will occur and reinforcement of the walls by cable bolting is recommended. This is discussed in more detail later in this section.

The stope design has been constrained by rock mechanics limitations recommended by Piteau and Associates (Refs 10 and 11) as follows:

- a minimum of 12m of intact rock should be left in place to buttress the South Wall Fault
- the maximum exposure of the wall adjacent to the fault should be limited to 50m.

These constraints have resulted in the formation of two pillars in the proposed stope design:

(i) a transverse pillar, with a minimum thickness of 10m, between the two stopes;

(ii) a pendant longitudinal pillar within the main stope.

In view of the slenderness of these pillars and the large wall exposures, it is considered that these pillars will not be stable and some modification to the stope design will be necessary.

The Piteau rock mechanics recommendations were originally related to the stability of the south wall in an open pit extending to RL205. In this context, they were quite reasonable since open pit operations were required to be carried out at the toe of this wall. However in an underground operation, the mine operators are protected by underground openings which are of small dimensions; these can be adequately supported and the above constraints need not necessarily apply.

There appears to be no valid reason for limiting mining against the South Wall Fault since the fault is gouge filled and is clearly very weak. This fault will form a natural break line for any rock failure during stoping in this area. Inspection of drill cores (CB20 and CB21) shows that, below a depth of 30m, the rock behind the south wall is unweathered and reasonably competent. The main structural weakness is a well developed foliation which dips near vertically. For this reason, it is considered that it would be acceptable to mine to the fault in the underground operation. If this recommendation is adopted it will also be necessary to mine to the fault in the open pit since, if this is not done, a large block of rock would be undercut by the stoping operations and would be clearly unstable.

An alternative stope layout incorporating these recommendations has been prepared. This layout envisages two open stopes, one abuting the South Wall Fault and the other in the north-east part of the pit bottom. These stopes are separated by a longitudinal (east-west) pillar which, however, has limited dimension since the east wall of the south stope slopes up at 55°. It is planned to mine the open pit to a horizontal surface, covering the proposed stoping area, at RL315. The South Wall Fault will be exposed over a vertical height of 55m and it is planned that the exposed wall will be intensively cable bolted in order to:

- protect the open pit operations
- ensure stability of the upper part of the wall when stoping proceeds below the base of the open pit.

The modified stoping layout will provide a somewhat greater tonnage of ore at a similar grade to that in the existing stoping proposal.

The following modifications and additions are recommended to the proposed stoping layout and are equally applicable to the modified layout, in relation to rock mechanics aspects:

(i) In the modified layout, the north stope should be mined first and progressively filled with plant reject while the south stope is being mined. Mining of both stopes would retreat from west to east (to minimise the influence of the east dipping joints which have caused fragmentation problems in the open pit operations). With this sequence, the longitudinal pillar is not formed until the last stage of the mining operations and only after the north stope has been filled.

(ii) The stopes would be mined by mass blasting in order to minimise stope wall exposures, improve fragmentation and give some support to the stope walls during drawdown. In this way, any dilution from wall failure would fall on top of the broken ore and have minimal effect. It would also minimise the requirement for hole charging adjacent to freshly blasted walls and the crests of such walls could be presupported by cable bolting.

(iii) The permanent stope walls should be smooth blasted using parallel holes and reduced charge densitites. The walls should also be pre-supported by cable bolting at all available locations (i.e. top, middle and bottom of walls).

(iv) The proposed method of progressively silling out the intermediate drilling level is not feasible from a ground stability viewpoint. The intermediate level will require a pattern of drilling drives and crosscuts and some angled blastholes will be required in the lower half of the stopes. The drilling level

layout must include a perimeter drive to permit cable bolting of the walls at this level and parallel blastholes along the stope walls. The modified level development layout should not increase operating costs since much less rock is drilled, blasted and handled on this level. Drilling and blasting costs will be slightly increased by the need to use angled blastholes and an additional requirement for watergel explosives.

(v) The proposed method of silling out to 20m x 20m dimension on the undercut level is also not considered feasible from a ground stability viewpoint. The pyramidal undercuts will be required to be developed by ring drilling from a perimeter drive on the undercut level. The cost of this method should not be significantly different from that in the existing proposal.

(vi) Some degree of ground support will be required in most of the underground development. Swellex rock bolts will be suitable for the normal development but longer cable bolts will be required in the larger excavations, e.g. crusher chambers and pump sump. The following recommendations for ground support are made:

- decline - first 50m - lagged steel sets
  next 150m - 5 bolts/metre plus mesh
  remainder - 2 bolts/metre average

- level development - 4 bolts/metre average.

Unit cost of ground support will be small because of the high tonnes/metre development in the proposed stoping method.

(vii) Particular attention will be required to ground support in the extraction development immediately beneath the stopes, because of the large volume of broken rock which will be required to pass through this area. There is some scope for detailed modifications to this development to increase stability and

to reduce ground support requirements.

(viii) It is proposed that the stopes would be filled with treatment plant reject as they are completed. This could be achieved at little cost since the plant reject now being transported to the waste can be diverted directly to the completed stope. At the conclusion of final mining there will be an unfilled void which may have to be filled.

3.3 Mine Equipment

The individual pieces of equipment proposed for the mining operation are, in general, well proven for their proposed application either on site or elsewhere. Relevant comments are as follows:

(i) The proposed method of driving the decline, using a Haggloader mucking directly to the permanent conveyor system is, to our knowledge, a novel approach. The method appears to be sound but precautions will be required to ensure that the conveyor system is not damaged by face blasting and that provision is made to handle large rocks produced by face blasting.

(ii) The Atlas Copco Boomer development jumbo and Simba ring drilling rig, both equipped with hydraulic rock drills, are well proven machines for their proposed application.

(iii) It is proposed to use the existing Ingersoll-Rand T4 drilling rig to drill 80m deep blastholes from the bottom of the open pit. This type of rig has been used successfully for this purpose at Ardlethan, including a 93m long V.C.R. raise. However, it will be essential for the rig to be fitted with rod stabilisers and particular care will be required in operation to achieve the desired drilling accuracy.

(iv) The Atlas Copco Promec M188 underground drilling rig is proposed for drilling 165mm blastholes from the intermediate drilling level. This is a relatively new machine which, however, has been

extensively tested at the Swedish test mine. Mount Isa Mines (Ref. 5) routinely drill 100m deep 200mm diameter blastholes, including angled holes, from underground development using Robbins 11MD and 12MD rotary drills and the application of such machines to Mt. Carbine should be further investigated. Irrespective of machine, careful attention will be required to setting up to achieve the required drilling accuracy.

(v) Ore extraction and crushing equipment (chain controls, Ross chain feeder, Jaques jaw crusher) are all well proven equipment. A similar crusher has already crushed 10 million tonnes of material at Mt. Carbine. If a Stamler type feeder breaker proves to be feasible for the Mt. Carbine ore, smaller crusher chambers would be required, with savings in excavation and support costs.

(vi) The proposed conveyor systems are conventional and well proven.

(vii) It is likely that at least one small mobile loader will be required for mucking short development ends, such as will be required on the intermediate drilling level, where it would be inconvenient to use conveyors. It is understood that an existing loader from the open pit operations will be used for this purpose.

GOLDER ASSOCIATES PTY. LTD.
per:

K.E. Mathews

K.J. Rosengren

KEM/KJR/dg

4. DRILLING AND BLASTING REQUIREMENTS

4.1 Summary

This section reviews the proposals for drilling and blasting at Mt. Carbine summarised in reports dated May 1983 (Ref. 12) and February 1984 (Ref. 13). It also includes comments on a later modified proposal (refer Section 3 of this report).

4.1.1 Explosives/Blasting Technology

It is likely that new or modified existing explosives (e.g. emulsions and emulsions/ANFO mixtures) and explosives accessories will be available when the project commences. However the concepts and practices covered in the above reports are in complete accord with the present state of explosives and blasting technology.

In general, the blast design parameters and geometry and the initiation systems proposed for Mt. Carbine are sound. However it is desirable that (for large diameter blastholes) the detonator sensitive 'MOLANITE' 115 be replaced by a blasting agent such as AQUAPOUR 108 which can also be made at the Mt. Isa Explosives Factory. This step will then make all explosives systems compatible with the proposed non electric initiation system.

4.1.2 Mass Blast Concept

The proposed mass blast technique confers many advantages over conventional open stoping. However, more holes will be wet thus requiring the use of more costly water resistant explosives. This factor arises out of the new conceptual design where silling out of the undercut and intermediate drill level is replaced by conventional drill drives and crosscuts. Thus less holes will break through and be self draining. It is considered that the slightly higher blasting cost is warranted by the consequential

improved safety (in operating conditions) and production capacity.

4.1.3 Surface Explosives Facilities

Present surface facilities are marginal for the mass blast system. However, scheduling of explosives deliveries, some underground magazine storage, the hiring of bulk equipment for the period of charging the mass blast, and the installation of a small central ANFO mixing station will remedy the situation.

4.1.4 Manpower

Both the mass blast and conventional open stoping systems are predicated on the basis that experienced and skilled miners are available. Skills can be learnt through suitable training and from responsible knowledgeable supervisors.

4.2 Decline and Horizontal Development

Although the majority of mechanised driving in Australian underground mines is carried out with blasthole diameters less than 51mm there is no valid reason why 51mm diameter blastholes should not be used. Indeed, there are many advantages to be gained by adopting that size - as mentioned in the reports.

It will be necessary to exercise strict control in order to obtain advance rates per blast of 95 percent of the blasthole length - even using relief holes longer than the normal drive holes. An overall 92 to 93 percent performance rating is more likely, with only 90 percent being obtained initially.

The proposed blast design is sound, as are the explosives estimates. Although the times allocated to individual unit operations in Table 6

of Ref. 13 will vary for a number of reasons, there should be no difficulty in attaining the anticipated cycle time.

4.3 Inverted Pyramid Undercuts

The change in overall mining design means that excavation of the undercuts will be different to that given in Ref. 13. Because of the need to maintain brow integrity at the bottom of the undercuts (for chain control, etc.), the lower 6 to 8m of the undercuts will require hand mining.

The inclined cut off 2.3m x 2.3m raises (forming the basis to excavate the undercuts) will now be in the centre of the west or east walls of the pyramids. These raises can be excavated as covered in Ref. 12. It will be necessary to follow the recommendations closely in order to obtain acceptable performance.

A central cut off drive (4.5m x 5.5m, say) along the east-west axis will enable a central cut off slot to be excavated, thus facilitating the blasting of rings drilled from the east and west cross-cuts on the undercut level, with angled trim holes from the north and south access drives.

The overall procedure and sequence of operations to excavate the undercuts are different to those given in Ref. 13, but similar principles can be adopted. However, a higher proportion of blastholes will possibly be wet and demand the use of water resistant explosives, thus increasing costs.

4.4 Expansion Boxes

To facilitate mass blasting and provide sufficient voids into which to blast, expansion boxes between the bottom of the open cut (at RL305) and the undercut level will be required. As described in Ref. 13, the

cut off raises can be excavated by either raise boring or by using vertical crater retreat (VCR) mining techniques. For VCR raising, accurate drilling and careful, controlled blasting are prerequisites. With proper supervision and careful training of drillers and shotfirers, procedures recommended in the report can be followed in order to obtain satisfactory performance - even though 80m VCR raises are not common.

In the north stope, two expansion boxes, 30m (east-west) x 25m (north-south) are required for the mass blast design. The basic principles outlined in Section 6 and Figs 11 and 12 of Ref. 13 can be used to excavate the box with vertical 200mm diameter down holes (drilled from the surface) blasting into a north-south cut off slot.

Similarly, for developing the expansion boxes between the intermediate drill level (85m below the floor of the open cut) and the undercut level (75m below the intermediate drill level) the concepts given in Section 6 are still valid. Hole lengths will need to be altered to suit and the box can be excavated from rings drilled out from drives along the north and south boundaries on the intermediate drill level.

In blasting the expansion boxes, it should be possible to use longer individual charge lengths than those given in the report, as experience is gained. Certainly, it is vital that the charge lengths be kept short initially, particularly close to the cut off raise.

A higher number of holes will not break through (compared to open stoping with silled out horizons where most holes will break through) and therefore the proportion of wet holes will increase with concomitantly higher explosive costs.

4.5 Mass Blasting

The mass blast concept calls for two major blasts in the north stope and three in the south stope. For the north stope, the west end

(i.e. using the east boundary of the west expansion box) is blasted into the west expansion box and the east end is blasted into the east expansion box and the void of the west expansion box.

The overall stope design is somewhat different from that proposed in Ref. 13 but the principles illustrated in Fig. 17 (200mm diameter blastholes) and Fig. 18 (165mm diameter blastholes) can be followed for the mass blasts. The blast parameter and geometries are soundly based, as are the performance factors. As well as vertical holes, it will be necessary to drill some declined 165mm diameter blastholes (rather than all vertical holes) from the intermediate drill level, with a consequential increase in overall drilling meterage. However, little in the way of blast efficiency will be lost.

The proportion of breakthrough holes will be small compared with the open stoping/silling method and therefore the number of wet blastholes will be proportionately greater. Accordingly, blasting costs will be somewhat higher.

Note that the increased costs of using higher quantities of water resistant explosive can be offset to some degree by using a less costly explosive than 'MOLANITE' 115, e.g. AQUAPOUR 108 which can also be made at the Mt. Isa Explosive Factory.

A blasting agent such as AQUAPOUR 108 has an added advantage in that the conventional proposed non-electric initiation system of slider/primer and 5g/m detonating cord downlines can be used. With detonator sensitive 'MOLANITE' 115, either electric delay or 'NONEL' delay detonators would have to be used.

4.5.1 Mass Blasting Compared to Long Hole Open Stoping

Mass blasting requires careful design and planning and strict attention to detail in order to be successful. The consequences

of failure are potentially high unless design and operating procedures are given this painstaking approach.

However, the many advantages to be obtained from mass blasting means that a number of mines now use the principle as a matter of course. (Some examples include Mount Isa Mines, Mount Lyell and Mount Charlotte in Australia and INCO, Kidd Creek and COMINCO in Canada).

The inherent advantages of mass blasting include:

- safer working conditions as drilling and blasting crews are not working near or under large expanses of freshly blasted rock,
- concentration of effort enabling efficient use of resources under close supervision and control,
- decreased opportunity for slabs and/or large blocks of rock to fall from a number of freshly blasted faces,
- improved fragmentation as a result of the advantages accruing from the use of optimum multi row firing rather than 2 or 3 row firing (as well as less wall fall off), and
- more readily achievable production schedules due to large broken ore inventory.

4.6 Surface Facilities

The mine presently has capacity to carry 40t of high explosives and 80t of Ammonium Nitrate. ANFO is mixed as required in a 1.4t capacity lift on/lift off mixing unit which is currently permanently truck mounted.

For a mass blast of approximately 900,000t some 133t of explosives will be charged from the intermediate drill level (to the undercut level) and 153t from the surface (to the intermediate drill level). Therefore, present ANFO facilities are adequate if charging is completed over 3 to 4 weeks (assuming that only 40 percent of the holes break through and can be charged with ANFO; it is possible that the proportion of dry holes will be less than 40 percent).

By allowing a capability for some underground explosives storage, there is no need to increase surface magazine capacity. This statement assumes that explosives delivery schedules are tightly controlled and/or on site manufacture (e.g. mix-pump truck) considered. Either or both possibilities are entirely feasible and on site manufacture of bulk products for surface charging will free packaged explosives for underground use.

It will be desirable to set up a COXON mixer to manufacture ANFO and ANFO/polystyrene for perimeter and pillar line holes. Such a surface installation will cost about $3,000 to $4,000.

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JKM/dg

5. CAPITAL AND OPERATING COST ESTIMATES

5.1 Introduction

This review is based on cost estimates presented by S.B. Management Pty. Ltd. in the 1984 feasibility report (Ref. 1) and supported by supplementary reports and quotations, as follows:

- drilling and blasting (Ref. 13)
- electrical installations (Ref. 15)
- conveyor installations (Ref. 16)
- mechanical equipment quotations.

In general, these reports and quotations were prepared for an earlier study dated May, 1983 and upgraded for the present study. In some instances, upgraded quotations were obtained as follows:

- Jaques Limited, Vickers Ruwolt — upgraded for escalation due to time difference
- Atlas Copco — current quotations for equipment and consumables
- D. Richardson — alternative proposal.

Features of the feasibility study relevant to the cost estimates are as follows:

(i) Design parameters
- 250 working days per year
- total diluted mineable ore reserve - 6.452 million tonnes
- annual mining rate 900,000 tonnes

(ii) Only one underground crusher is required; this will be relocated as individual stopes are completed. Surface stockpiles will maintain production during crusher moves and during other underground production interruptions (e.g. during cyclonic storms).

(iii) Electric power requirements will be minimised by staggering production operations, e.g.

- production drilling on day shift
- crushing and conveying on afternoon shift
- pumping from sump during weekends (production ceases and all power to pumps during cyclonic storms).

(iv) Existing mine staff will supervise decline and main development excavation. Additional supervisors will be recruited when ore production commences.

(v) It is planned that the Ingersoll-Rand T4 drill will be used for production drilling from bottom of open pit. An existing front-end loader and grader will be utilised in the underground operation.

(vi) Exploration drilling (refer Section 2) is included in a separate exploration budget.

The cost estimate review is based on the original stoping layout outlined in the 1/84 feasibility study (Ref. 1). However, an estimate is made of the variation in costs likely to arise from the modified stoping layout (refer Section 3). All costs are quoted in March 1984 Australian dollars. All cost calculations are detailed on work sheets (available separately if required) and only summaries are presented in this report.

5.2 Capital Cost Estimates

5.2.1 Equipment

All equipment listed for the project is considered satisfactory for the respective duty requirements.

Equipment cost estimates are summarised in Table 5-1. Variations to the original estimates are as follows:

(i) updated quotations on major equipment
- net increase $6,150

(ii) allowance for stores to include major equipment spares
- increase $100,000

(iii) allowance for small mining equipment (e.g. rock breaker, rockdrill, chain saw)
- increase $40,000.

Total capital equipment estimate is increased from $1.557 million to $1.703 million, an increase of $0.146 million or 9 percent.

5.2.2 Underground Development

Capital cost estimates for underground development are summarised in Table 5-2. Total cost estimate has been increased from $7.984 million to $8.915 million, an increase of $0.931 million or 12 percent.

Variations on individual items are as follows:

(i) Decline Development

Total cost of the decline, fully equipped, is increased by 4 percent. Unit cost is increased from $1,199 per metre to $1,248 per metre, attributable mainly to variations in labour and power costs.

(a) Labour

In Ref. 13, an average labour cost of $173 per shift is assumed for all classifications. It is considered that higher rates should be used for some classifications (refer Section 5.3.1 below),and a more appropriate figure is $190 per shift plus 32 percent on cost, i.e. $250 per shift.

(b) Power

Power costs in the feasibility study (Ref. 1) relate to production costs only and no allowance has been made for power costs in development. Development power costs for the decline are estimated to be $53.29 per metre.

(ii) Sub-Level Development

Total cost of sublevel development is increased by 39 percent, with unit cost increased from $652 per metre to $907 per metre. This arises mainly from increases in labour and power as discussed above for the decline. The estimated development cost is in line with current costs using conventional loading and hauling equipment; the major cost savings in this project arise from the use of conveyors for production haulage.

(iii) Grizzly Complexes

Total cost of excavation and support of the grizzly complexes is increased by 35 percent, arising mainly from increased allowance for:

. mucking	$ 30,000
. conveying	$ 7,800
. ground support	$ 14,200
	$ 52,000

(iv) Pump Sump

Total cost of excavation of the pump sump chamber is increased by 192 percent arising from increased allowance for drilling, blasting, mucking and ground support. Components of cost are estimated to be:

. initial development		$121,500
. stripping		$116,154
. ground support		$ 10,000
		$247,654
	say	$250,000

(v) Crusher Stations

Jaques Limited advise that their original May 1983 budget price of $600,000 for a 48 x 42 jaw crusher mounted on a mobile platform should be increased by 10 percent, i.e. to a total of $660,000. Transport and installation costs remain unchanged at $77,000, giving a total cost of $743,000. There appears to be no allowance for excavating the crusher chambers which are estimated to be:

. drilling and blasting	$ 41,500
. mucking	$ 12,500
. conveying	$ 3,500
. ground support	$ 4,500
	$ 62,000

5.2.3 Total Capital Cost

The total capital costs for equipment and underground development are summarised in Table 5-3. The total estimated cost is $10.62 million, an increase of $1.08 million, or 11 percent, over the original estimate of $9.54 million.

5.3 Operating Cost Estimates

Operating cost estimates are summarised in Table 5-4. Total direct operating cost is estimated to be $2.01 per tonne, an increase of $0.29 per tonne, or 17 percent, above the feasibility estimate of $1.73 per tonne. It is recommended that a contingency of 15 percent be applied to this figure (refer Section 5.3.4 below).

5.3.1 Labour Costs

The following average basic labour costs are proposed for this review, as being representative of current earning rates in the mining industry around Australia:

. jumbo development miners	$ 190 per shift
. air leg miners	$ 160
. blast hole drillers	$ 150
. blasting crews	$ 125
. loader drivers *	$ 125
. haulage drivers	$ 105
. underground crusher operators	$ 105
. underground labourers	$ 80
. underground supervisors	$ 106

* including Haggloader operators

To these figures must be added an oncost of 32 percent, comprised of:

. payroll tax	5.0 percent
. holiday pay	12.5
. sick leave	3.8
. public holidays	3.8
. long service leave	2.5
. workers compensation	4.4
	32.0 percent

(Reference: Mr. H. McCaig, Chief Accountant, R.B. Mining Pty. Ltd.).

Therefore, average total labour costs used in the study review are:

. jumbo development miners	$ 250 per shift
. airleg miners	$ 210
. blast hole drillers	$ 198
. blasting crews	$ 165
. Haggloader operator	$ 165
. underground crusher operators	$ 145
. underground labourers	$ 106
. underground supervisors	$ 140

These figures can be compared to an average labour rate of $173 per shift used in the feasibility study and therefore there will be variations in estimates, depending on the nature of the underground operations.

5.3.2 Explosive Costs

Variations in blasting costs, where applicable, were due to the adoption of actual costs at the Mt. Carbine mine (reference: telex Dayrell Wolff, Mine Manager to A.J. Murphy, dated March 26, 1984).

5.3.3 Conveying Costs

Operating costs for conveying ore from underground were adopted from reports prepared by Beltline Services Pty. Ltd. dated November 18, 1983. Beltline Services are specialists in this field and have considerable experience in materials handling with conveyors.

5.3.4 Underground Operating Costs

Variations from the feasibility estimates are summarised in Table 5-4 and are discussed below:

(i) Stope Preparation

- stope undercuts - reduction in costs of 7 percent due to reduction in cost of 55mm gelignite and variation in labour costs
- stope raises and slots - reduction of 2 percent
- silling out - increase of 267 percent due to arithmetic error in feasibility study

(ii) Stope Production

- increase of 8 percent due to higher drilling costs, particularly for 200mm diameter blastholes

(iii) Cable bolting

- Presupport of stope walls by cable bolting is considered essential to control wall slabbing (refer Section 3). This was not included in the original estimates and represents $750,000 or $0.12 per tonne.

(iv) Consulting Services

It is clear that a considerable amount of specialist technical advice will be required to ensure the success of the project. The requirement for this advice will be greatest in the early years and will decrease as operating experience is obtained. It is proposed that a figure of $30,000 per annum be included as an average over the life of the project.

(v) Contingency

Giving due regard to the skill and experience that has gone into the development of these operating costs, one must accept the fact that the concepts employed are unique and therefore there are several unknown factors not backed by historical knowledge.

Accepting the fact that everything goes to plan mechanically, consideration must also be given to the limited number of stopes and drawpoints which will be in operation at any given time, should any mishap occur in stope blasting or around the crushing station.

All individual operating costs are considered accurate to within ±25 percent. Therefore in quoting costs for a financial model some consideration of the degree of accuracy of the calculations should be made.

This is to some degree a matter of statistics and for this study a contingency of 15 percent is considered appropriate. When applied to the basic operating cost of $2.01 per tonne, this gives a total operating cost of $2.32 per tonne.

5.3.5 Sensitivity of Operating Costs

The following table gives a detailed breakdown of the major unit costs, based on 900,000 tpa at $2.316 per tonne.

	$/t	Percent	Annual Dollars
Labour (staff & award)	0.643	27.8	478,700
Drill consumables	0.189	8.2	170,100
Blasting materials	0.292	12.6	262,800
Ground control	0.122	5.3	109,800
Rilling/crushing/conveying	0.448	19.3	403,200
Power (not incl. in conv.)	0.043	1.9	38,700
Major provisions	0.133	5.7	119,700
Other	0.144	6.2	129,600
Contingency at 15 percent	0.302	13.0	271,800
Total	2.316	100.0	2,084,400

(a) Effect if total labour increased by 20 percent:

Increase = 0.2 x $578,700
= $115,740
= 5.5 percent of total operating cost.

(b) Effect if blasting materials cost increased by 50 percent:

Increase = 0.5 x $262,800
= $131,400
= 6.3 percent of total operating cost

Note that blasting materials generally have increased from 75 to 100 percent over the past six years (1978-1984). For example,

	1978	1984	Percent Increase
Nitropril	$248.80/t	$473.00/t	90
Molanite 95	$ 45.00/case	$ 79.00/case	76
ANGD75	$ 45.21/case	$ 84.00/case	86
Anzomex primers	$ 2.01 each	$ 3.95/each	97

Blasting material costs will, most likely, be more affected by a change in charging patterns (watergels replacing ANFO) rather than price increases.

(c) Drill Consumables

Drill consumables have not risen as much as explosives materials over the past few years due to stronger competition, especially with large orders. There is also more room to negotiate drill consumable contracts to keep prices down.

5.3.6 Accuracy of Cost Estimates

It is considered that the order of accuracy of operating cost estimates would be in the range ±25 percent, for the following reasons:

(i) Detailed stope development preparation and production schedules have not been prepared and operating costs are averaged over a life of mine basis. It would therefore be expected that operating costs in the early years would be higher than average and those in later years lower than average.

(ii) Detailed manning charts have not been prepared and labour costs have been estimated as a component of the various unit operations of the mining system. In fact, men are paid for a full shift including any non-productive time, and actual labour costs are likely to be higher than those estimated.

In order to obtain greater accuracy in cost estimates, it will be necessary to prepare detailed production and development schedules, together with manning charts, on at least an annual basis, and so calculate the variation in operating costs over the life of the mine.

Note that the capital cost estimates have a higher degree of accuracy since most of the equipment costs are backed up by dealer quotations and development costs are based on unit costs which are in line with current Australian mining costs.

5.4 Proposed Stope Design Modifications

As indicated in Section 3, it is considered that some aspects of the original mining plan are not feasible and that some modifications will be required to the original design. The principal modifications will be:

(i) It will not be possible to sill out the intermediate drilling level and lower blasthole drilling will be carried out from a pattern of development on the intermediate level.

(ii) As a result of (i), the upper blastholes will not all break through and there will be a higher proportion of wet blastholes.

(iii) Also as a result of (i) above, it will not be possible to drill all parallel holes in the lower half of the stope, and some additional drilling will be required.

(iv) It will not be possible to sill out the stope undercuts and the inverted pyramids will be formed by angle drilling from development on the undercut level.

(v) The stopes will be mined by mass blasting and two cut-off slots will be required per stope.

The additional cost arising from these modifications are:

(a) Intermediate drilling level

. silling out	$ 748,000
. development (1200m @ $900/m)	$1,080,000
. additional cost	$ 332.000
	= $0.05 per tonne

(b) Upper blastholes - assume 50 percent increase in explosive costs for 50 percent of ore reserve. From Ref. 13 weighted average cost of blasting materials is $0.34 per tonne and additional unit cost would be $0.09 per tonne.

(c) Lower blastholes - assume 20 percent increase in drilling costs for 50 percent of ore reserve. From Ref. 13 average drilling cost for 165mm blastholes is $0.231 per tonne and additional unit cost would be $0.02 per tonne.

(d) Pyramid undercuts - assume 20 percent increase in drilling and blasting costs. From Ref. 13 cost of each 40m x 48m pyramid is $46,000 and increase in cost will be

$$4 \times 46000 \times 0.2 = \$36,800$$
$$= \$0.01 \text{ per tonne.}$$

(e) Additional cut-off slots - from Ref. 13 cost for raising and slotting for two slots is $466,000. Therefore additional cost for two additional slots is $466,000 or $0.07 per tonne.

The total additional cost for the modified design is $0.24 per tonne. This figure will be reduced to some degree since the modified design requires only two crushing chambers and four pyramid undercuts and total ore reserve is increased by 800,000 tonne. It is also likely that this differential cost could be further reduced by optimisation of the stope design at the detail design stage.

A.J. Murphy
Consulting Mining Engineer

AJM/dg

TABLE 5-1

MECHANICAL EQUIPMENT COST ESTIMATES

	Feasibility Report - Feb. '84	Cost Overview - April '84	Variance Dollars	Variance Percent
Development Jumbo - H125-38	283,700	283,700		-
. Steel	5,300	5,300	-	-
. Transport	3,000	3,000	-	-
Production Jumbo - SIMBA H221, complete	227,000	234,270	7,270	+ 3.2
Haggloader 10HR, complete	307,350	291,230	-(16,120)	-(5.2)
. Transport	6,000	6,000	-	-
Production Drill - Promec M188	268,848	268,848	-	-
. Rod handling system	71,032	71,032	-	-
. Dust collection system	31,470	31,470	-	-
PT-60 carrier unit	41,000	41,000	-	-
Jetanol charging unit	14,626	14,626	-	-
Minimax PH 250	70,000	70,000	-	-
ER718 compressor	80,000	80,000	-	-
Personnel carriers (3 off)	30,000	45,000	+ 15,000	+33.3
Transport	18,000	18,000	-	-
Stores increase (major spares)	100,000	200,000	+100,000	+100.0
Small mining equipment	-	40,000	+ 40,000	
	1,557,326	1,703,476	+146,150	+9.3

Note: All costs in March 1984 Australian dollars

TABLE 5-2

CAPITAL DEVELOPMENT COST ESTIMATES

	Feasibility Report - Feb. '84	Cost Overview - April '84	Variance Dollars	Variance Percent
Portal establishment	74,125	76,000	+ 1,875	+ 2.5
Haul road culvert	42,700	45,000	+ 2,300	+ 5.3
Surface conveyors	354,816	374,816	+ 20,000	+ 5.6
10,000 tonne ore bin & surface tunnels	48,700	50,000	+ 1,300	+ 2.7
Feeder from bin	21,325	21,325	-	-
Surface conveyor chutes & discharge tower	123,455	127,755	+ 4,300	+ 3.5
Electrics completed	1,249,340	1,249,340		-
Main haulage & decline conveyors, ($1,081,593 allowed for in unit costs)	-	-	-	-
Sub-level conveyors complete	186,100	186,100	-	-
Underground crossovers complete	123,326	124,626	+ 1,300	+ 1.1
Underground feeders (2 off)	42,658	42,658	-	-
Underground change room/cap lamps	80,000	80,000	-	-
Decline, 5.5M x 4.5M fully equip. 2/3 dry: 1/3 wet - 2,151 metres	2,579,049	2,684,448	+105,399	+ 4.1

continued overleaf

TABLE 5-2 (contd)

	Feasibility Report - Feb. '84	Cost Overview - April '84	Variance Dollars	Variance Percent
Sub level drives & crosscuts (5.5M x 4.5M) 2/3 dry: 1/3 wet - 1,745 metres	1,137,740	1,582,715	+444,975	+ 39.1
Service rooms underground	25,100	25,750	+ 650	+ 2.6
Rilling, grizzly, breaking chamber	150,000	202,000	+ 52,000	+ 34.6
Pump sump	85,500	250,000	+164,500	+192.4
Crusher complete, installed	677,000	737,000	+ 60,000	+ 8.9
Ross chain feeder complete, installed	175,000	180,000	+ 5,000	+ 2.9
Equipped sizing chamber equipment	190,000	190,000	-	-
Steel rills - 2 off @ $94,000	188,800	188,800	-	-
Ventilation raise	295,500	300,300	+ 4,800	+ 1.6
Dewatering pumps complete	134,000	134,000	-	-
Excavations - Crushing Chambers	-	62,000	+ 62,000	-
Total:	7,984,234	8,914,633	+930,399	+ 11.6

Note: All costs in March 1984 Australian dollars

TABLE 5-3

TOTAL CAPITAL COST ESTIMATES

		Feasibility Report	This Review	Variance Dollars	Variance Percent
(i)	Equipment	1,557,326	1,703,476	+ 146,150	+ 9.3
(ii)	Development	7,984,234	8,914,633	+ 930,399	+ 11.6
	Total:	9,541,560	10,618,109	+ 1,076,549	+ 11.2

Note: All costs in March 1984 Australian dollars.

TABLE 5-4

OPERATING COST ESTIMATES

		Feasibility Report	This Review	Variance Dollars	Variance Percent
1. Stope Preparation					
Stope undercuts		195,142	182,297	- (12,845)	- (6.6)
Stope raises and slots		465,857	454,574	- (11,283)	- (2.4)
Silling out		204,000	748,000	+ 544,000	+266.7
Sub-total		864,999	1,384,871	+ 519,872	+ 60.1
2. Stope Production					
Above 215 Level					
22,700 Stope	1,142,000t	660,596	725,742	+ 65,146	+ 9.9
Eastern Stope	3,035,100t	1,532,725	1,705,726	+ 173,001	+ 11.3
Below 215 Level					
22,700 Stope	261,400t	216,178	220,622	+ 4,444	+ 2.1
Eastern Stope	2,013,100t	1,117,270	1,169,611	+ 52,341	+ 4.7
Sub-total	6,452,500t	3,526,769	3,821,701	+ 294,932	+ 8.4
Total Ore Break	6,452,500t	4,391,768	5,206,572	+ 814,804	+ 18.6
	Cost/tonne	0.6806	0.8069	+ 0.1263	+ 18.6

TABLE 5-4 (contd)

	Feasibility Report	This Review	Variance Dollars	Variance Percent
Ore breaking (carried forward)	0.6806	0.8069	+ 0.1263	+ 18.6
3. Indirect Mining Costs				
Rilling, crushing, transporting	0.6150	0.6267	+ 0.0117	+ 1.9
Power not already included	0.0430	0.0430	-	-
Staff supervision	0.1830	0.1830	-	-
Tradesmen	0.1050	0.1050	-	-
Transport	0.1000	0.1000	-	-
Sub-total	1.7266	1.8646	+ 0.1380	+ 7.9
4. Additions				
Cable bolting 50,000m	-	0.1162	+ 0.1162	-
Consulting services $30,000 p.a.	-	0.0333	+ 0.0333	-
Total Operating Cost	1.7266	2.0141	+ 0.2875	+ 16.6
5. Contingency at 15 percent	-	0.3021	+ 0.3021	-
TOTAL COST/TONNE	1.7266	2.3162	+ 0.5896	+ 34.1

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Appendix H:
Report on Slope Stability Analysis and Design of Open Pit Slopes (Piteau & Associates 1982)

R.B. Mining Pty. Ltd.
Mount Carbine Mine
Queensland, Australia.

SLOPE STABILITY ANALYSIS AND DESIGN

OF THE OPEN PIT SLOPES

April 1982

Piteau & Associates

(Copy)

HD042

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MOUNT CARBINE MINE

REPORT
ON
SLOPE STABILITY ANALYSIS
AND
DESIGN OF THE OPEN PIT SLOPES

Prepared by

Douglas R. Piteau
Dennis C. Martin
and
Eric J. Byres

Project 81-358

April 1982

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1. INTRODUCTION

The purpose of this report is to describe the results of studies which were carried out concerning slope stability analyses and related design for the Mount Carbine Mine. The scope and nature of the proposed geotechnical work were discussed with mine personnel during an initial visit to the mine by D.R. Piteau in late February, 1981. The terms of reference for this work are described in a proposal letter dated April 27, 1981 from D.R. Piteau to D. Wolff of R.B. Mining Pty. Limited.

The project was initiated on June 15, 1981 when D.C. Martin and E.J. Byres of Piteau & Associates visited the mine to organize the field mapping and mine office studies. Mr. E. Byres remained at the site until late November, 1981 to complete the geologic structural mapping, drilling studies, core logging, associated field work and preliminary analysis of the field data. Mr. D. Martin revisited the mine in early September, 1981 to review the program and to initiate a geotechnical drilling program. A rock strength testing program was also started at this time at James Cook University, Civil Engineering Department.

Significant findings of the study relating to engineering geology, analysis techniques, results and our preliminary slope design recommendations were discussed by D.R. Piteau, D.C. Martin and E.J. Byres with E. Brachmanski by telephone on January 13, 1982 and February 10, 1982. Draft copies of the report were prepared in late March, 1982. D.R. Piteau visited the mine in early April, 1982 at which time all aspects of the study and design recommendations were presented to mine personnel.

2. DESCRIPTION OF THE INVESTIGATION

2.1 FIELD DATA COLLECTION AND DATA COMPILATION

2.1.1 Geological Mapping

Geological mapping was carried out on all accessible benches in the open pit. This work involved engineering geology assessments relating to lithology, rock strength and geological structures (such as faults, shears, joints and geological contacts) to determine the physical and mechanical properties of the slope forming materials. Detailed line geological mapping techniques were used for the bench mapping and data was recorded on standard field sheets for computer processing and analysis.

Studies of rock competency, degree of fracturing, degree of weathering, rock hardness and bench face angles were conducted during the mapping to assist in evaluating the rock mass and related behaviour of slopes.

All major faults were carefully mapped and considered as thoroughly as possible. A review of historical geological information, level plans and geological sections was carried out to incorporate all relevant information in terms of defining the overall geologic model as accurately as possible. Other documented information concerning the geology, engineering properties and other aspects relevant to the problem were also reviewed.

The geological mapping information was used to develop a composite geology map and geological sections. This mapping showed the location and spatial relationship of major features, such as faults, geological contacts, etc. A realistic model was developed which could be used to determine both the location of the significant geologic structural features and the distribution of the various rock types on the proposed final pit wall. The structural geology and engineering geology of the open pit is shown in plan in Fig. 1 and on sections in Appendix A.

2.1.2 Geotechnical Drilling and Core Logging

A geotechnical drilling program, consisting of two diamond drillholes and eleven percussion drillholes, was carried out in the area of the south wall. Samples from these holes were logged and the results were compiled into sections showing lithology, weathering and rock strength profiles in the south wall. Drill logs are included in Appendix B. In addition, foliation angles were recorded in the diamond drillholes and were used to orient the core so that joints in the core could be analyzed statistically. The locations of the South Wall Fault at depth was also accurately determined from these drillholes.

Relogging of existing diamond drillholes was also carried out during the drilling program. Relevant sections of these holes were logged for lithology, weathering, breakage, foliation, RQD and joint frequency. The results were analyzed using the cumulative sums technique. Intersections of the South Wall Fault in existing drillholes was used to assist in locating the fault accurately and to develop a structure contour map of the fault.

2.1.3 Hydrogeological Investigations

In conjunction with the geotechnical investigation, a brief hydrogeological investigation and assessment was carried out. The purpose of this investigation was to determine if it would be necessary to depressurize the pit slopes, and hence improve pit slope stability. The study concentrated on the south wall since this is a particularly critical area of the pit.

Twenty piezometers and five standpipes were installed in the geotechnical drillholes to monitor water pressures in the south wall. Water levels were recorded by mine personnel throughout the rainy season and falling head tests were conducted in each piezometer to assess the permeability of the rock mass. In addition, a review of climatic data supplied by the mine was carried out.

2.2 STRENGTH TESTS AND BACK ANALYSIS OF FAILURES

2.2.1 Strength Tests

To obtain realistic strength data, four direct shear strength tests were performed on selected samples of open discontinuities. These tests were carried out to determine the relevant friction and cohesion properties of joints and foliation joints on the south wall area. The samples used in these tests were core samples obtained from diamond drilling.

A series of point load tests and unconfined compressive tests were performed to evaluate the intact rock strength of the schists and greywackes in the south wall. Both weathered and unweathered samples were collected and this allowed a realistic appraisal of the effect of weathering on rock strength to be made. The unconfined compressive strength tests were performed by Dr. H. Bock of James Cook University. Point load index tests were performed both at James Cook University as well as by Piteau & Associates.

2.2.2 Back Analysis of Failures

In order to obtain a better appreciation of the behaviour of the slope and the shear strength parameters of discontinuities involved in failures, particularly in the weathered schist and related rocks in the south wall, back analyses were carried out. Rotational failures in weathered rock on Bench 375 and a plane failure on Bench 365 were analyzed and strength parameters were developed. Road cuts along the Rex Range Highway near the Mount Carbine Mine were also documented and analyzed. The similarity of these road cuts, in terms of lithology, rock strength, weathering and structure, to the upper benches of the south wall of the pit make it possible to apply the results of this study to the design of the south wall.

2.3 GEOLOGIC STRUCTURAL ANALYSES

Geologic structural analyses and slope stability analyses were carried out using the geological data and test results. Geological mapping data was processed using a desktop computer at the mine to

plot equal area projections. Statistical methods were used to define the basic geologic structural parameters and to develop an accurate appreciation of the nature and distribution of these features in the rock mass.

2.4 STABILITY ANALYSIS AND SLOPE DESIGN

Based on the markedly different engineering geology, character and constraints on slope design, slopes south of the South Wall Fault were considered separately from the remainder of the pit. For this reason, two separate sections on analysis and design are presented. The first section considers stability analysis and slope design in the bulk of the pit; the second section considers design and remedial measures for slopes south of the South Wall Fault.

2.4.1 Stability Analyses and Design Based on Design Sectors

Based on the results of the structural analysis, the pit was divided into areas where the rock type, strength and geological structure are similar in a statistical sense, i.e. structural domains. The final pit was divided into design sectors within which the orientation of the proposed ultimate slopes in the individual structural domains are similar. Separate slope stability analyses were carried out, and related design criteria were established for each design sector. Equal area projections were used to determine the kinematically possible failure modes which are likely to control slope design in each design sector. Mechanical stability analyses were carried out for possible failure modes. When a large number of possible failure modes exist in a particular design sector, statistical analyses were used to evaluate these potential failures in the process of determining optimum slope design.

Slope designs were developed with due consideration to the possibility of instability involving both benches and large sections of the overall slope. Consideration was also given to effects of plan radius of curvature, variation of geological structure, strength and groundwater conditions in the final open pit.

2.4.2 Analysis and Design of Slopes and Remedial Measures South of the South Wall Fault

Design of slopes and remedial measures in weathered schists and greywackes on the south wall above the South Wall Fault was carried out with due consideration of both deep seated rotational failures in the weathered rock as well as failure along discontinuities. The occurrence of a well developed weathering profile, weak rocks, unfavourably oriented discontinuities and critical nature of the slope was considered in preparing a slope design and remedial measures. Geological mapping, drilling, strength testing and back analyses results were used to prepare a rational design and remedial measures, with due consideration of the constraints imposed by the nature of the slope forming materials and location of the existing primary crusher and roads near the crest of the slope.

3. REGIONAL GEOLOGY

The Mount Carbine area is underlain by deep-water turbidite sequences of the Hodgkinson Formation, which consists mainly of metasediments of Middle Devonian to Lower Carboniferous age. These sediments were intruded by late-orogenic and post-orogenic granites and unconformably overlain by Permian and Triassic sediments. The region has undergone four stages of folding and low grade metamorphism (Amos, 1968).

At the mine, the Hodgkinson Formation consists of thinly bedded, intercalated units of greywacke, quartzitic greywacke, siltstone and shale, with minor chert and basic volcanics. Within the pit area, regional metamorphism as well as local and contact metamorphism from nearby intrusions have altered the sedimentary rocks to micaeous schists, siliceous greywackes, hornfels, phyllites and slates in addition to the original lithologies. Within the ore zone, extreme pneumatolytic tourmalinization and silicification has occurred, altering the engineering characteristics of the rock significantly.

Several large batholiths of Mareeba Granite can be found near Mount Carbine. The most dominant intrusion, which consists mainly of biotite-muscovite granite, forms the Mount Windsor and Mount Carbine tablelands. It is believed that this intrusion was responsible for the contact metamorphism which led to hydrothermal alteration, silicification and emplacement of the tungsten bearing quartz veins at Mount Carbine.

The quartz veins strike east-west and are distributed en-echelon along Mount Carbine Hill. The southern boundary of the quartz veins and significant silicification is defined by the South Wall Fault. This fault is the most significant structural feature in the pit.

According to Amos (1968), at least four stages of folding have been documented in the region. At Mount Carbine the first two phases of deformation have been completely masked by the third phase of deformation, which resulted in the development of a strong axial plane cleavage which obliterated the original bedding cleavage in the grewackes and siltstones. This axial plane cleavage now appears as generally steep dipping foliation throughout most of the mine. The fourth phase of deformation occurs as folding of the foliation cleavage.

4. LITHOLOGY

The basic engineering geology, lithology and structural geology are shown on plan in Fig. 1 and on geotechnical sections in Appendix A. A general description of the main rock types in the mine are given in the following.

4.1 HORNFELS

Hornfels is the predominant rock type in the pit (see Photo 1). Hornfels hosts the tungsten bearing quartz veins, giving rise to its common name of "Host Rock". However, hornfels does occur in areas without mineralization or quartz veins, and hence the term host rock is not used in this report.

The hornfels is a highly tourmalinized and silicified version of the surrounding greywackes and siltstones, which have undergone low grade metamorphism. This alteration has occurred throughout the rock mass without regard for original lithologic boundaries, and has masked most of the original lithologic differences. For purposes of this study, the hornfels has been divided into two main lithologic types based on present characteristics and estimated original composition as described in the following. This division is preliminary only, and careful petrographic investigation is needed before accurate divisions can be made.

4.1.1 Laminated Hornfels (LHF)

Laminated hornfels (LHF) is derived from the argillaceous and micaceous siltstone facies common in the region. This rock is dark grey, fine grained and contains up to 30 percent fine, light coloured quartz rich laminations. Laminations may be planar and uniform or highly twisted and deformed, giving the rock an irregular, gneissic texture.



PHOTO 1: View of hornfels and related rocks on the north wall of the open pit.

Unweathered, laminated hornfels is tough and has a hardness of between R4 and R5 (i.e. an unconfined compresive strength of greater than 8000 psi (56 MPa)).* Laminated hornfels tend to fracture along foliation when hit with a rock hammer, giving the rock a blocky appearance.

Weathered laminated hornfels has a hardness of R2 and R3, i.e. an unconfined compression strength of 1000 to 8000 psi (7 to 56 MPa), depending on the amount of siliceous banding and degree of weathering. Weathered rocks are a dark olive green colour. Extremely weathered rocks are bleached.

4.1.2 Banded Hornfels (BHF)

Banded hornfels (BHF) is derived from arenaceous greywackes that have undergone quartz segregation prior to tourmalinization and silicification. They are composed of 5mm to 20mm quartz rich bands separated by thin layers of dark argillaceous rock. These bands can comprise between 60 to 90 percent of the total volume of the rock. Bands are usually regular, but extreme deformation and boundinage is not uncommon.

Unweathered, banded hornfels is light blue-gray and has a glassy appearance. Banding may be obscured by silicification. Banded hornfels is generally less brittle than the laminated hornfels, and has an estimated hardness of R5 (unconfined compressive strength greater than 16,000 psi (112 MPa). There is no preferred fracture direction and banded hornfels rarely breaks along foliation.

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* A complete description of hardness as related to unconfined compressive strength is given in Fig. 9.

Weathered banded hornfels has a hardness of R3 (unconfined compressive strength of 4000 to 8000 psi (28-56 MPa). This rock has a rusty red brown colour and banding is highlighted by weathering.

4.2 IRON DUKE ROCKS

Iron Duke rocks are those units which have undergone low grade metamorphism, but have not been affected by the extreme tourmalinization and silicification noted in hornfels. Iron Duke rocks are formed from the same facies as the hornfels. Iron Duke rocks were noted on the south wall of the open pit above the South Wall Fault (see Photo 2). Iron Duke Duke rocks were also noted on the flanks of Mount Carbine hill outside the ore zone.

4.2.1 Siliceous Greywacke (GWK)

Siliceous greywacke (GWK) consists of bands, stringers, augens and clasts of quartz and feldpathic material in a variable matrix of silicified argillaceous material. Grain size is highly variable and large clasts of chert are common. Cherty zones and schistose zones several metres thick are common. Contacts between units of greywacke are gradational. The degree of silicification is variable and this effects the degree of weathering and the rock strength. Foliation is evident, but is often twisted and contorted. Such contortions may contribute in a substantial way to shear strength of the rock mass.

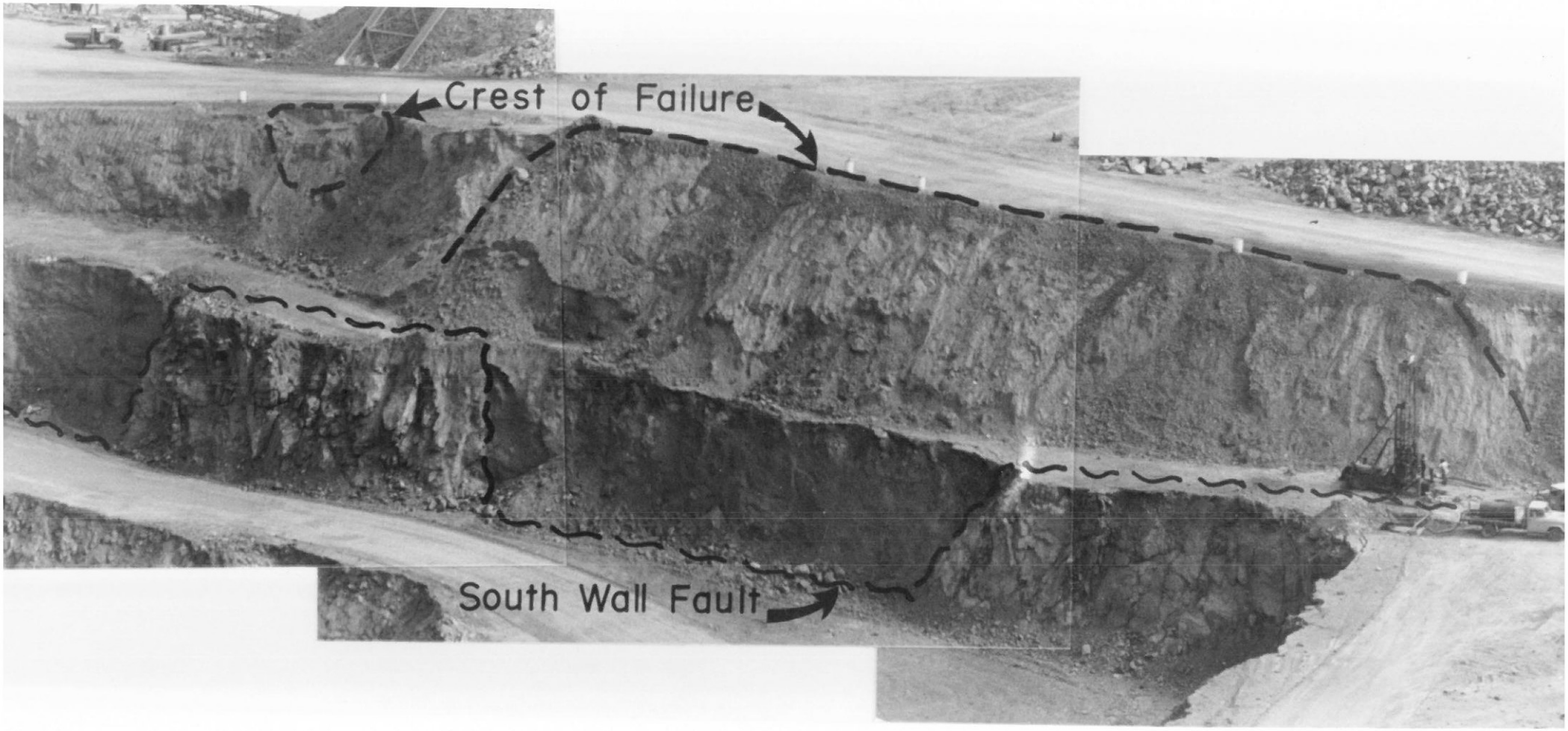


PHOTO 2: View of south wall showing location of South Wall Fault and highly weathered schists near the pit crest. Note rotational failures in highly weathered rock above 375m elevation.

Unweathered, siliceous greywacke is light or dark grey. Cherty zones have a slight green cast. Some of the mottling is probably caused by differences of grain size rather than mineralology, but the majority is caused by to the bands and stringers of quartz-feldspar material. The rock has a hardness of R3 to R4 (i.e. unconfined compressive strength of 4000 to ~~16000~~ 8000 psi (28 to 56 MPa).

Weathered silicious greywacke develops a rusty overall colour with well defined mottling and banding. The argillaceous matrix is considerably weakened by weathering, with the result that hardness drops to between R0 and R2 (unconfined compression strength of 100 to 4000 psi (0.7 to 28 MPa)).

Siliceous greywacke has been found in drillholes behind the south wall and in highly weathered outcrops on the east and west ends of the south wall. No unweathered surface outcrops have been located. This rock is expected to form part of the upper benches of the final pit, above the South Wall Fault.

4.2.2 Green Argillaceous Schist (GAS)

Green argillaceous schist (GAS) is found on the south wall of the pit where it forms a band or lense adjacent to the South Wall Fault (see Fig. 1 and Photo 1). The rock has a well developed undulating schistosity and is weakly silicified. Argillaceous schist grades into the siliceous greywacke, becoming more siliceous and containing occasional stringers and blobs of light coloured, quartz rich rock. Quartz stringers are oriented along laminations at approximately 40° to the schistosity.

Unweathered argillaceous schist is dark green to dark grey and has a hardness of R3. Light green mottling, which is caused by slight changes in grain size, is common but has no affect on strength. Once weathered, argillaceous schist loses strength rapidly; slightly to moderately weathered schist has a hardness of R2 and heavily weathered schist has a hardness between S4 and R1. Fresh rock exposed to weathering is likely to deteriorate rapidly due to its low silica content.

The upper benches in the centre of the south wall are expected to be composed of argillaceous schist.

4.2.3 Black Slate (BST)

Black slate (BST) was noted in drillholes and outcrops behind the south wall. Black slate is very thinly laminated and has well developed slatey cleavage. It is uniform in both composition and degree of lamination and has a hardness of R3 when unweathered. Weathered samples have not been found, but very low strengths are likely.

Black slate is unlikely to appear in the walls of the final pit, but is mentioned here as it occurs close to the crest of the final open pit and is a major lithologic unit in the mine area.

4.3 INTRUSIVE AND VOLCANIC ROCKS

4.3.1 Felsite (FLS)

Felsite is a pale creamy coloured quartz-porphyry intrusive, which forms an approximately 5m wide dyke visible on the west side of the pit. It is coarse grained (except along the chill margins) and is acidic in composition. Unweathered, felsite has a hardness of R4. Felsite appears to weather rapidly and can have a hardness as low as R1. Weathering is most severe along chill margins. Stiff green clay, which probably occurs as a result of weathering, has been noted in the dyke at surface and in drillhole CB13, over 75m below the surface. Hardness of the clay is S5 (i.e. unconfined compression strength of 14 to 28 psi).

The felsite dyke is expected to occur on the west wall of the final pit, although its exact location is not clear due to the variable orientation of the dyke boundaries.

4.3.2 Andesite (ADS)

Several dykes up to 2m wide of purple grey, fine grained intermediate andesite (ADS) were mapped in the pit. These rocks have a hardness of R4. Moderate to severely weathered andesites have a hardness of R2 to R3. Andesites may form relatively small dykes on the east wall of the final pit.

4.4 SILICIFICATION

The most significant silicification and tourmalinization has occurred in the hornfels north of the South Wall Fault and west of Iron Duke Fault. Silicification has resulted in increased rock strength, increased resistance to weathering and general increase in competency of the rock mass. In the remaining areas of the pit, particularly in the schists and greywackes south of the South Wall Fault the rock is either slightly silicified or completely unsilicified.

The South Wall Fault and Iron Duke Fault appear to control the degree of silicification in the pit. East of the Iron Duke Fault the size and number of quartz veins and degree of silicification decreases gradually with the result that the rock becomes more susceptable to weathering. South of the South Wall Fault the rock is only slightly silicified. There are no mineralized quartz veins and the rock is extremely susceptible to weathering. This sharp contact of silicification may be related to the actual offset of the fault. Alternatively, it is noteworthy that the silicification in the hornfels increases as the South Wall Fault is approached. This suggests that the fault may have existed prior to silicification and acted as a dam to the migration of silica and tungsten bearing fluids. Detailed study of the relationship between the faults and ore emplacement is beyond the scope of this study.

4.5 WEATHERING

Rocks in the upper part of the open pit form a well developed weathering profile. This profile is particularly well developed in weaker rocks on the south wall. The weathering profile is clearly defined from surface mapping (see Fig. 2), in surface outcrops (see Photo 3) and from examination of diamond drill cores and percussion drillhole chip samples as shown in Photos 4 and 5.

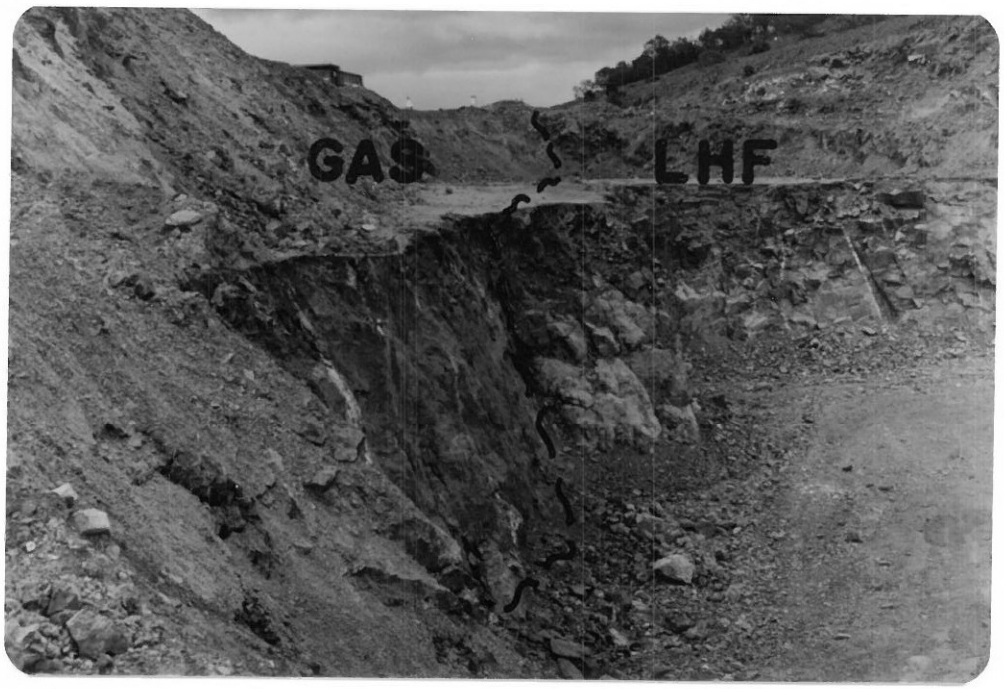


PHOTO 3: View of South Wall Fault in southwest corner of the pit. Note that silicified hornfels north of the fault is less deeply weathered than green argillaceous schist south of the fault.



PHOTO 4: View of core in drillhole CB-20 showing marked decrease in weathering and increase in rock strength at a depth of about 40.1m.



PHOTO 5: Illustration of decrease in degree of weathering with depth in chip samples from percussion drillhole MCP4.

Residual soil and rocks within the weathering profile have been divided into five categories, based primarily on the degree of weathering and related rock strength. These categories range from extremely weathered residual soil (Category A) to hard unweathered rock (Category E). Definitions of each weathering category are given in the legend in Fig. 2.

The distribution of weathered zones in the open pit, based on geological mapping and core logging, is shown in Fig. 2 and on sections in Appendix A.

Assessment of information on weathering indicates that hornfels and related silicified rocks have a very limited weathering profile, whereas less silicified rocks south of the South Wall Fault have a well developed weathering profile. The contrast of depth of the weathering profile across the South Wall Fault is clearly illustrated in Photo 3.

Weathering has no significant effect on rock strength below the first bench in the silicified hornfels north of the South Wall Fault. In the less silicified rocks south of the South Wall Fault, a weathering profile up to 30m deep is developed as shown in Fig. 2 and Appendix A. The markedly different strength of the rocks within the weathering profile, and increase in strength with depth, indicates that a different slope design will be required for each succeeding bench in this area.

A summary of the weathering profile in rocks south of the South Wall Fault is given in Table I. Detailed discussion of the variation of rock strength within the weathering profile is given in Section 6.

5. STRUCTURAL GEOLOGY

Rational slope stability analysis and pit slope design requires that the pit be subdivided as best as possible into areas of approximately similar geologic structural characteristics. The engineering behaviour of the slope forming material can be expected to differ in different parts of the pit which have different geologic structural characteristics. Extrapolation of stability analysis results and slope design criteria is valid only within parts of the rock mass which have physical and mechanical properties which are similar in a statistical sense. Such areas with similar geological structure are called structural domains.

Attitude of geological structures is the most important consideration in determining whether geologic structural populations within a structural domain or between structural domains are similar or dissimilar. Other parameters, such as continuity (joint extent or size), joint infilling, waviness, etc., are also considered in evaluating the engineering properties and nature of joint sets, but are not used for designation of structural domains.

Structural domains at Mount Carbine were determined initially by assuming the boundaries of the structural domains were major faults, geological contacts and/or boundaries of areas with similar foliation. Attitudes of the geologic structural populations within different parts of each structural domain then were evaluated and compared. Six preliminary structural domains (i.e. Structural Domains 1 to 6) were chosen as shown in Fig. 1. In order to further compare populations within the structural domains, several structural sub-domains (i.e. Structural Domains 5A to 5D, 6A and 6B) were chosen based on variation in foliation dip.

Equal area projections were used to define the peak or average attitude and possible range of attitudes for the various sets of discontinuities in the individual structural domains. Four major joint sets, foliation, several minor joint sets, a vein set and two fault sets have been recognized in the open pit. The nature, distribution and possible genesis of these structural features are discussed below. Average orientation of discontinuity sets based on detailed line mapping are summarized in Table II.

5.1 FOLIATION

5.1.1 Nature and Distribution of Foliation

Foliation is a laminated structure developed parallel to "compositional layering" in the metasediments as shown in Photos 6 and 7. Foliation is well developed throughout the pit, although it is often difficult to recognize in unweathered hand specimens.

Equal area projections of foliation in structural domains are shown in Fig. 3 and summarized in Table II. These plots clearly show the variation of foliation orientation in the various structural domains. It can be seen that there are marked differences in orientation in argillaceous schist and greywackes south of the South Wall Fault. It also noteworthy that foliation is more variable in the area south of the South Wall Fault.

Foliation in hornfels dip steeply to the northeast or southwest at about 70^{o} to 90^{o}. Average dip directions vary from 041^{o} to 056^{o} and 221^{o} to 239^{o}. Iron Duke rocks south of the South Wall Fault have foliation that dips approximately due north at about 75^{o}.

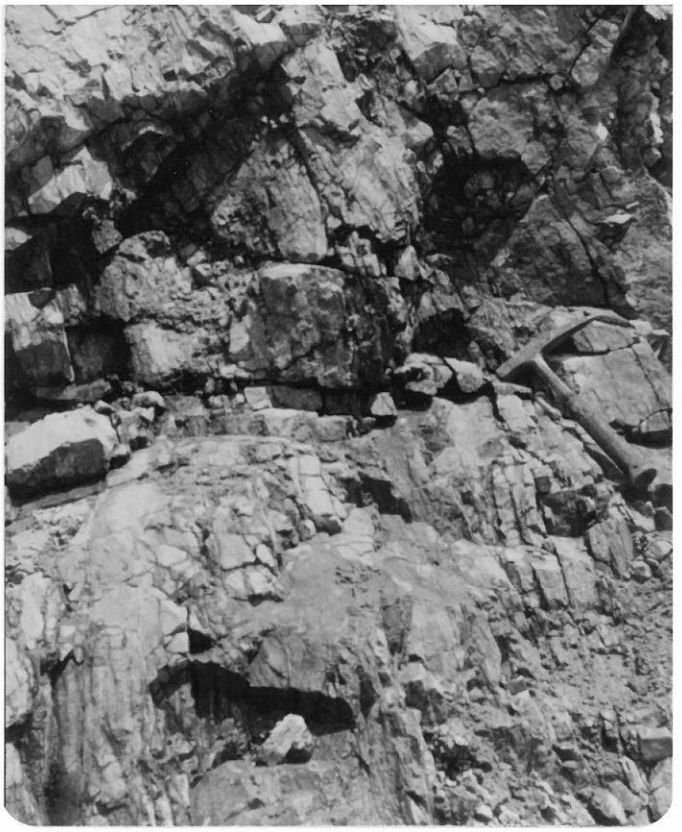


PHOTO 6: View of foliation and foliation joints in weathered banded hornfels in the southeast corner of the pit.

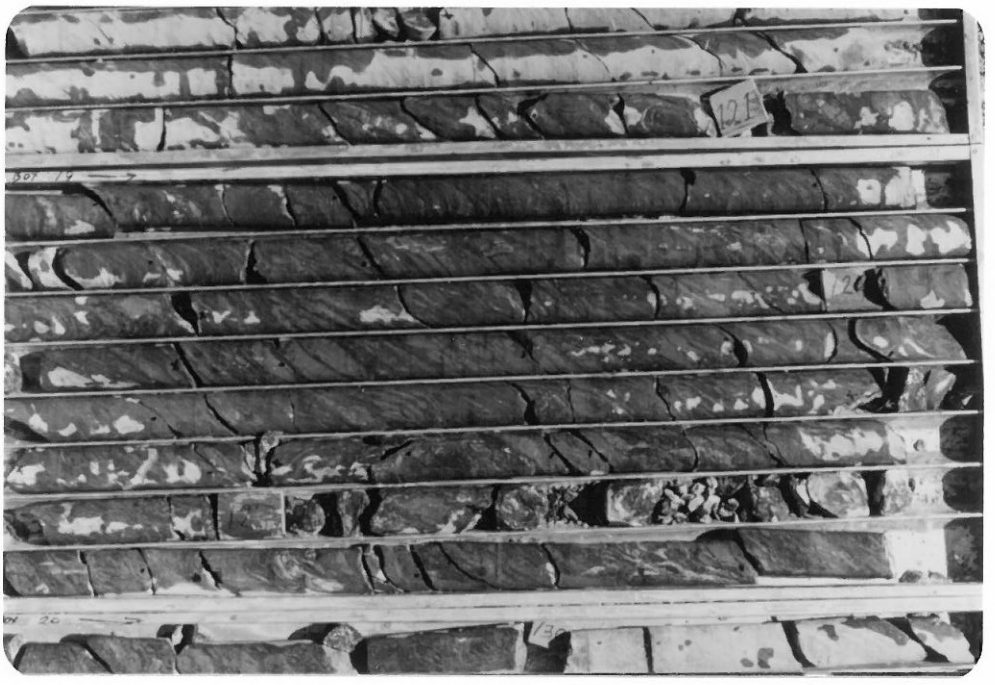


PHOTO 7: View of foliation in core from drillhole CB20.

Within individual structural domains there are marked variations in foliation dip due to the presence of minor folds. As a result, it is extremely difficult to predict variations in foliation dip or to delineate areas of consistent dip in the pit.

5.1.2 Assessment of Variation of Foliation Using the Cumulative Sums Technique

Foliation dip was assessed statistically using the cumulative sums (cusums) technique. This technique provides a rapid and precise method of determining major trends above or below a particular reference value (generally the mean), and of ascertaining both the magnitude and location of these variations. Complete details of the construction and interpretation of cumulative sums plots are given in Appendix C.

Data for the cusums analysis was collected at 3m intervals along all benches during the detailed line mapping. In addition, foliation angles were recorded at 3m intervals in drill core from selected drillholes.

The results of the cusums analysis of foliation dip were plotted on a current pit plan and on sections. Spot checks of foliation in critical areas and foliation measurements made by mine personnel during production face mapping were also plotted for comparison.

This information was used as a basis for defining zones with similar foliation dip and to prepare a three dimensional model of the distribution of foliation dip. The distribution of these zones on the current pit plan is shown in Fig. 3.

5.1.3 Selection of Structural Domains Based on Areas of Similar Foliation Dip

Distribution of zones of similar foliation dip direction and dip was used to assist with selection of structural domain boundaries as shown in Fig. 3. Within individual structural domains the foliation is expected to have a reasonably consistent dip direction and dip. In some cases the dip direction and dip of the foliation is variable over small areas. For engineering geology purposes, the foliation in these areas is assumed to have two or more dominant orientations at any one location. Areas of relatively flat dipping foliation, such as those mapped on the north wall or west wall, are included with steeper dipping foliation in each structural domain (see Fig. 3). In terms of slope stability analyses, these flatter foliation dips are considered in the slope design only in areas where they are considered to be statistically significant.

5.1.4 Origin of Foliation

Foliation in hornfels and related rocks appears to be related to the metamorphism and folding described by Amos (1968).

Within the schists and siliceous greywackes in Structural Domains 1 and 2 the foliation is variable, but generally oriented subparallel to the South Wall Fault. This suggests that foliation in these rocks may be, in part at least, related to the shearing and displacement along this fault. Foliation dips steeply to the northeast in hornfels in

Structural Domains 5D and 6A in the areas adjacent to the South Wall Fault. Confirmation of foliation origin and orientations in the argillaceous schists and siliceous greywacke is difficult due to the lack of good unweathered exposures of these rocks.

5.2 JOINTS

Lower hemisphere equal area projections were used to define the peak or average attitude, and possible range of attitudes, for each main joint set mapped in individual structural domains. The distribution of joints within the various structural domains (as determined from detail line mapping) is shown in Figs. 4 and 5. Average orientations of the main joint sets are summarized in Table II.

Equal area projections indicate that most joint sets occur as reasonably tight clusters, with moderate scatter in the data. In most cases, it is reasonable to represent each joint set by a single peak orientation. However, some joint sets are diffuse enough that they may be represented by two or three different peaks. In such cases the joint set is represented by a number of subsets, e.g. Joint Set B1, Joint Set B2, etc.

In addition to foliation joints (Joint Set A), three major joint sets and several minor and miscellaneous joint sets occur within the pit area. Joint Sets A and B occur consistently throughout the pit, while Joint Sets C and D occur in all domains north of the South Wall Fault. Minor and miscellaneous joint sets occur in specific domains, and only appear to be significant on a local basis only. In most cases, differences in attitude of joint sets are evident from one structural domain to another. The main joint sets are described in the following:

5.2.1 Joint Set A

Joints of Joint set A are foliation joints and their distribution is shown in Fig. 4. Average strike orientation of foliation joints is generally within 5^{o} of peak orientation of foliation in any structural domain.

Foliation joints have an estimated average spacing of 0.5m and are generally less than five to ten metres long. Small rolls, undulations and waves are common. Foliation joints in hornfels and related rocks are moderately rough, whereas foliation joints in argillaceous schists and siliceous greywacke are generally rough and irregular.

Foliation joints are well developed in weathered areas, but become infrequent in unweathered rocks in the centre of the pit. Typical foliation joints are shown in Photos 6 and 7. Infilling of serpentine and/or chlorite are common on foliation joints in schists and greywacke. Foliation joints in hornfels are generally unfilled.

5.2.2 Joint Set B

Joints of Joint Set B are the most well developed in the entire pit. These joints form the host set for tungsten-bearing quartz veins. The similarity of peak orientations of vein sets with peak orientations of Joint Set B has been used as a selection criteria to designate Joint Set B from other joint sets.

Joints of Joint Set B are long and continuous, often extending over several benches. In most areas of the pit these joints have an average dip direction between 324° and 360°, and an average dip greater than 80°. In structural domains adjacent to the South Wall Fault, average dip direction varies from 324° to 020° and average dips vary from 55° to 76°. Joint Set B characteristically occurs as two distinct subsets, with a 20° to 30° separation of average dip direction.

Joints of Joint Set B have a mean roughness of 2.7. Slickensides and other evidence of shearing are common. Typical joints of Joint Set B are shown in Photo 8.

The origin of Joint Set B is not definitely known. It is worth noting that the peak orientations of these joints is consistently 60° from the peak orientation of foliation. Whittle (1969) states these joints are tension joints, based on the matching wall infilling of the quartz veins. If this is true, slickensides on joint would have developed during a later stage of deformation.

5.2.3 Joint Set C

Joints of Joint Set C are well developed in hornfels north of the South Wall Fault (see Photo 9). These joints dip shallowly to the east, with mean dips between 18° and 36° and mean dip directions between 060° and 115°. There is a possibility that the dip increases with depth, but this cannot be confirmed without further mapping as the pit is deepened.

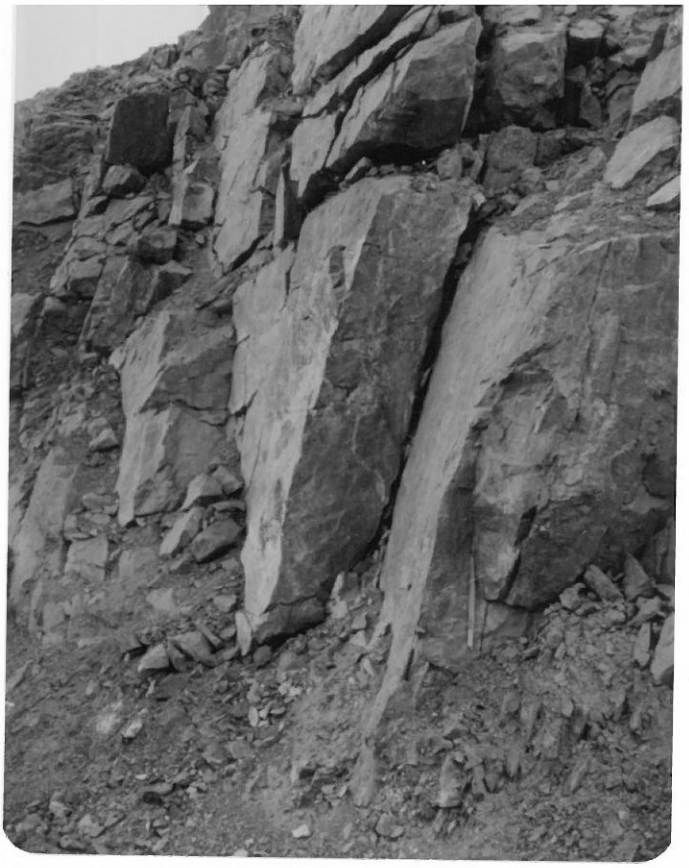


PHOTO 8: View of typical smooth continuous joints of Joint Set B.

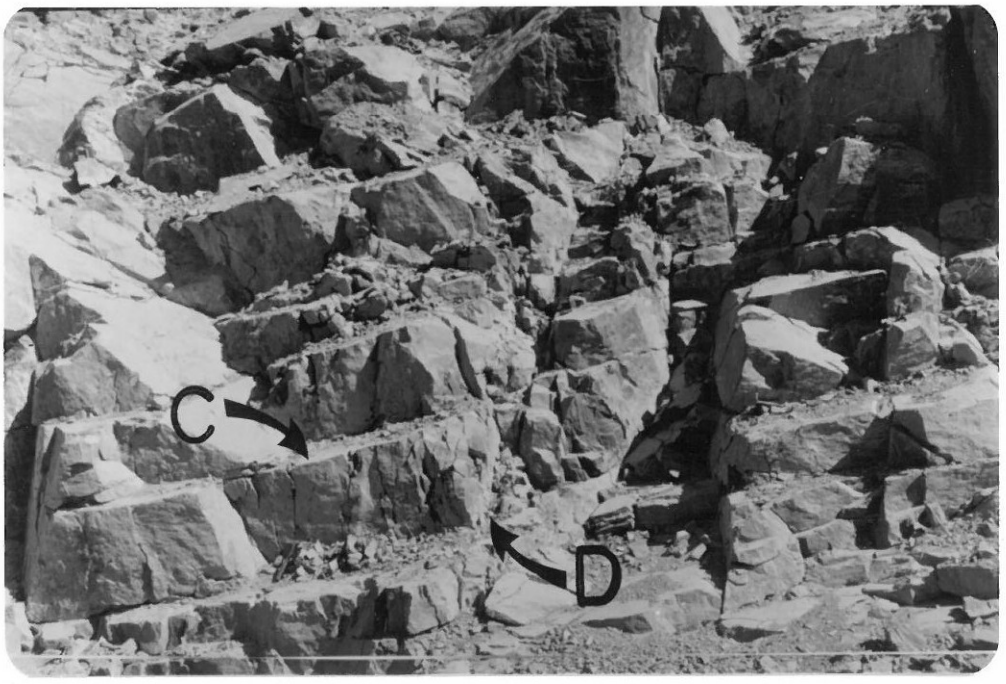


PHOTO 9: View of flat lying joints of Joint Set C and steep dipping joints of Joint Set D in laminated hornfels.

Joints of Joint Set C are typically long, continuous and closely spaced, as shown Photo 9. These joints have a roughness between 3 and 5. Significant water flow has been observed along joints of Joint Set C during periods of heavy rain.

5.2.4 Joint Set D

Joints of Joint Set D are well developed in all hornfels north of the South Wall Fault (see Photo 9). The joints dip steeply to the west and northwest, with average dips of 80° to vertical. In Structural Domains 5A to 5D, average dip directions are between 275° and 299°. In Structural Domains 4, 6A and 6B, average dip direction is between 315° and 327°. This variation of dip direction was used to separate Structural Domains 5 and 6.

5.2.5 Joint Set E

Joints of Joint Set E are subparallel to foliation, but are distinct from foliation joints. These joints are weakly developed in Structural Domains 3 and 6B and are poorly developed in other Domains. Average dip direction is 050° and average dip is between 72° and 76°. Joints of Joint Set E are short and discontinuous, rarely extending over 5 metres. These joints have an average roughness of 3 or greater.

5.2.6 Joint Set G

Joint Set G is weakly developed in Structural Domains 1, 2, 5A, 5C and 6B. Average dip directions vary between 340° and 009° and dip varies between 43° and 50°. Although often

widely spaced, joints of Joint Set G may be continuous, with trace lengths of 10 metres and greater. Roughness of less than 3 are not unusual for these joints. A plane failure along a joint of Joint Set G occurred in Green Argillaceous Schist on bench 375. A typical joint of Joint Set G in schist is shown in Photo 10.

5.2.7 Miscellaneous Joint Sets

In addition to the joint sets described above, several miscellaneous joint sets have been mapped in the open pit. These joint sets vary considerably and may be significant on a local basis only.

5.3 VEINS

Tungsten bearing quartz veins are found in hornfels north of the South Wall Fault. All tungsten ore mined in the pit is contained in these veins.

The quartz veins are sub-vertical, and occur subparallel to joints of Joint Set B or along pre-existing joints of joint set B. Two subsets are common in most areas, corresponding to the subsets in Joint Set B. Distribution of veins in the open pit is shown in Fig. 6 and summarized in Table II.

Thickness of quartz veins varies from a few centimetres to one to two metres. They are very continuous and can often be traced over several benches (see Photo 11).

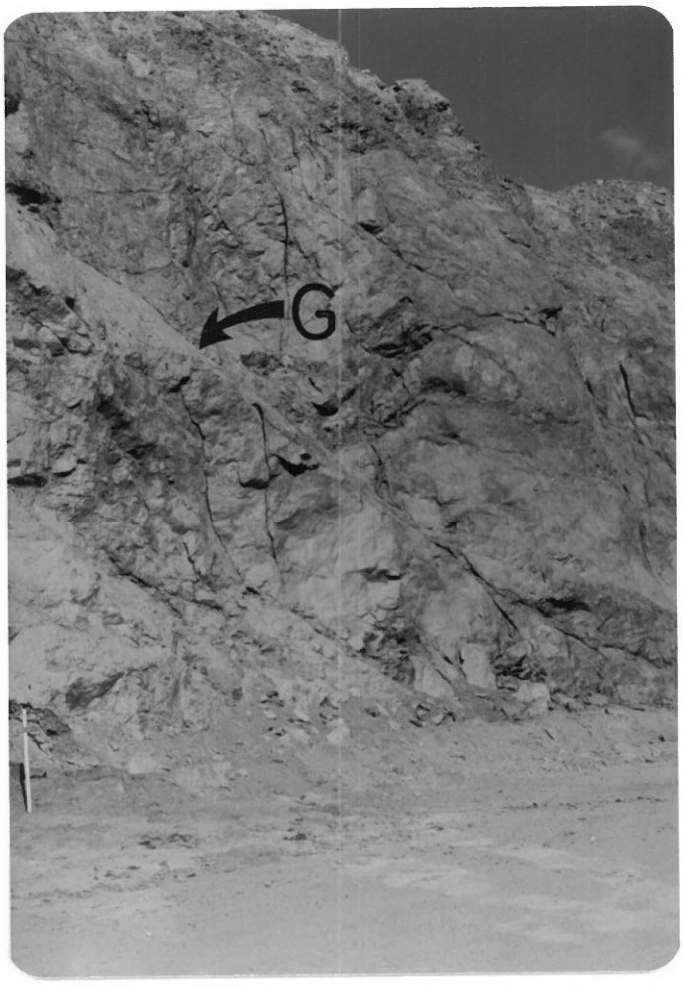


PHOTO 10: View of joint of Joint Set G in green argillite schist on bench 365 on the south wall. Note potential plane failure on this joint.



PHOTO 11: View of tungsten bearing quartz veins on the west wall of the pit.

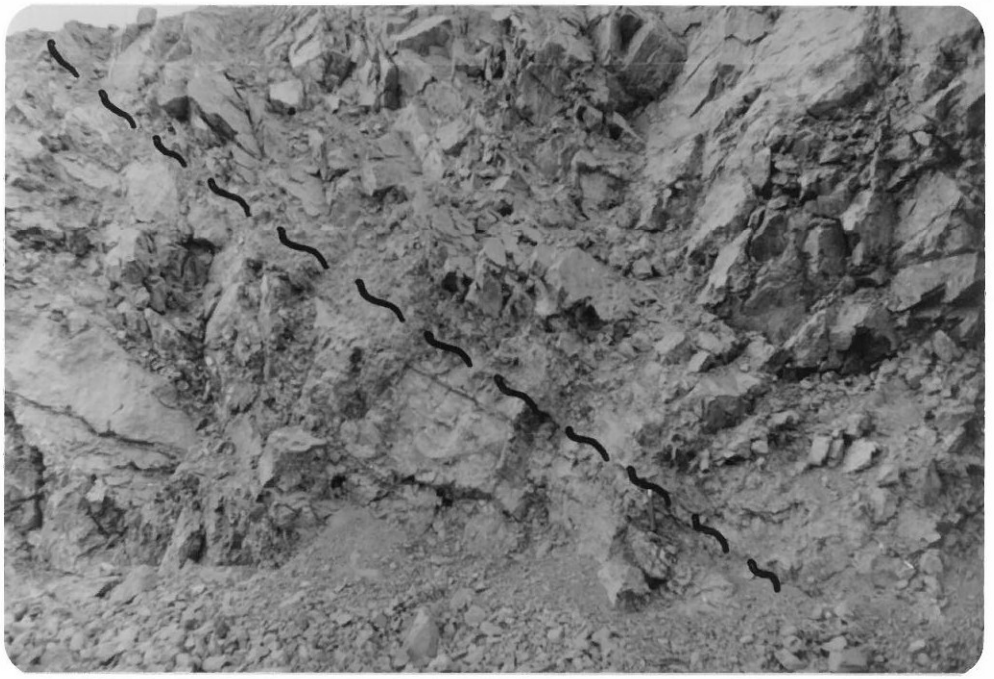


PHOTO 12: Flat lying shear of Shear Set SR1 on bench 385 on the north wall.

Quartz contained in veins is hard, brittle and often sheared and broken. The wall rock contact of veins is also often sheared and the quartz breaks away cleanly from this contact. These contacts are rough and irregular and may be healed or open.

5.4 FAULTS

Two major faults and a number of smaller faults and shears have been recognized in the pit. Their distribution throughout the pit is shown in Fig. 7.

5.4.1 South Wall Fault

The South Wall Fault is the most continuous and significant structural feature in the pit. It cuts across the south wall of the open pit, dips towards the north at 70° and forms the southern limit of the ore zone (see Fig. 7). The structure contour plan of the fault given in Fig. 8 indicates the fault is planar and has a uniform dip and strike. Typical exposures of the South Wall Fault are shown in Photo 2 and 3.

The South Wall Fault consists of an approximately one metre wide zone of sandy clay silt which has been sheared and brecciated. Rocks within one or two metres of the fault are often sheared and brecciated.

Orientation of foliation in rocks adjacent to the fault is often significantly different than in other areas of the pit. Additional joint sets have been noted in the vicinity of the fault , and joint sets are often more diffuse in this area. As stated in Section 4, rocks south of the fault are only weakly silicified, resulting in increased susceptibility to weathering.

5.4.2 Iron Duke Fault

The Iron Duke Fault occurs in the northeast corner of the pit as shown in Fig. 7. It dips steeply to the north/northeast at about 85°. The fault zone is less than 0.5 metres wide and consists of oxidized clay gouge. To the northeast of the fault there is a noteable decrease in quartz veining and silicification, which results in an increased susceptibility to weathering. This increased susceptibility to weathering is not as pronounced as that south of the South Wall Fault, because the degree of silicification does not decrease as rapidly across the Iron Duke Fault.

5.4.3 Fault and Shear Sets

The distribution of all fault and shears mapped is shown in Fig. 7, and their orientations are summarized in Table III. Due to the relatively few observations available, Structural Domains 4, 5 and 6 were grouped together to form a more statistically meaningful population of faults and shears in the various areas of the open pit.

The results show two main fault and shear sets exist in Structural Domains 4 and 5. Both fault sets have dip directions of 035 and 045. Fault Set SR1 has an average dip of 35° to the northeast (see Photo 12). Fault Set SR2 has an average dip of 72° to the northeast. No consistent set of faults or shears are evident in Structural Domain 6. The South Wall Fault dominates Structural Domains 1, 2 and 3.

Faults are characterized by rough walled gouge zones filled with clay rich gouge and breccia (see Photo 12). The gouge zones are rarely wider than 10cm and are usually highly oxidized. Trace lengths are usually between 10 and 20 metres, but several 100 metre long faults are visible in the east wall.

6. STRENGTH PROPERTIES AND DOCUMENTATION OF SLOPE FAILURES

6.1 STRENGTH OF INTACT SAMPLES OF FRESH AND WEATHERED ROCK

6.1.1 Distribution of Rock Hardness in the Open Pit

The intact strengths of samples of fresh and weathered rock in the open pit have been determined primarily from simple field assessments, which consist of a set of simple mechanical tests based on the physical properties of the rock. Using this method, the hardness or the resistance of hand specimens to breaking or cutting can be related to the unconfined compressive strength using a simple classification system as summarized in the legend in Fig. 9. The distribution of rock hardness in the open pit, based on the detailed line mapping, is given in Fig. 9.

Fig. 9 indicates that most hornfels and related silicified rock in the open pit are uniformly hard, having a hardness greater than R4 (i.e. unconfined compressive strength greater than 8,000 psi (56 MPa). These rocks are extremely hard due to silicification. Additional rock mechanics testing of hornfels is not warranted at this time.

Schists, greywackes and other less silicified rocks south of the South Wall Fault have variable hardnesses, depending on the degree of weathering and silicification of the rock (see Figs. 1 and 2). Unweathered rocks in this area have hardnesses of R2 to R4 (i.e. unconfined compressive strength of 1000 psi to 16,000 psi). Weathered rocks have hardnesses of R0 to R3 (i.e. unconfined compressive strength of 100 psi to 8000 psi). Residual soils have hardnesses of S4 to R0 .

Earlier discussion in Section 4.5 indicate that there is a well defined variation of rock hardness with depth in the weathered rocks in this area (see Fig. 9 and the sections in Appendix A). These results are corroborated by examination of rock cores and percussion drill hole records.

6.1.2 Laboratory Tests

Detailed assessment of strength of weathered rocks and weaker schists in the open pit were estimated, based on field assessments and laboratory testing of selected core samples and block samples at James Cook University (as summarized in Table IV). These results are consistent with the distribution of hardness described above, and indicate that extremely weathered rock near surface are very weak and can be expected to behave as a soil. Hardness and strength increases with depth as the rock becomes less weathered.

6.1.3 Interrelationship of Hardness, Weathering and Unconfined Compressive Strength

Based on the distribution of hardness indicated in Fig. 9 and on the geotechnical section and the laboratory test results summarized in Table IV, the distribution of rock strength and degree of weathering has been defined for rocks south of the South Wall Fault. The distribution of rock strength and weathering with depth within these rocks is summarized in Table I.

North of the South Wall Fault the silicified hornfels and related rocks have a uniform hardness of R4 to R5 in all weathering zones, except the extremely weathered zone which occurs within a few metres of ground surface. In this area the upper 10m could be expected to be somewhat more weathered and broken than the rest of the rock mass.

6.2 SHEAR STRENGTH TESTING OF DISCONTINUITIES

Direct shear tests were carried out on selected core samples of four representative joints from the south wall area. Test results, summarized in Fig. 10, indicate that these joints have friction angles greater than 36° and a relatively high cohesion. Cohesion on all joints tested was about 28 to 42 psi (193 to 290 kPa) as shown in Fig. 10. Subsequent back analyses of a plane failure along a shallow dipping discontinuity on the south wall indicate that a cohesion of 20 kPa to 51 kPa would be required along the joint plane for an acceptable factor of safety (see Section 6.4).

Based on the test results, and back analyses described in Section 6.4 it is felt justified to use a cohesion of at least 10 kPa for moderately rough discontinuities on the south wall. The typically planar discontinuities which occur in hornfels and related rocks are assumed to have a friction angle of 36° and little or no cohesion.

Actual effective cohesion may be substantially decreased or increased, depending on the effects of blasting on the rock mass. Clearly, controlled blasting would help to preserve cohesion of the rock mass, and thus improve the stability of the slope.

6.3 DOCUMENTATION AND BACK ANALYSIS OF FAILURES IN WEATHERED ROCKS

6.3.1 Failures in Weathered Rock on the South Wall

Several failures were mapped in weathered rocks and soil on the south wall of the open pit. These failures appear to be typical soil type failures, with characteristic rotational failure surfaces (see Photo 2). Back analyses were carried out for the large failure below the primary crusher area, as this failure is the highest in the slope (being approximately nine metres high).

Back analyses were carried out using standard charts to determine likely shear strength properties for various possible groundwater conditions which may have existed prior to failure. If it is assumed that the friction angle, of the material is 24^{o}, the analyses indicates the cohesion (C') required for a factor of safety (F) of 1.0 varies from about 39 kPa to 45 kPa, depending on the groundwater conditions in the slope at the time of failure. These analyses indicate an average mass cohesion C' of about 40 kPa should be used for slope stability assessments in this area.

Analyses were carried out for a cohesion C' of 40 kPa and a friction angle Ø' of 24^{o} for 10m, 15m and 20m high slopes (bench faces). The results are summarized in Table V. These results indicate that slopes should be well drained to maintain reasonably steep slope angles.

6.3.2 Documentation of Highway Slopes in the Mt. Carbine Area

In order to assess shear strength properties of residual soils and weathered rock, slopes on the road between Mount Molloy and Port Douglas were documented. This road crosses through mountainous terrain and there are numerous cut slopes up to 10m high in weathered rock and residual soil. These slopes contain weathered schists and greywackes, which are similar to the rocks observed behind the South Wall Fault at Mt. Carbine. Also, the distribution of rocks of various strengths and degree of weathering is similar to that at Mount Carbine. It is noteworthy that these slopes appear to have been successfully excavated by ripping and extensive surface drainage ditches have been provided on these slopes (see Photo 14).

A plot of slope height vs slope angle for documented cut slopes showing stable, failed and partially failed slopes is given in Fig. 11. These results may be used to delineate the maximum safe slope angles for various slope heights, depending on rock strength as shown in Fig. 11. Because weathering decreases with depth and rock strength increases with depth, the relationship between slope height and slope angle is not consistent. Hence, an approximate line dividing stable and unstable slopes has been defined for extremely weathered to totally weathered rock (i.e. Weathering Category A and B) and highly weathered rock (i.e. Weathering Category C).

The results in Fig. 11 indicate that slope angles of 50^{o} would be acceptable for highly weathered rock and residual soil up to 10m high. Slope angles of 57^{o} would be acceptable for 10m high slopes in moderately weathered rock. Slopes up to 20m high would consist of residual soil in the



PHOTO 13: View of plane failure on joint of Joint Set G in green argillaceous schist on Bench 365 on the south wall.

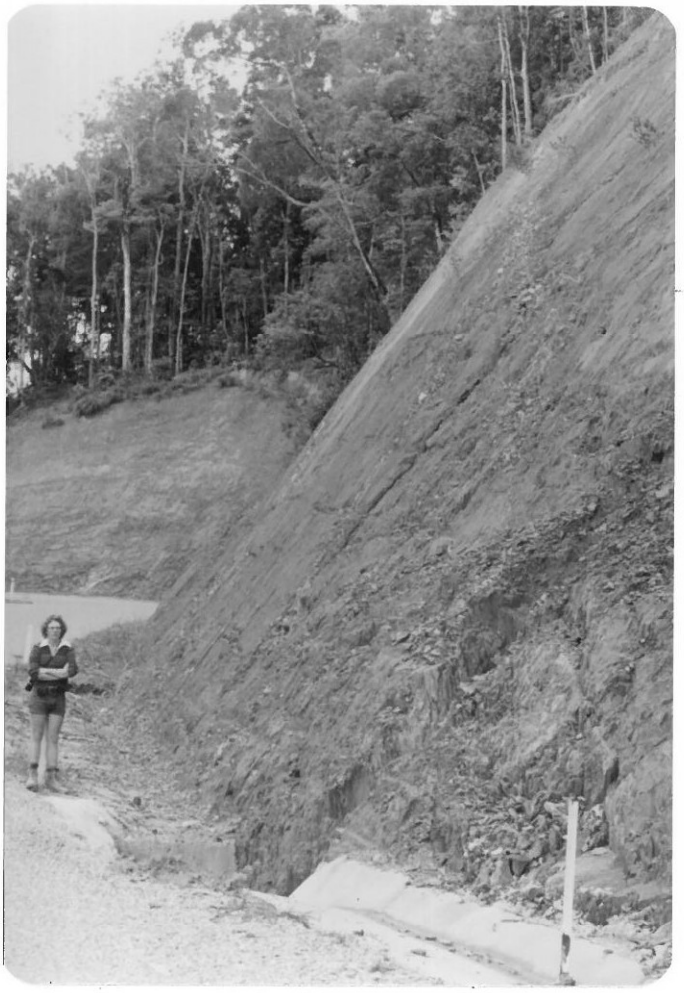


PHOTO 14: View of slopes in residual soil and weathered rock in the Rex Range near Mt. Carbine. These slopes were excavated by ripping and extensive surface drainage control measures have been installed.

upper portions and moderately weathered rock in the lower portions. Overall slope angles for slopes 20m high are indicated to be about 46° (as shown in Fig. 11).

Although somewhat erratic and sparse, these results are consistent with the back analyses carried out using design charts (as described in Section 6.3.1). Hence, these results provide a reasonable estimte of shear strength of the weathered rock and residual soil for slope design in these materials.

6.4 BACK ANALYSES OF FAILURES ALONG DISCONTINUITIES

Numerous small wedges and plane failures, involving one bench in height, have been noted on the pit walls. Most of these failures are steep, and hence they have failed during or shortly after excavation. These failures provide little information concerning the shear strength of discontinuities, because their factor of safety is expected to be much less than 1.0.

Back analyses were carried out for one large plane failure on the 375m elevation near 22,925E (see Photo 13). This failure occurs primarily along a joint of Joint Set G, which has an average orientation of 330/47 and is typical of a possible failure which controls stability on the south wall.

Back analyses were carried out assuming a 10m high bench, a bench face angle of 80°, a failure plane with a dip of 47° and a friction angle of 36°. Back analyses indicate that the cohesion required for a factor of safety of 1.0 to 1.5 varies from 20 kPa to 51 kPa for

a slope with a tension crack (see Table VI). Additional analyses were carried out to determine the possible artificial support requirements, assuming that cohesion of 10 kPa could be mobilized along the joint.

Analyses results summarized in Table VI indicate the total anchor forces and number of anchors required to attain a factor of safety of 1.5 for this failure for a 10m high single bench. Results in Table VI indicate that the required anchor force decreases as the bench face angle is decreased. These results indicate that it is feasible to use grouted dowels or anchors to prevent small failures in the slope, provided dowels capable of maintaining sufficient loads can be installed in the slope. Results of trial dowel installations and pull out tests indicate that this is feasible.

6.5 DOCUMENTATION AND ASSESSMENT OF TRIAL INSTALLATIONS FOR POSSIBLE ARTIFICIAL SUPPORT

6.5.1 Background

In order to assess the feasibility of designing artificial support in the south wall, a series of trial dowel installations and pull out tests was recommended. The object of these tests was to install and test fully grouted dowels in representative weathered and unweathered rock types on the south wall. Details of dowel locations, installation details and test results are given in Table VII.

6.5.2 Installation and Test Results

Recommended locations and details of trial installations were summarized in a telex to the mine on October 18, 1981. Locations and test results for trial installations were transmitted by telex from the mine on February 8, 1982. These results are summarized in Table VII.

Cables tested had a nominal ultimate strength of 75 metric tonnes. Of ten dowels tested, nine tests were successful. The tenth test experienced jack failure and the jack could not be repaired on site. For all successful tests the cable strands failed at loads of 64 to 78 Tonnes. In no case did the anchor pull out for the test loads applied.

The average failure load was about 72 tonnes which indicate that a maximum design working load of 50 Tonnes (500 KN) would be reasonable and could be used for design of support systems for the dowel length specified.

7. HYDROGEOLOGY

Detailed assessment of hydrogeological conditions in the open pit is beyond the scope of this report. However some assessments of groundwater conditions in the open pit are justified, based on the obvious contribution of water to failures in weathered rock near the pit crest.

7.1 HYDROGEOLOGICAL CONDITIONS ON THE SOUTH WALL

Location of piezometer installations is shown on plan in Fig. 1 and on sections in Appendix A. A summary of all installations, maximum and minimum piezometric levels and hydraulic conductivities, based on falling head test results, is given in Table VIII.

Permeability test results indicate that rocks on the south wall have hydraulic conductivities of 3.8×10^{-7} to 2.7×10^{-10} m/sec. Hydraulic conductivities measured in percussion drillholes are generally about two orders of magnitude greater than those measured in diamond drillholes. Piezometric levels in individual piezometers and between adjacent piezometers indicate that groundwater on the south wall is related to local infiltration and flow in the immediate vicinity of the south wall. The South Wall Fault appears to form a barrier to groundwater flow, in that the water levels in some piezometers south of the fault are considerably higher than water levels north of the fault.

Regular weekly monitoring of piezometers indicates that there are reasonably large and rapid fluctuations in piezometric levels in response to precipitation. The moderate permeabilities and rapid fluctuation of piezometers indicates that the bulk of the groundwater in the south wall may be related to infiltration of surface water. It is likely that control of surface water, using sealed ditches and

inclined benches, would limit the amount of groundwater in the slope. Because of the moderately permeable nature of the rocks, it is likely that the adverse effects of groundwater in the slope could be reduced by simple depressurization techniques, using subhorizontal upward inclined drainholes in critical areas.

7.2 HYDROGEOLOGICAL CONDITIONS ON THE NORTH, WEST AND EAST WALLS

Little is known concerning hydrogeological conditions in areas of the pit other than the south wall, because no installations were placed in these areas. Presence of water in the sump in the pit indicates some groundwater flow could occur towards the open pit as it is deepened. There will also be a significant contribution to water flow in the pit as a result of precipitation within the pit limits.

To date no significant effects of groundwater have been noted on the north, east or west walls.

7.3 GROUNDWATER CONTROL AND DEPRESSURIZATION

The importance of groundwater control depends on the volume of water, rate of flow through the rock mass and water pressure in the slope. The necessity for control of groundwater is expected to vary, depending on the sensitivity of the particular area of the slope to variation in groundwater pressure. Stability analyses discussed in Section 8 indicate that in many areas groundwater pressure is expected to have little effect on slope stability and slope design.

In areas where groundwater is expected to affect slope stability, groundwater control and depressurization measures, consisting of subhorizontal upward inclined drainholes, are recommended near bench toes. Drainholes are particularly important on the south wall to

control water pressures in weak or weathered rocks south of the South Wall Fault. Drainholes are also recommended to control water pressures behind the South Wall Fault or other major faults. Drainholes may also be required in selected areas of the pit to control water pressures.

Location, length and spacing of drainholes is difficult to predict, based on the limited information available. However, optimum length and spacing of drainholes could be determined by installation of additional piezometers and monitoring the response when drainholes are installed near piezometers. In areas where drainholes are to be installed, it is suggested that piezometers should be installed and monitored prior to installing the drainholes. Drainholes should be installed initially at about 10m to 20m spacings. Spacing should be adjusted based on response of piezometers until an optimum spacing of drainholes has been achieved and the slope is depressurized.

Sealed piezometers should be installed on the south wall as the final pit is excavated. These piezometers should be monitored regularly to assess the effectiveness of drainholes, and to clearly determine the length and spacing of drainholes required to obtain effective depressurization of the slope.

7.4 SURFACE WATER CONTROL

Due to the unfavourable effects of groundwater on slope stability, particularly in the south wall of the open pit, it is recommended that a properly designed system of surface water control be constructed in the pit. Surface water control should consist of the following:

(i) A sealed drainage ditch behind the pit crest in all areas to intercept all water which could infiltrate into the rock mass.

(ii) The area around the entire pit crest should be properly graded to divert water into the drainage ditch or away from the pit.

(iii) Benches and haulroads on the south wall should be inclined and/or graded to divert water off the slope.

(iv) Drainage ditches or closed pipes are important to collect and control water from drainholes on the south wall.

(v) A sealed drainage ditch should be constructed on the haulroad to convey water off the slope and into sumps for pumping out of the open pit. Uncontrolled water flow should not be permitted in any area of the open pit.

(vi) Sealed drainage ditches should be constructed in areas of the pit other than the south wall only as required.

7.5 ADDITIONAL HYDROGEOLOGICAL INVESTIGATIONS

Other than specific areas as discussed above, serious groundwater problems have not occurred in the open pit. Hence, detailed investigation of hydrogeological conditions in the open pit is not considered warranted at this time.

However, it is recommended that sealed piezometers should be placed at strategic locations around the open pit to monitor groundwater pressures as the pit is developed. If monitoring indicates that

adverse groundwater pressures are developing in certain areas, horizontal drainholes should be installed until the slope is sufficiently depressurized. Depending on the severity of groundwater problems encountered, additional study may be warranted at a later date.

8. SLOPE STABILITY ANALYSES AND SLOPE DESIGN

Slope stability analyses involved investigating all kinematically possible failure modes with respect to faults, joints and other discontinuities which could lead to shallow failure of individual benches and/or deep seated failure involving large sections of the interramp slopes between haulroads. Consideration was also given to the past performance of the slope with respect to evaluation of basic failure modes as well as general rock mass behaviour. Plan radius of curvature of the proposed final slopes was also considered in the design. Back analysis of failures in the pit was used to assist in evaluating the effective friction and cohesion of discontinuities and to complement strength testing results. Back analysis of failures which occurred in the weathered schist and residual soils in the upper portion of the south wall was used to prepare a slope design and remedial measures in this area.

8.1 BASIC SLOPE DESIGN CONSIDERATIONS

In rock slopes, instability occurs as a result of failure along structural discontinuities, such as foliation joints, geological contacts, faults, etc. Seldom is instability due to failure through intact material, unless the rock is very soft or weak such as in the weathered schists and greywackes near the crest of the south wall. Therefore, the most important single factor in the stability analysis and design of rock slopes is to evaluate and determine the orientation, geometry and spatial distribution of the discontinuities in the slope. Having done this, the next step is to evaluate these

discontinuities with respect to the orientation and alternative possible angles of the proposed pit slope. It is following these basic principles that the slope stability analyses were carried out.

Slope control can be basically accomplished in two ways:

a) to design the slope so that no failures occur, or

b) to excavate the pit under controlled conditions and design the slope with adequate access so that failures can be caught on berms and removed if necessary.

The first solution is usually too conservative to be economically feasible. The second solution requires thorough consideration of slope geometry so that failures are contained on berms and safe access is available to the berms to allow removal of collected debris if required. This solution provides adequate safety at minimal cost, although special design or remedial measures may be required to insure the stability of haulroads or critical installations on benches.

The parameters which govern the geometry of a slope are shown in Fig. 12. These are bench height (H), berm width (ℓ), and bench face angle (β). These parameters are governed by the strength and nature of the slope, government mining regulations and equipment available. Bench height should be such as to provide a safe working slope as well as an optimum overall slope angle. It should be noted that without affecting the slope angle, higher benches will allow wider berms for better protection and more reliable and easier access, if this is desirable, although the size of possible failures may increase.

Berm width should be controlled to a certain extent by the amount of access required to the slope as well as the optimum width to accommodate failures. It must be accepted that, even with careful perimeter or controlled blasting techniques, a certain amount of breakback may occur. In general, slopes should have berms wide enough so that falling debris will be trapped and, equipment can have access to keep berms clean and effective as catchments if required.

By inclining the bench faces, blasting damage is reduced and high stresses are less likely to develop near the bench crests. Hence, tension cracks and overhangs are minimized. Avoiding these problems reduces the amount of rockfall and increases the safety of the slope.

8.2 DEEP SEATED FAILURE CONSIDERATIONS AND MAJOR FAILURES

Deep seated failure, involving several benches or even the whole slope, may involve major throughgoing faults or other major discontinuities. Deep seated failures may also develop through a complex interaction of minor and/or major structures to form a large, continuous, if somewhat irregular, failure surface(s). In some cases deep seated failure surfaces may in part develop by failure through intact rock bridges between discontinuities. Such failures are often precipitated by small slope readjustments and high stress concentrations at the toe of the slope, which tend to exceed the strength of the rock mass. This type of failure mechanism is particularly common in slopes where softer material at the toe of the slope, such as coal, potash, or schist bands, is squeezed out due to the load which is applied by the overlying strata.

8.2.1 Deep Seated Failure Involving Major Faults

As discussed in Section 5.4, major faults in the open pit are steep dipping. Hence, it is expected that even if undercut by mining instability would be confined to one or two benches at the most. In terms of the proposed design, some local design modifications and/or remedial measures may be required in areas of major faults. This is particularly the case for the South Wall Fault, wherein it is recommended that the benches be excavated to avoid undercutting this fault.

Major faults could result in significant damming of groundwater. Hence, drainholes may be required in the vicinity of major faults to control water pressures and stabilize slopes on a local basis.

8.2.2 Deep Seated Failures Involving Fault and Shear Sets

An equal area projection of planes representing the average orientation of faults and shears in the open pit is given in Fig. 13. The main orientations of fault sets and shear sets (summarized in Section 5.4) indicates that plane failures could occur along faults of either Set SR1 or Set SR2 in the south or southwest side of the pit where these faults dips to the northeast out of the slope. It is noteworthy that, based on geological mapping, these discontinuities are relatively poorly developed in Structural Domains 5D, 6A and 6B which occur on the south and southwest walls of the open pit.

Faults and shears of Set SR1 have an average dip of 35°. Large potential areas of instability could occur along these shears, or along a combination of faults and shears of Set SR1 and SR2. Because the average dip of these faults is similar to the average friction angle of discontinuities described in Section 6.2, it is possible that failures could occur along these discontinuities, particularly, if high groundwater pressures develop in the slope. It is likely that shear strength along faults and shears would be less than that along joints. However, the surfaces of faults and shears of Set SR1 have been noted to be rough and irregular and may have some effective cohesion.

Because faults and shears of Set SR2 have an average dip of 72°, it is expected that failures involving these discontinuities would only be developed over one or two benches. Such failures could form small areas of local instability, requiring remedial measures, if undercut by mining.

The possibility of occurrence of major faults of Sets SR1 or SR2 on the south and southwest walls of the final pit cannot be clearly stated at this time. Hence, it is not considered justified to flatten the slope in this area, based on the possible occurrence of a major fault. However, it is imperative that the slopes be carefully mapped and monitored. If a major failure develops, provision should be made for possible remedial measures such as artificial support, depressurization or possible slope flattening, if required.

8.2.3 Deep Seated Rotational Failures

For engineering purposes, the principal consideration in evaluating the compressive strength of the rock is to determine if there is any possibility of excessive deformation and ultimate rotational failure of the slope due to failure of the intact material, resulting from the weight of the overlying strata. In general, normal stresses up to 1000 psi (7 MPa) can be expected in deep, open pits. Thus, slopes which have part of the rocks with compressive strengths less than this could be subject to significant deformation and possibly failure if the crushing strengths are exceeded.

Based on the relatively high hardness and accordingly high compressive strength of most intact rocks in the pit, the likelihood of time dependent strain and subsequent failure of intact material in the slope appears to be small, the exception being the weathered or decomposed rocks on the upper benches of the south wall. Hence, the possibility of deep seated rotational failure, due to failure of intact material involving the whole slope, is low (at least within the range of overall slope angles which are geometrically feasible, and which are considered in this analysis).

Specific design and remedial measures to control possible rotational failures over one to two benches in the highly weathered rocks and residual soil near the crest of the south wall are discussed in Section 8.7.

8.3 STABILITY ANALYSES BASED ON GEOLOGIC STRUCTURAL ANALYSIS RESULTS

8.3.1 Description of the Design Sector Concept

Rational slope stability analysis and design requires prediction of the geologic structural conditions which occur on the final pit wall. Such a prediction includes determining the distribution and location of lithologic units, geological contacts, major faults and structural domain boundaries.

Not only must structural domains be considered for individual analysis, but also the overall orientation of the final pit wall must be considered as well. Different pit wall orientations require basically different design considerations. Hence, it is necessary to define zones which contain essentially one structural domain and one general pit slope orientation; these zones are designated design sectors.

If the orientation of the pit wall changes within a structural domain, depending on the number of different pit slope orientations, two or possibly more design sectors may be required within that structural domain. If, on the other hand, two structural domains occur where the orientation of the pit wall is constant, two design sectors will result.

All available geological mapping and core logging information was used to project the structural domain boundaries onto the proposed final pit wall. The boundaries of the structural domains and straight slope segments on the proposed final pit walls were used to determine the design sector boundaries, and thus delineate the design sectors, as shown in Fig. 14.

The proposed final pit was divided into 17 design sectors, designated Design Sectors 1-1, 6B-1, 6B-2 etc. In some cases, where small portions of the pit theoretically should comprise a separate design sector, these areas have been incorporated into larger design sectors. Information relating to pit wall orientation, structural areas, main rock types and related slope information for each design sector is given in Table IX.

8.3.2 Design Criteria Concerning Orientation of Geological Structure

Because there are significant variations in intensity, orientation and dip of each joint set and fault set in various areas of the pit, the effects of each joint set acting individually or in combination with other joint sets should be evaluated statistically. The statistical significance of one particular failure mode on stability may be low. However, the combined statistical significance of all possible failure modes, with respect to both the actual observed and predicted performance of the slope, should be evaluated to prepare a rational pit slope design.

Statistical analysis of joint sets is of key importance for bench design. In this regard, the volume of slope failure, which is considered to be statistically significant, is used to determine the bench design required to contain failed material on benches and provide a safe slope.

Within most rocks in the pit many joints are continuous over several benches. However, because of the generally steeply dipping nature of most structures in the pit, it is unlikely that bench failures, involving more than one or two benches,

would develop along single sets of discontinuities or combinations of single sets of discontinuities. As discussed earlier, it is possible that large failures could develop involving occasional major discontinuities, which dip towards the pit and daylight in the wall. This is not seen to be a significant factor, however, in terms of the design criteria at Mt. Carbine. The location and extent of such shallowly dipping features cannot be predicted with any degree of confidence within practical limits on the final pit wall.

8.3.3 Determination of Kinematically Possible Modes of Failure

Equal area projections of planes representing the peak orientations of the various discontinuity sets (i.e. faults, shears, joints, veins and foliation in each design sector) were used to define the possible failure modes as shown in Fig. 14.

8.3.4 Mechanical Stability Analyses

Appropriate stability analyses, using a desktop computer, were carried out for each possible failure mode. Friction properties of the discontinuities used in the analyses were based on laboratory test results, as summarized in Section 6.

Stability analyses results were used to determine the kinematically possible failure mode(s) which controls slope stability. The failure mode(s) which has the shallowest average dip or plunge for a factor of safety of 1.2 and 2.0 were assumed to control stability for dry (or drained slopes) and

saturated (underwatered slopes), respectively. In these cases the slope design would be based on the "worst case" assuming all possible failures would be controlled on each bench.

Because of numerous kinematically possible failures in the pit, stability analyses were also approached statistically, using simple limit equilibrium methods. The analysis technique assumed dry slopes to simplify the analysis. With regard to stability analyses, a factor of safety greater than or equal to 1.2 was considered adequate to insure stability of dry (i.e., drained or dewatered) slopes. A factor of safety greater than or equal to 2.0 (assuming the dry condition) was considered adequate for stability of slopes subject to adverse groundwater conditions (i.e. undrained or fully saturated slopes).

8.4 STATISTICAL ANALYSES OF POSSIBLE WEDGE FAILURES

In most areas, slope stability appears to be controlled by plane or wedge failures on benches. These failures are generally formed by a combination of joints, veins and/or faults. Thus, in terms of design of interramp slopes between haulroads, optimum bench geometry will control the overall slope design.

8.4.1 Determination of Possible Critical Failure Modes

The number and geometry of possible failure modes in each design sector is determined by evaluating the various combinations of discontinuity sets with respect to the proposed orientation of the final pit wall. Discontinuities are evaluated based on the peak or average orientations of each

joint set. Kinematic plots of discontinuity sets in each design sector are presented in Fig. 14.

Because the analysis is developed for bench design, all kinematically possible failure modes which dip or plunge out of a slope face with an angle of up to 90^{o} and a factor of safety of less than 2.0, are considered in the analysis. These possible failures are designated "critical failure modes" or "critical wedges", in that they could lead to failure or breakback of individual bench crests.

In most design sectors there are a large number of possible critical failure modes, since several joint sets and fault sets occur in each design sector. Also, because vertical (90^{o}) bench face angles are considered for analysis purposes, a large number of critical failure modes has resulted. In such cases, statistical analysis was used to considerable advantage.

In some design sectors there are few joint sets, and consequently only a few critical failure modes. In these areas the dip or apparent plunge of the least favourable failure mode with a factor of safety less than 1.2 (dry slope) and 2.0 (undrained slope) is chosen for design. In these cases, the slope geometry is optimized to control possible failures on benches.

8.4.2 Statistical Analysis of Possible Critical Wedges

i) Orientation of Sets of Discontinuity

Sets of discontinuities which form critical failure modes are defined by the peak or average orientation of the discontinuity sets. Peak orientations of different discontinuity sets and subsets give an appreciation of the range of possible orientations of the discontinuity sets in the particular design sector.

ii) Determination of Number and Orientation of Possible Critical Failure Modes

Based on the critical failure modes identified, the total number of possible wedges was determined for all possible combinations of the peak orientation of each joint set. The number of possible wedges was determined by adding the number of discontinuities which correspond to the orientation of each discontinuity set involved in a particular possible wedge combination. Equal area projections of the joint sets were used to determine the average plunge of each possible wedge failure, as well as the apparent plunge relative to the proposed final slope. The apparent plunge was recorded for purposes of determining the actual size or volume of possible failures. All possible combinations were tested for type of failure, and a factor of safety was calculated using a standard wedge analysis method.

iii) Development of Cumulative Frequency Plots

Equal area projections and the stability analysis results summarize the orientation and apparent plunge of the possible critical failure modes examined. Unique statistical plots are used to assess the distribution and relative number of possible failure combinations. The cumulative frequency of possible failures are plotted aginst apparent plunge of the possible wedges in terms of those wedges which have a factor of safety less than 2.0 and less than 1.2, respectively. Cumulative frequency plots for all design sectors assessed by this method are given in Appendix D.

Cumulative frequency plots have been developed for wedges with a factor of safety less than 1.2 and 2.0, because it is considered that these values are required to prevent failure of a dry (or dewatered) slope or undewatered slope, respectively. In many cases, because of the steeply dipping nature of most discontinuity sets, there was little or no difference between the cumulative frequency plots for factor of safety less than 1.2 and 2.0.

iv) Interpretation of the Cumulative Frequency Plots

The statistical cumulative frequency plots described above were assessed by evaluating the apparent plunge of failures in terms of the cumulative percentages and factors of safety of the respective possible

wedge failures in each design sector. The appropriate cumulative frequency plots in Appendix D, may be used to assess the significance of the cumulative frequency distribution for each design sector and the difference in apparent plunge for each factor of safety.

Most of the cumulative frequency plots have a somewhat characteristic, though crude, S shape, as shown in Appendix D. For any given design sector there is usually a point on the curves beyond which, for an increase in apparent plunge of wedges, there is a correspondingly sharp increase in the cumulative frequency of possible wedge failures. Cumulative percentages and corresponding apparent plunges for the break in curvature of the cumulative frequency distribution in each design sector are also presented in Tables IX.

8.4.3 Analysis of Wedge Failures When There Are Insufficient Wedges to Carry Out Statistical Analyses

In cases where there are not enough critical failure modes to carry out a statistical analysis, slope design is determined based on the least favourable failure mode with a factor of safety less than 2.0 and 1.2. The least favourable failure mode corresponds to a worst case. This failure mode is used to determine the berm widths, bench heights and bench face angles required to catch failed debris on individual benches. Design charts based on slope geometry and failure geometry are developed for these cases.

8.4.4 Effects of Plane Failures on Statistical Analysis Results

In cases where plane failure on shallow dipping joints dominates slope design, statistical analyses techniques are not valid. In these cases the slope design would be controlled by the "worst case" as described in Section 8.3.4.

At Mt. Carbine plane failures could occur primarily along joints, faults, shears or veins which dip towards the pit. In all design sectors where the dip of a possible failure plane is steeper than the angle of friction along these surfaces, planar sliding is assumed to be kinematically possible, and the slope should not be excavated at a steeper angle than these planes. This would be the case unless specifically required remedial measures such as artificial support or depressurization or both, are used. In general, the slope should be designed so that failures along single surfaces are caught on berms. Dips of failure surfaces for design sectors where plane failure controls slope design are summarized in the appropriate columns in Table IX. In several design sectors, shallow dipping planar failures are indicated, which involve poorly developed joint sets or fault sets. In these cases, it is not considered realistic to flatten the slope based on the questionable occurrence of these features. However, it is imperative that the slopes be carefully mapped and monitored. If failures are encountered, provisions should be made for possible remedial measures if required.

8.5 BENCH BREAKBACK ANALYSIS

An analysis of bench breakback was carried out to compare the current geometry in the pit with the failure geometry indicated by the stability analyses of possible failure modes. Bench breakback angle was obtained by calculating the existing bench breakback for 10m high benches from profiles taken normal to the pit walls in various areas of the current pit (October, 1981). Measurements taken for slopes of similar orientation in similar areas of the open pit were grouped together, and the average breakback was calculated (as summarized in Table X).

Bench breakback occurs in virtually all sections of the pit, due primarily to bench failures on steep dipping discontinuities, as well as the adverse effects of blasting. Typical breakback in the pit is shown in Photo 15. The analysis indicates that generally the average bench breakback is as steep or steeper than the geologic structures which control the potential failure modes. This is probably due to the favourable effects of asperities, intact rock bridges, cohesion, etc., which tend to add sufficient additional resisting forces to prevent complete failure of the potential sliding blocks. The presence of cohesion in the slope has already been indicated by the back analysis results for bench failures discussed previously.

The average breakback in various areas of the open pit (as summarized in Table X) ranges from 2.45m to 4.88m. It is noteworthy that in areas where controlled blasting has been used on the east wall, breakback is about 2.45m. Examination of the breakback in the pit indicates that over half the breakback on benches occurs near the bench crests and results primarily from blasting damage (see Photo 15). On the east wall, where controlled blasting has been used, bench breakback appears to be approximately half that compared to where controlled blasting was not used.



PHOTO 15: View of breakback of bench crests due to natural failures and blast damage on the west wall of the open pit. Note that over one half the breakback occurs near the bench crests.

Based on the analyses summarized in Table X, it is reasonable to assume that, if careful controlled blasting is used on the final wall, the average break back at the crest of vertical benches would be approximately 2.5m for every ten metres of bench height. This would result in breakback angles of 76°. Therefore, 10, 20 and 30 metre high benches would be expected to have bench breakbacks of 2.5, 5.0 and 7.5m, respectively (provided that careful controlled blasting were used). It appears that if controlled blasting were not used, breakback would be significantly greater.

If bench faces are inclined, the breakback at bench crests would be accordingly reduced. Hence, bench faces at 76° or less would be expected to have minimal breakback, in that the slopes would be excavated shallower than the anticipated breakback angle. Benches excavated at 80° would be expected to have breakback of about 0.74m, 1.47m and 2.21m for 10, 20 and 30m bench heights, respectively.

8.6 DESIGN OF INTERRAMP SLOPES BASED ON STATISTICAL ANALYSES RESULTS

Statistical analysis of kinematically possible failure mechanisms was applied to design of benches and interramp slopes in all areas of the open pit. However, the stability of slopes in the weathered schists and greywackes south of the South Wall Fault is controlled largely by rotational failures, as well as failures along shallow dipping discontinuities. Because of the critical nature of this wall, and constraints on mining geometry as a result of the primary crusher and stock piles near the pit crest, the statistical analyses were not suitable by themselves for slope design in the area south of the South Wall Fault. Hence, other types of analysis had to be considered in this area. Detailed slope design and remedial measures for the area south of the South Wall Fault are discussed in Section 8.7.

8.6.1 Presentation and Evaluation of Analysis Results for Slope Design

The results of stability analyses for the various types of kinematically possible failure mechanisms are presented in Table IX. The average dip of planar failures or plunge of wedge failures for the worst case, or for design sectors where statistical analyses were not carried out, are recorded in the appropriate columnns. The results of the statistical analysis of wedges are also given for a cumulative frequency of 20% of possible unstable wedges, and for the break in the cumulative frequency plot for factors of safety less than 2.0 and 1.2, respectively.

In general, it is considered reasonable to design slopes to accommodate the bulk of the bench failures. Therefore, if the slope design is based on a cumulative percentages of 20%, this could result in 20% of the possible failure modes not being caught on berms or controlled on individual benches. Hence, it is possible that a failure, which is not controlled on a bench, would spill over and be caught on a lower bench. Consequently, safe reliable access on strategic or critical benches for clean up is desirable.

Based largely on engineering experience at other open pit mines, it is considered reasonable for preliminary slope design purposes to assume that a cumulative frequency of 20% of the possible wedge failures would not be retained on a single bench. In many cases, however, the break in the curve

appears to be more realistic for design. Therefore, for purposes of the statistical analysis, the lesser of these two values is used to determine the apparent plunge angle of the possible wedge failures for design.

Based on the above discussion, the least favourable analysis results for each design sector are chosen for slope design. These values are circled in Table IX.

8.6.2 Determination of Slope Angle and Slope Geometry Based on Failure Geometry

The failure modes or apparent plunge of wedges, which are considered to control slope design in each design sector, are used to determine the possible failure geometry and slope design required to control these failures. Design charts have been developed for slope design, based on slope geometry and possible failure geometry, for 20m and 30m high benches, as shown in Figs. 15 and 16.

Bench heights of 20m to 30m are considered feasible in hornfels and related rock north of the South Wall Fault, due to the high compressive strength of the rock and steep dip of most joints. The analyses presented in this report are carried out for both 20m and 30m high benches to determine the optimum bench height to be used for each design sector.

The design charts may be used to determine the size of potential failures, the minimum berm width and the intermediate slope angle between haulroads required to control possible bench failures defined by structural discontinuities. These

calculations are based on the dip or plunge of possible failures, β_w, which is indicated from the statistical analysis discussed above and circled in Table IX.

The volume of material in a bench failure is proportional to either the dip of a failure surface or plunge of wedge failure, β_w, bench face angle and bench height. The shallower the dip or plunge of a failure, the greater the volume of material which could fail onto the bench. Calculation of the cross-sectional area (A) of a possible bench failure for a particular bench height gives an estimate of the volume of failed material per unit width of berm (see Figs. 15(a) and 16(a)).

Cross-sectional area of a possible bench failure is used to calculate the minimum berm width (ℓ_{req}) which is required to catch all possible failed material (see Figs. 15(b) and 16 (b)). In this calculation, it is assumed that the failed material completely breaks down and comes to rest at the natural angle of repose (r) of the failed material, which is assumed to be 38^{o}. Minimum berm widths may be used to calculate the interramp slope angle between haulroads (θ), for the particular bench height and bench face angle which is assumed in the analysis (see Figs. 15(c) and 16(c)). A bulking factor due to an increase in volume of material during failure is not considered in the calculation of minimum berm width (ℓ_{req}). Results of the analyses with regard to the bulking factor are considered to be conservative.

It is recommended that the total berm width be calculated by adding the berm width required to catch failed material to the anticipated average breakback (ℓ_{bb}) at the bench crests. As discussed in Section 8.5, the average breakback is expected to be 5.0m and 7.5m for 20m and 30m high vertical benches, provided controlled blasting is used on final walls. If bench faces are inclined, the amount of breakback would be reduced accordingly. Total berm width recorded in Table IX is the sum of the calculated berm width, i.e.

$$\ell_{total} = \ell_{req} + \ell_{bb}$$

The total berm width is used to determine the interramp slope angle using the design charts in Figs. 15(c) and 16(c). These angles are assessed and a slope design prepared accordingly.

8.6.3 Determination of Optimum Bench Design

Analyses were carried out using the design charts described above for both 20m and 30m high benches to determine the optimum interramp slope angle. The optimum interramp slope angle is determined from the possible failure mode which is expected to control stability of slopes, using the design charts as described in the following and summarized for 20m and 30m high benches in Table IX.

(i) Selection of Optimum Bench Face Angle

For 20m or 30m high benches it is considered practical to excavate bench faces at 70° to 80° in order

to provide better control on the final face and reduce high stresses near crests of individual benches.

The optimum bench face angle was selected based on the dip or apparent plunge of the failure mode. For 20m high benches the optimum bench face angle is 70^{o} for failure modes which are less than 54^{o}. The optimum bench face angle is 80^{o} for failure modes which are steeper than 54^{o}. For 30m high benches the optimum bench face angle is 70^{o} for failure modes which are less than 67^{o}, but the optimum bench face angle is 80^{o} for failure modes which are steeper than 67^{o}.

(ii) Calculation of Berm Width

The total berm width required to retain failed debris on the berm, with due consideration to the average expected breakback, was calculated for the optimum bench face angle.

For purposes of preliminary slope design, minimum allowable berm widths not including average breakback are assumed to be 9m and 10m for 20m and 30m high benches, respectively. These minimum berm widths are recommended to provide adequate safety, catchment, and access to the slope. Minimum berm widths could possibly be reduced for final slope designs, depending on the performance of interim slopes.

(iii) Calculation of Optimum Interramp Slope Angle

The optimum interramp slope angle was determined from the design charts based on the optimum bench face angle and total berm width. Calculated interramp slope angles for 20m and 30m high benches are summarized in Table IX and Fig. 14. Alternative slope angles were compared and the optimum bench height and slope design was selected.

8.6.4 Modification of Design Based on Effects of Plan Radius of Curvature at North and South Ends of Pit

It is considered justified that the relatively tightly curved slopes in the east and west ends of the open pit may be excavated at angles somewhat steeper than those indicated from the stability analyses, due to the effects of lateral constraint or arching caused by the relatively tight plan radius of curvature. Current theories of slope stability deal with the slope as a two-dimensional problem, i.e. the analysis is carried out on the basis of plane strain for a slice of unit thickness cut from within an infinitely long straight slope. As the radius of curvature decreases, horizontal tangential stresses increase and "arching" occurs which improves the stability of the slope. In effect, the tight curvature of a slope provides lateral constraint which tends to increase the cohesive forces and the competency of the rock mass as a whole.

Based on compilation by Coates and Sage (1974) of empirical data from field studies and mathematical modelling of radius of curvature effects in several open pits, a simple formula to recognize these effects in design has been developed. A correction increment (i) is proposed which represents the allowable increase in slope angle due to the effects of plan radius of curvature (R) and slope height (H) where

$$i = \frac{3}{2\frac{R}{H} - 1} \quad \text{for R/H greater than 0.5}$$

The plan radius of curvature and allowable increase in slope angle (i) are shown for the east and west wall in Fig. 14 and summarized in Table IX. These radius of curvature effects mainly apply to the lower reaches of the east and west wall. All other areas in the pit have a large radius of curvature and there is no significant effect of lateral constraint.

8.6.5 Recommended Slope Design

(i) Interramp Slope Design Between Haulroads in Design Sectors

The final recommended design for interramp slope for both dry, (i.e. drained or dewatered) conditions are summarized in the columns on the extreme right side

in Table IX. These slope designs have been determined by adjusting the optimum interramp slope angle based on consideration of effects of plan radius of curvature and requirements for access and safety particularly on the south wall. These slope designs are also summarized on the proposed final pit plan in Fig. 17.

Based on the design criteria and procedures described above, the optimum interramp slope angle may be selected for the case of either 20m or 30m high benches (as summarized in Table IX). In general, 30m high benches result in interramp slopes as steep or steeper than those for 20m high benches, mainly because the required minimum berm width for 30m high benches is similar to that for 20m high benches. Hence, steeper slopes would generally be achieved if 30m high benches are used.

In certain areas of the open pit, particularly on the south wall, the proposed slope design and remedial measures require the use of 10m and 20m high benches (as described in Section 8.7). In nearly all areas it is important to maintain access to some benches. Access is particularly important on the south wall for maintenance of drainage ditches, remedial measures, monitoring etc.

Examination of the proposed pit plan indicates that, even though 30m high benches would be feasible in most areas north of the South Wall Fault, 20m high

benches will be required in all areas between elevation 305 and 345m to insure access to benches on the south wall. Bench heights of 30m are feasible for interramp slopes above 345m and below 305m. Below 305m, the angle of the overall slope is considerably flattened as a result of haulroads. Hence, increased interramp slope angles and bench heights are considered justified. Above 345m, 30m high benches could be blended relatively easily to 10m high benches on the south wall with some loss of access. These bench heights are considered justified, based on the specific ground conditions at Mount Carbine. Distribution of the areas where 20m and 30m benches recommended are shown in Fig. 17.

(ii) Blending and Modification of Recommended Slope Designs for Pit Planning Purposes

Slope designs recommended are based on analysis of information within design sectors, but without due consideration of pit planning requirements and designs in adjacent design sectors. Design of the final pit slopes must include zones of transition between the slope designs of adjacent design sectors. In general, the recommended slope angles for a design sector should not be exceeded in transition zones. However, because of the additional berm width provided in the slope design to account for bench breakback, it is considered justified to steepen interramp slopes by up to three degrees over small sections of the slope and accept the possibility of increased failures spilling over benches. Therefore,

if transition zones are not overly wide, it may be justified to increase slope angles up to three degrees near the boundaries of design sectors in order to enable blending of the slope designs between adjacent design sectors.

Results of blending slopes and related modification to slope design based on the probable mining geometry constraints are summarized in Fig. 18. Fig. 18 shows the recommended general slope designs, bench heights maximum and interramp slope angles in all areas of the pit except the areas south of the South Wall Fault (where specialized design and remedial measures have been prepared (see Section 8.7)).

(iii) Production Blasting and Final Wall Blasting

If 20m or 30m high benches and steep interramp slopes are used, it is imperative that breakback of the final wall should be minimized with careful perimeter blasting, using small diameter and lightly loaded holes. Blast design should be re-evaluated and trial blasting should be carried out to assess possible control of breakback on 20m and 30m high benches. Reduced breakback would indicate feasibility of steeper bench face angles, and hence steeper interramp slope angles.

(iv) Groundwater Control and Drainage

Little is known concerning groundwater conditions in the open pit. Horizontal drainholes may be required in selected areas to control groundwater pressures. Piezometers should be installed at appropriate locations to monitor groundwater if problems develop.

Control of surface drainage is extremely important. A carefully engineered surface drainage system with drainage ditches should be provided on all roads and selected benches to control water flow in the pit. Many of these drainage ditches should be lined in appropriate areas.

(v) Artificial Support

The steep slopes recommended herein could result in occasional failures which could result in loss of berms or loss of part of the haulroads. It is suggested that either predowelling or postdowelling with cables may be beneficial in some areas to prevent loss of the bench catchment immediately above haulroads or loss of part of the haulroad itself. Location and number of dowels would be determined based on detailed geologic structural mapping during excavation to identify possible failures so that appropriate remedial measures could be designed. It is noteworthy that, where any failures appear imminent or in a state of slow translation which could significantly affect the operation, predowelling may be the most effective approach.

(vi) Trial Slopes

Trial slopes, consisting of 30m high benches, steeper bench face angles and/or narrower berms, could be worked into the slope on a trial basis with due consideration of operational constraints and ramifications if the trials are not satisfactory. Trial slopes are particularly desireable in that the stability and feasibility of 20m and 30m high benches is essentially unknown. Results of monitoring of trial sections would be useful for preparing final slope designs in the open pit as mining proceeds.

(vii) Cleaning Berms and Scaling

Rockfall hazards can be minimized if berms are cleaned and all benches are carefully scaled during excavation. This is particularly important in the vicinity of haulroads or critical installations.

(viii) Geological Mapping and Monitoring

All slopes should be mapped during excavation. This is particularly important on the south wall where relatively little information is available concerning the geological structure below the South Wall Fault Mapping should be updated on an ongoing basis and assessed to predict changes in structural geology conditions. In this way justificiation for flattening or steepening can be considered on a rational basis in the lower reaches of the pit. Slopes should

be carefully observed for signs of instability, tension cracking, movement, etc. If instability develops, a survey monitoring network should be established to determine the magnitude and rates of movement.

8.7 DESIGN OF SLOPES ON THE SOUTH WALL ADJACENT TO AND SOUTH OF THE SOUTH WALL FAULT

Slopes in Design Sectors 1-1, 2-1 and 3-1 south of the South Wall Fault require special design considerations. This is due to the presence of weaker rocks in the weathered zone, the strong structural control of the South Wall Fault as well as presence of relatively shallow kinematically possible failure modes. Kinematic stability analyses of structural discontinuities and back analyses of failures in weathered rock, as well as along discontinuities, were used to prepare a rational design for slopes in these design sectors. Because of the constraints on slope design which arise as a result of the location of the primary crusher and ore stock piles near the pit crest, specific remedial measures including, controlled excavation, artificial support and drainage are recommended to develop slopes at angles steeper than those which would normally be anticipated for the slope forming materials which exist in this area. Feasibility of using fully grouted cable dowels has been demonstrated by pull out tests of trial dowels. Pull out tests on dowels in ten selected locations indicated that acceptable loads were obtained in all dowels tested. It should be noted that, because kinematically possible failures could develop on the south wall slope, artificial support consisting of grouted dowels is necessary to maintain steep slope angles. Alternative methods of artificial support such as gabions, buttresses, shotcrete etc. would not be sufficient to prevent the failures along joints documented in these slopes.

Degree of weathering decreases and rock strength increases with depth in slopes south of the South Wall Fault (as summarized in Table I). Hence, slope design must be developed for individual benches based on the possibility of both rotational failure and failure on discontinuities. Back analyses results for both types of failure (see Section 6) and kinematic stability analysis results summarized in Table IX have been used to prepare a rational slope design for each bench and the entire slope. Details of the recommended design are shown in Fig. 19.

When designing artificial support, it is important that the strength provided by the dowels or anchors is fully utilized. In addition, it is imperative that an adequate distribution of pattern support be established across the failure surface. Hence, although it may be possible to develop high strength on individual dowels, it will be necessary to install a sufficient number of dowels to provide an even distribution of support in the slope.

The slope designs presented in this section pertain only to slopes south of the South Wall Fault and for the first bench below and north of the South Wall Fault. Design of slopes more than one bench north of the South Wall Fault is described in Section 8.6.

8.7.1 General Slope Design Recommendations

(i) Excavation Method

In weaker materials on the upper benches it is suggested that flatter bench face angles be adopted to control soil type failure. Steeper bench face should be used in lower benches where rock progressively becomes harder.

The slope should be excavated by ripping in the top three benches. Ripping is recommended on other benches wherever possible. If ripping is not used on lower benches or in the hornfels rock, preshearing or some other acceptable perimeter blasting technique using lightly loaded, closely spaced, small diameter holes should be used. Careful controlled blasting is required to maintain cohesion in the rock mass, since cohesion contributes significantly to stability of the south wall.

(ii) Artificial Support

Where required, use of vertical and inclined fully grouted dowels are recommended to provide artificial support of the slope to increase the stability of kinematically possible failures and enable steeper overall slopes to be mined on the south wall. Vertical dowels should consist of old drill steel, steel rail, beams, reinforcing bars or equivalent stiff members grouted into clean vertical holes using an acceptable cement grout. Inclined dowels would consist of degreased cables grouted into drillholes inclined at about -10^{o} (i.e. 10^{o} below horizontal).

Dowels should be placed in clean drillholes which have been thoroughly flushed to remove all loose debris, dust and drill cuttings. Cables should be clean and free from grease or deleterious substances. Dowels should be centred in the holes as best as possible. Grout should be an acceptable nonshrink

cement grout capable of developing adequate bond strength. Grout should completely fill the drill holes and cables should be fully encased in grout. Preliminary lengths and spacing of dowels are recommended based on stability analyses results and necessity to obtain distribution of pattern support across possible failure surfaces.

If adequate distribution of support could be obtained with dowels it would be feasible to increase dowel spacing, although care should be taken to support all possible blocks in the slope. In the following a standard dowel spacing of 3m has been recommended for 200 kN (20 Tonne) dowels. In that dowel pullout tests indicate that it is possible to develop ultimate loads in excess of 700 kN (70 Tonnes) and design loads of 500 kN (50 Tonnes). In this regard it may be feasiblle to increase dowel spacings to about 5m on a trial basis on benches below the 365m elevation, provided that adequate distribution of support and sufficient restraint of surface blocks is obtained.

If additional support is required to retain small blocks or ravelling, it is suggested that bearing plates may be required for the dowels. Alternately, steel straps might be placed between the dowels for additional support. Also a sufficient length of dowel could be left at the face to enable the dowels to be laced together to provide additional support if required.

(iii) Drainage Ditches

A proper sealed drainage ditch should be placed at the pit crest to prevent infiltration of surface water. The area behind the pit crest should be sloped away from the pit and/or slightly cambered so that all surface water is directed into drains and carried away from the south wall. The existing topography in the south wall area is favourable for construction of a well engineered surface drain at the pit crest.

Drainage ditches should be placed on each bench to convey surface water or drainage water off the slope. Benches should be slightly inclined towards the drainage ditches. Benches should be given a sufficient grade across the slope to carry all water in surface drains off the slope and to a sump for removal from the pit. The haulroad possibly also should be inclined or cambered to control surface water, and a well engineered sealed ditch should be placed at the edge of the haulroad.

(iv) Sub Horizontal Drainholes

Drainholes, slightly inclined upwards at $+5^{o}$ to $+10^{o}$, approximately 30 metres long and spaced at 10 to 15 metre intervals should be installed on each bench. Spacing of drainholes may be increased on lower benches, depending on the volume of water encountered and how well surface water infiltration is

controlled. Piezometer should be placed at selected locations on benches to monitor the effectiveness of drainholes and assist with determination of optimum length and spacing of drainholes.

(v) Piezometer Installations

Two to four piezometers should be installed on each bench on the south wall to assess effectiveness of drainholes and to monitor groundwater pressures in the slope.

(vi) Geological Mapping

The wall should be mapped as excavation proceeds and additional analyses carried out to determine dowel requirements in the lower reaches of the south wall. This is particularly important if dowel spacing is increased on a trial basis. It is mandatory that mapping and analysis be carried out during excavation to assess this design and apply and/or modify remedial measures as required.

(vii) Monitoring

Slopes should be monitored for movement on a regular basis, using relatively simple techniques. If movements are indicated, detailed monitoring should be initiated to determine the extent and nature of movement to enable rational design of remedial measures.

8.7.2 Design of the First Bench Above 375m

(i) One to two rows of vertical dowels should be installed at the crest of the slope. If two rows are used, they should be about 2m apart, and should be staggered with respect to the first row. Dowels should be 10m long and spaced at 3m along the crest. Dowels should consist of old drill steel, steel rail, H beams, or reinforcing bars grouted into blastholes drilled from the crest.

(ii) The slope should be ripped at a slope angle of 50^{o} in two lifts. The first lift should be ripped to 380m elevation and one row of vertical dowels should be installed as above. These dowels should be 7m long and spaced at 3m along the slope.

Where the pit crest extends above 385m, a row of vertical dowels should also be installed at 385m as described above (see Fig. 19).

(iii) The slope should continue to be ripped at an angle of 50^{o} to 375m elevation and a 5m wide berm should be established at 375m. Horizontal drainholes and a sealed ditch should be installed at the 375m elevation before commencing further excavation of the slope.

8.7.3 Design of the Second Bench (365 to 375m)

(i) The bench face should be ripped at 57° in two lifts. Firstly, rip the slope to 370m and install one row of 200 kN (20 Tonne) cable dowels at -10° at 3m spacing at elevation 373m. Install a second row of cable dowels at -10° at 3m spacing at 370m elevation. These dowels should be 6m long (see Fig. 19).

(ii) Continue to rip the slope at 57° to 365m elevation and establish a 6m wide berm.

(iii) Install horizontal drainholes and a sealed ditch on bench 365m before further excavation.

8.7.4 Design of the Third Bench (355 to 365m)

(i) The bench face should be ripped at an angle of 70° in 2 to 3 lifts down to elevation 355m. Install three rows of 200 kN (20 Tonne) cable dowels at -10° at elevations of 364m, 362m and 360m after each lift and as excavation proceeds. Dowels should be 8m long, spaced at 3m. These dowels should be placed prior to excavating more than 2m below each row. Dowel spacing could be increased to 5m on a trial basis if 500 kN (50 Tonne) cable dowels are used provided rock mass conditions would appear to be feasible for the wider dowel spacing.

(ii) A 6m wide berm should be established at elevation 355m.

(iii) Horizontal drainholes should be installed and a drainage ditch should be established at elevation 355m prior to further excavation below 355m elevation.

8.7.5 Design of the Fourth Bench (345 to 355m)

(i) Design is the same as for the third bench. If ripping is not possible control blasting should be used. Excavation lifts should not exceed 5m height in order that dowels can be placed prior to excavation of lower lifts. Three rows of 200 kN (20 Tonne) cable dowels should be installed at 354, 352 and 350m after each lift and as excavation proceeds. Dowels should be 8m long and spaced at 3m. As described above, dowel spacing could be increased to 5m on a trial basis if 500 kN (50 Tonne) dowels are used.

(ii) No subgrade drilling should be carried out.

8.7.6 Design of the Fifth Bench (325 to 345m)

(i) This bench should be 20m high (double bench) and the bench face should be ripped at 70^{o} in 5m high lifts. If ripping is not possible, adequate perimeter control blasting should be used. Lifts should be a maximum height of 5m in order that dowels may be placed prior to excavation of lower lifts. Install five rows of 500 kN (50 Tonne) dowels inclined at

-10° at elevations 343m, 340m, 337m, 334m and 331m with specific dowel lengths of 12m, 10m, 9m, 8m and 6m, respectively. Dowels should be spaced at 3m. Because the bench height is 20m, a greater number of dowels is required than for the 10m high bench. Hence, 500 kN (50 Tonne) dowels spaced at 3m are required (see Fig. 19).

(ii) Establish a 10m wide berm at elevation 325m.

(iii) Drainholes and a drainage ditch should be placed at the toe of the bench face.

(iv) No subgrade drilling should be carried out.

(v) The need for the fifth bench only exists for a distance of about 60m on the south side of the South Wall Fault.

(vi) Additional benches below 325m south of the South Wall Fault would be developed using the same procedure as described for the fifth bench.

8.7.7 Slope Design Immediately North of the South Wall Fault

(i) It is recommended that 20m high benches should be used north of the South Wall Fault. Details of slope design in design sectors north of the South Wall Fault are given in section 8.6. Because of the

geometry of South Wall Fault, this fault could lead to local instability if undercut. Therefore, it is important to design the first bench north of the fault in such a manner that the fault is not undercut by mining. In this regard a bench face angle of 70° is recommended on the first bench immediately north of the South Wall Fault.

(ii) Drainholes are essential to drain or depressurize the fault for one to two benches north of the fault.

(iii) Benches north of the South Wall Fault should be excavated using preshearing, cushion blasting or some other acceptable perimeter blasting techniques, using lightly loaded and closely spaced steeply inclined drillholes. No subgrade drilling should be carried out on benches.

(iv) Dowel requirements north of the South Wall Fault are difficult to estimate due to limited information available in this area. Preliminary assessment of data indicates joints exist which dip at 44° to 50° in the rock in this area. Continuity of these joints is difficult to assess and dowelling may or may not be required.

(v) For the support of the haulroad it is advisable to anticipate the use of grouted dowels similar to those required for the 20m bench south of the fault (as described in Section 8.7.6 above). On lower benches dowelling requirements probably will be reduced and should be used primarily to contend with individual failures as required.

9. SUMMARY AND RECOMMENDATIONS

A detailed engineering geology and rock mechanics data collection and analysis program was carried out at the Mount Carbine Mine for the purpose of conducting slope stability analyses and preparing an optimum design of final slopes in the open pit. Particular emphasis was placed on design of slopes and remedial measures in weak and weathered rocks on the south wall of the open pit.

9.1 DESCRIPTION OF THE INVESTIGATION

Detailed geological mapping was carried out on all accessible benches and outcrops in the open pit to determine the physical and mechanical properties of slope forming materials. Two diamond drillholes and eleven percussion drillholes were used to define the nature of the rock and distribution of rock strength behind the south wall. Core orientation and core logging were carried out for selected existing diamond drillholes in the pit to assist with correlation of geological structures, such as foliation, to delineate the South Wall Fault and to develop a three dimensional rock mass model.

Core samples of intact rock and discontinuties were tested to obtain basic unconfined compressive strength and shear strength properties for design. Sealed piezometer and standpipes were installed in drillholes on the south wall to obtain an appreciation of groundwater conditions in this area of the open pit.

Lower hemisphere equal area projections were used to determine the attitude, general characteristics and behaviour of the various sets of discontinuities in each area of the pit and to define structural domains. Based on lithology, distribution of structural domains and orientation of proposed final pit walls, the pit was divided into design sectors. For each design sector, kinematic analyses and the appropriate mechanical stability analyses were carried out for each possible failure mode to determine the optimum design of interramp slopes between haulroads. Effects of bench breakback, plan radius of curvature, blasting methods, groundwater distribution, as well as constraints of mining geometry were also considered in the design.

9.2 ENGINEERING GEOLOGY

9.2.1 Lithology and Rock Strength

The engineering properties of rocks in the open pit appear to be controlled primarily by processes of silicification and weathering. The bulk of the rocks in the open pit consist of fine grained metasediments of the Hodgkinson Formation which is of middle Devonian to Lower Carboniferous age. To the north of the South Wall Fault moderate to intense silicification of the metasediments has resulted in the formation of tough hard hornfels. This rock appears to be very resistant to surface weathering. Laminated hornfels and banded hornfels have been mapped within the open pit. South of the South Wall Fault the rocks consist of unsilicified or weakly silicified green argillaceous schist and siliceous greywackes, which are designated as Iron Duke rocks. Moderately silicified hornfels also occur south of the South Wall Fault on the east side of the open pit. Unsilicified and weakly silicified rocks have low to moderate strength and

are extremely susceptible to weathering. As a result, rocks south of the South Wall Fault have formed a weathering profile up to 30m deep which varies from residual soil at surface and changes gradually to highly weathered, moderately weathered and slightly weathered rocks with increasing depth. As the degree of weathering decreases the rock strength and competency increases. Consequently, the slope design within the weathered profile south of the South Wall Fault is different on each succeeding bench as the rock strength and competency increases.

9.2.2 Structural Geology

Rational slope stability analysis and pit slope design requires that the pit be subdivided as best as possible into areas of approximately similar geologic structural characteristics. These areas are designated structural domains.

Structural domains at Mount Carbine were determined initially by assuming the boundaries of the structural domains were major faults, geological contacts and/or boundaries of areas with similar foliation. Attitudes of the geologic structural populations within different parts of each structural domain were then evaluated and compared. The distribution of major structural features, main rock types and structural domains is shown in Fig. 1. A brief description of the main geologic structural features in the open pit is given in the following, based on detailed statistical analyses of available data using appropriate techniques.

(i) Foliation

Foliation is a well developed laminated structure developed parallel to "compositional layering" in the metasediments. Foliation in hornfels dips steeply to the northeast or southwest at about 70° to 90°. Average dip directions vary from 041° to 056° and 221° to 239°. The Iron Duke rocks south of the South Wall Fault have foliation that dips due north at approximately 75°.

(ii) Joints

In addition to foliation joints (Joint Set A), three joint sets and several minor and miscellaneous joint sets occur within the pit area. Joint Sets A and B occur consistently throughout the pit, while Joint Sets C and D occur in all structural domains north of the South Wall Fault. Joint Sets E and G and other miscellaneous joints only occur in specific structural domains, and appear to be significant on a local basis only. Differences in orientation and geotechnical properties of joint sets have been documented in individual structural domains in the pit.

(iii) Veins

Tungsten bearing quartz veins and barren quartz veins are sub-vertical and occur subparallel to joints of Joint Set B or along pre-existing joints of Joint Set B. Two subsets are common in most areas,

corresponding to the subsets of Joint Set B. Veins are very continuous and can often be traced over several benches.

(iv) Faults and Shears

Two major faults and a number of small faults and shears have been recognized in the pit. The South Wall Fault is the most continuous and significant structural feature in the pit. It has a uniform strike and dips towards the north at 70°. This fault forms the southern limit of the zone of extensive silicification and delineates the boundary of the ore zone. The Iron Duke Fault occurs in the northeast corner of the pit and dips steeply to the north/northeast at about 85°.

Two main fault and shear sets exist in the hornfels rocks. These faults have dip directions of 035 and 045 and dips of 72° and 35°, respectively. These faults could affect stability in the south and southwest sides of the open pit, in that they may daylight due to mining.

9.2.3 Strength Properties

Intact strengths of samples of fresh and weathered rock in the open pit have been determined primarily from simple field assessments of rock hardness. A limited number of laboratory tests consisting of uniaxial compressive tests and point load index tests were carried out to obtain more accurate estimates of strength parameters in weathered rocks.

Direct shear tests were carried out on selected core samples of four representative joints from the south wall area. Test results indicate that these joints have friction angles greater than 36° and a relatively high cohesion.

9.2.4 Back Analysis and Documentation of Failures

Back analyses were carried out for a large rotational type failure in residual soil and weathered rock below the primary crusher using standard design charts. Analyses indicate that appropriate values for cohesion and friction angle for these materials are about 40 kPa and 24° respectively. Comparison of slopes in the pit with road cuts in similar weathered rocks and residual soil indicates that the design parameters discussed above are reasonable. The comparative analysis also indicates that these slopes should be well drained to maintain reasonably steep slopes.

Back analyses were carried out for one large plane failure which occurred on a well defined joint in the south wall. Back analyses results indicate that the cohesion required for a factor of safety of 1.0 to 1.5 varies from 20 kPa to 51 kPa for a slope with a tension crack (see Table VI). Additional analyses were carried out to determine the possible artificial support requirements, assuming that a cohesion of 10 kPa could be mobilized along the joint.

Back analyses results and results of trial installations based on dowel pull out tests indicate that it is feasible to achieve relatively steep slopes on the south wall using artificial support members. Fully grouted vertical or inclined dowels appear to provide ideal support for the slope in

question. The number, length and design load of dowels accordingly have been determined from the data collection, back analyses, laboratory tests and dowel pull out test results, from which the relevant design parameters have been obtained.

9.3 SLOPES STABILITY ANALYSIS AND DESIGN

9.3.1 Deep Seated Failure Considerations

Analyses of geological mapping data, core logs and strength testing results indicate that, within the range of overall slope angles which are geometrically feasible, the possibility of deep seated failure of the whole slope along a single major discontinuities is small. Plane failures could possibly occur along shallow dipping faults and shears of Set SR1 on the south wall and/or west wall of the open pit. However, the possibility of occurrence of major faults or shears cannot be clearly stated at this time. Hence, it is not considered justified to flatten the slope in this area based only on possible occurrence of a major fault. However, it is imperative that the slopes be carefully mapped and monitored. If a major failure develops provisions should be made for possible remedial measures such as artificial support, depressurization or possibly slope flattening if required.

Based on the relatively high hardness, and accordingly, high compressive strength of most intact rocks in the pit, the likelihood of time dependent strain and subsequent failure of intact material in the slope appears to be small except

within the weathered or weaker rocks on the upper benches of the south wall. Hence, the possibility of deep-seated rotational failure due to failure of intact material involving the whole slope is low (at least within the range of overall slope angles which are geometrically feasible, and which are considered in this analysis).

Specific design and remedial measures to control possible rotational failures in the weathered rocks and residual soil near the crest of the south wall are discussed in Section 8.7.

9.3.2 Stability Analyses and Design North of the South Wall Fault

Within the pit area local failures involving one or two benches are possible in most areas. Consequently, the bulk of the stability analyses were carried out to assess plane and wedge failures on benches, using the structural geologic information available, and were based on valid statistical techniques. This statistical approach in designing the slope was not used for the areas south of the South Wall Fault. In these areas slope design and remedial measures have been prepared for individual benches to enable design of relatively steep slopes in weak, deeply weathered rock. Details of design in this area of the pit is discussed separately below.

Not only must structural domains be considered for individual stability analysis, but another overriding consideration is the orientation of the final pit wall. Different pit wall

orientations require basically different design considerations. Hence, it is necessary to define zones of the proposed slope which contain one structural domain and one general pit slope orientation; these zones are designated design sectors.

Within each design sector the main modes of failure were determined and stability analyses carried out for both interramp slopes between haulroads and benches. Due to the considerable number of possible wedge failures of various orientations in most design sectors, limit equilibrium analysis results and wedge distributions were treated statistically. A recently developed statistical analyses technique was used, based on assessing the cumulative percentage frequency of possible unstable wedge failures with respect to the apparent plunge angle and factor of safety of the possible wedges. Slope angles were determined assuming that 20 percent of the possible wedges could spill over berms if they failed. Design charts were used to develop slope designs for interramp slopes based on the mode of failure which was considered to control slope stability. Due consideration also was given to bench breakback, effects of plan radius of curvature and groundwater conditions.

Slope stability analyses were carried out for both 20m high and 30m high benches. In most areas of hard unweathered silicified hornfels, 30m high benches appear to be feasible provided undue breakback does not occur due to uncontrolled blasting or bench failures. 30m high benches would result in wider berms, giving more reliable access and rockfall protection.

Contingent on successful trials, 30m high benches are recommended in the hornfels rocks above 345m elevation and below 305m elevation. Between 305m elevation and 345m elevation 20m high benches are recommended to insure reliable access to the south wall for maintenance of remedial measures and slope protection in the vicinity of the haulroad.

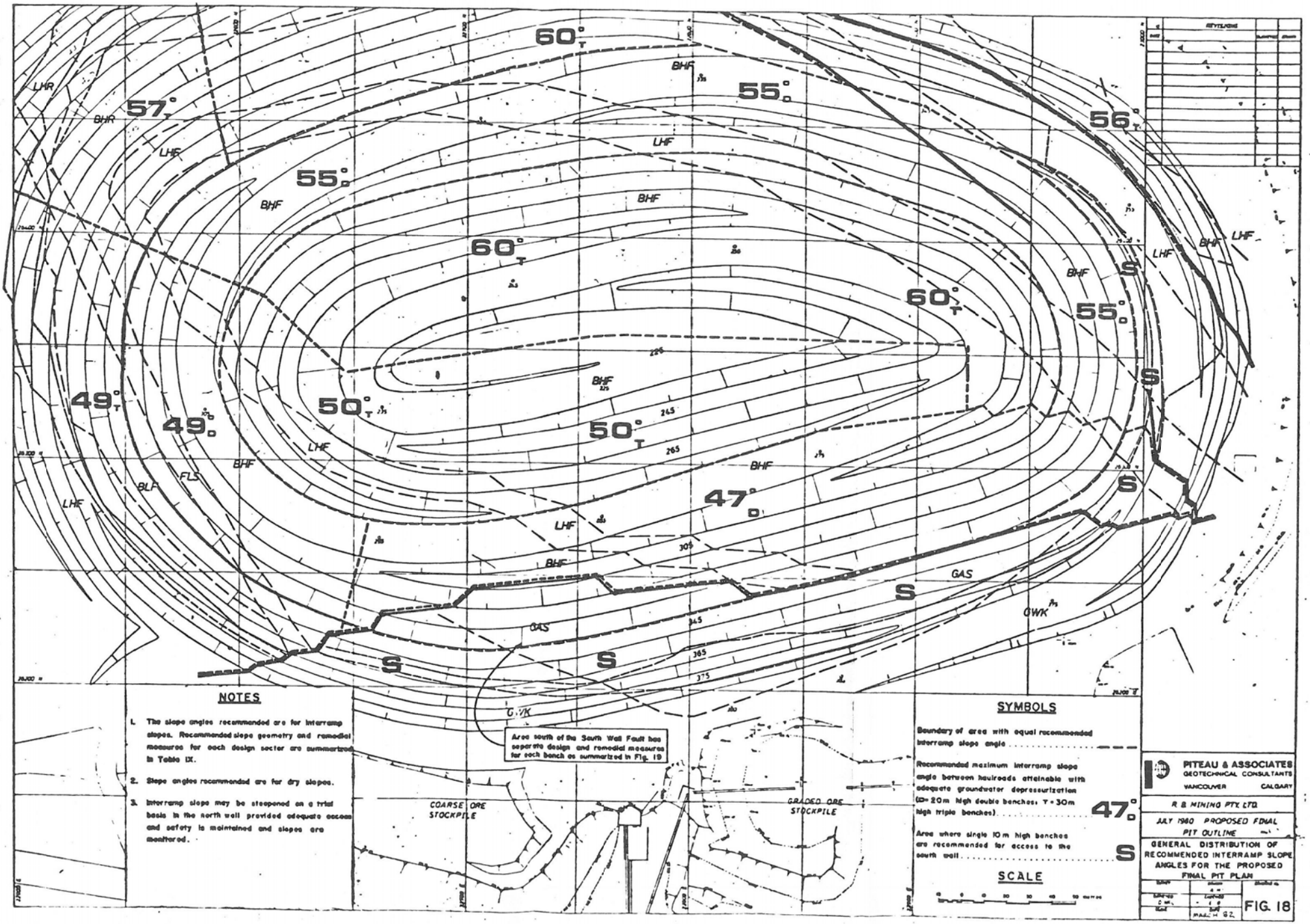
Information on individual design sectors, analyses results and specific slope design recommendations are presented in Table IX and Fig. 14. Modification to the design, based on recommended bench height, effects of breakback, plan radius of curvature and other relevant considerations for individual design sectors, are summarized in Fig. 17. In order to assist with mine planning and requirements of blending slope designs between individual design sectors, the general distribution of recommended interramp slope angles in each area of the open pit is shown in Fig. 18*.

Slope designs shown in Fig. 18 assume dry (i.e. drained or dewatered slopes). In areas where groundwater pressures are anticipated, slope depressurization using subhorizontal drainholes may be required.

9.3.3 Design of Slopes and Related Remedial Measures Adjacent to and South of the South Wall Fault

Slopes in Design Sectors 1-1, 2-1 and 3-1 south of the South Wall Fault require special design considerations. As discussed earlier, this is due to the presence of weaker rocks in the weathered zone, the strong structural control of

* Fig. 18 is included in the text (following page) as well as at the end of the report for convenience.


60° T
55° D
57° T
55° D
56° T
60° T
60° T
49° T
49° D
50° T
50° T
47° D
55° D
BHF
LHF
LHR
BHR
FLS
BLF
GAS
GWK
S
NOTES
1. The slope angles recommended are for interramp slopes. Recommended slope geometry and remedial measures for each design sector are summarized in Table IX.
2. Slope angles recommended are for dry slopes.
3. Interramp slope may be steepened on a trial basis in the north wall provided adequate access and safety is maintained and slopes are monitored.
Area south of the South Wall Fault has separate design and remedial measures for each bench as summarized in Fig. 19
COARSE ORE STOCKPILE
GRADED ORE STOCKPILE
SYMBOLS
Boundary of area with equal recommended interramp slope angle
Recommended maximum interramp slope angle between haulroads attainable with adequate groundwater depressurization (D= 20m high double benches; T = 30m high triple benches)
47° D
Area where single 10 m high benches are recommended for access to the south wall
S
SCALE
PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY
R B MINING PTY LTD.
JULY 1980 PROPOSED FINAL PIT OUTLINE
GENERAL DISTRIBUTION OF RECOMMENDED INTERRAMP SLOPE ANGLES FOR THE PROPOSED FINAL PIT PLAN
FIG. 18

the South Wall Fault and the presence of relatively shallow kinematically possible failure modes in the area. Kinematic stability analyses of structural discontinuities, back analyses of failures in weathered rock and artificial support considerations were used to prepare a rational design for slopes in these design sectors. Because of the constraints on slope design, which arise as a result of the location of the primary crusher and ore stock piles near the pit crest, particular emphasis had to be given to stabilization, protection and monitoring measures. Specific remedial measures, including controlled excavation without blasting, application of artificial support, drainage and careful slope monitoring are recommended if these slopes are to be developed at angles steeper than those which would normally be anticipated for the slope forming materials which exist in this area. Feasibility of using fully grouted cable dowels has been demonstrated by pull out tests of trial dowels. Pull out tests on dowels in ten selected locations indicate that acceptable loads were obtained in all dowels tested. It should be noted that, because kinematically possible failures could develop on the south wall slope, artificial support consisting of grouted dowels is necessary to maintain steep slope angles. Alternative methods of artificial support, such as gabions, buttresses, shotcrete, etc. without some form of deep artifical support, would not be sufficient to prevent the failures along joints which exist in these slopes.

Degree of weathering decreases and rock strength increases with depth in slopes south of the South Wall Fault. Hence,

different slope designs are recommended for individual benches, based on the possibility of both rotational failure and failure on discontinuities. Details of the recommended design of this slope are shown in Fig. 19*.

9.4 EXCAVATION METHOD AND BLASTING

9.4.1 Excavation Method

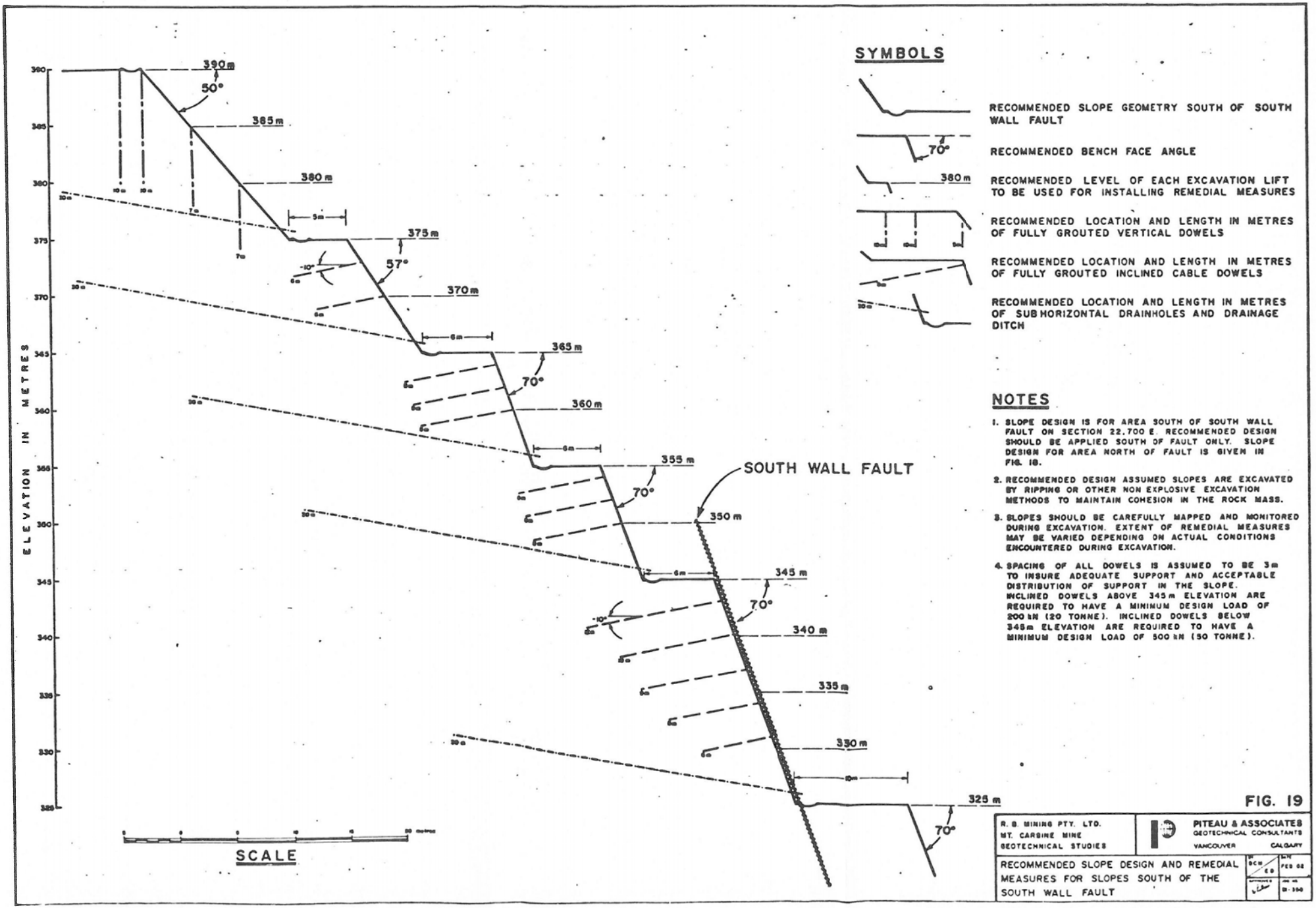
Slopes in weak or weathered rock should be excavated by ripping or some other accepted non-explosive method. Slopes should be excavated in lifts of limited depth to permit installation of remedial measures as required. In this regard, excavation lifts of 2 to 5m could be used to considerable advantage in certain areas of the south wall.

9.4.2 Controlled Blasting

In areas where ripping is not possible, all final walls should be developed by preshearing or some other acceptable form of perimeter or controlled blasting techniques. If proper controlled blasting is not used on the final wall, it may not be possible to achieve the steep slope angles recommended. Considerations should be given to using closely spaced, lightly loaded, small diameter blastholes which can be used to develop clean unbroken walls, maintain maximum cohesion in the rock mass and reduce breakback of bench crests. To maximize the effects of the perimeter blasting program, trial blasts should be carried out to determine the optimum blasting method on final walls.

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* Fig. 19 is included in the text (following page) as well as at the end of the report for convenience.



SYMBOLS

RECOMMENDED SLOPE GEOMETRY SOUTH OF SOUTH WALL FAULT

70°
RECOMMENDED BENCH FACE ANGLE

380m
RECOMMENDED LEVEL OF EACH EXCAVATION LIFT TO BE USED FOR INSTALLING REMEDIAL MEASURES

RECOMMENDED LOCATION AND LENGTH IN METRES OF FULLY GROUTED VERTICAL DOWELS

RECOMMENDED LOCATION AND LENGTH IN METRES OF FULLY GROUTED INCLINED CABLE DOWELS

RECOMMENDED LOCATION AND LENGTH IN METRES OF SUB HORIZONTAL DRAINHOLES AND DRAINAGE DITCH

NOTES

1. SLOPE DESIGN IS FOR AREA SOUTH OF SOUTH WALL FAULT ON SECTION 22,700 E. RECOMMENDED DESIGN SHOULD BE APPLIED SOUTH OF FAULT ONLY. SLOPE DESIGN FOR AREA NORTH OF FAULT IS GIVEN IN FIG. 18.
2. RECOMMENDED DESIGN ASSUMED SLOPES ARE EXCAVATED BY RIPPING OR OTHER NON EXPLOSIVE EXCAVATION METHODS TO MAINTAIN COHESION IN THE ROCK MASS.
3. SLOPES SHOULD BE CAREFULLY MAPPED AND MONITORED DURING EXCAVATION. EXTENT OF REMEDIAL MEASURES MAY BE VARIED DEPENDING ON ACTUAL CONDITIONS ENCOUNTERED DURING EXCAVATION.
4. SPACING OF ALL DOWELS IS ASSUMED TO BE 3m TO INSURE ADEQUATE SUPPORT AND ACCEPTABLE DISTRIBUTION OF SUPPORT IN THE SLOPE. INCLINED DOWELS ABOVE 345m ELEVATION ARE REQUIRED TO HAVE A MINIMUM DESIGN LOAD OF 200 kN (20 TONNE). INCLINED DOWELS BELOW 345m ELEVATION ARE REQUIRED TO HAVE A MINIMUM DESIGN LOAD OF 500 kN (50 TONNE).

FIG. 19

R. G. MINING PTY. LTD.
MT. CARBINE MINE
GEOTECHNICAL STUDIES

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

RECOMMENDED SLOPE DESIGN AND REMEDIAL MEASURES FOR SLOPES SOUTH OF THE SOUTH WALL FAULT

BY DCH / ED
DATE FEB 82
APPROVED
JOB NO. D-356

Regardless of location, to protect haulroads it is recommended that a more sophisticated or higher level of control blasting be carried out on the bench immediately above and below haulroads. Control blasting could also be used in the vicinity of other important installations in the pit. If control blasting is not sufficient to maintain the integrity of the slopes, berms may be reinforced by grouted dowels in site specific areas.

9.4.3 Production Blasting

Blast patterns, most particularly those near the final slope, should be designed so that blasting damage to the pit wall is minimized. With regard to benches, for example, this can be done by reducing subgrade drilling and having blastholes span the bench crests. Accurate location of all blastholes by surveying is essential. Optimum results can only be obtained by varying blasting techniques and correctly supervising and designing field trials where loads, spacing, burden, delays, etc. are varied to obtain the best possible results. It is sound engineering to make special provision for a series of test blasts to ensure optimum results for existing operating conditions.

9.5 GROUNDWATER CONTROL AND DRAINAGE

Stability analyses indicate that in certain design sectors groundwater control or depressurization could be used to advantage. The slope design for these cases is shown in brackets for the appropriate design sectors in Table IX and Fig. 14. Control of groundwater and surface water is essential in the south wall area and behind the South Wall Fault, as well as in some design sectors in other areas of the open pit.

In areas where groundwater is expected to affect slope stability, groundwater control and depressurization measures, consisting of subhorizontal upward inclined drainholes, are recommended near bench toes. Drainholes are particularly important on the south wall to control water pressures in weak or weathered rocks south of the South Wall Fault. Drainholes are also recommended to control water pressures behind the South Wall Fault or other major faults. Drainholes may also be required in selected areas of the pit to control water pressures which could precipitate local failures.

Sealed piezometers should be installed on the south wall as the final pit is excavated. These piezometers should be monitored regularly to assess the effectiveness of drainholes, and to clearly determine the length and spacing of drainholes required to obtain effective depressurization of the slope.

9.6 SURFACE WATER CONTROL

Due to the unfavourable effects of groundwater on slope stability, particularly in the south wall of the open pit, it is recommended that a properly designed system of surface water control be constructed in the pit. Surface water control should consist of the following:

(i) a sealed drainage ditch behind the pit crest in all areas to intercept all water which could infiltrate into the rock mass

(ii) the area around the entire pit crest should be properly graded to divert water into the drainage ditch or away from the pit

(iii) benches and haulroads on the south wall should be inclined and/or graded to divert water off the slope

(iv) drainage ditches or closed pipes are important to collect and control water from drainholes on the south wall

(v) a sealed drainage ditch should be constructed on the haulroad to convey water off the slope and into sumps for pumping out of the open pit. Uncontrolled water flow should not be permitted in any area of the open pit.

(vi) sealed drainage ditches should be constructed in areas of the pit other than the south wall as required.

9.7 TRIAL SLOPES

In addition to the slopes recommended, other slope geometries could be considered on a trial basis, on small sections of the wall. As stated earlier, trial slopes would be particularly useful for assessing the feasibility of using 30m high benches on the final slope. The performance of trial slopes will be helpful in modifying the slope for succeeding mining phases.

Trial slopes might include steeper bench faces, higher benches or narrower berms. Such trial slopes should be developed in areas where failures can be allowed to occur without affecting the efficiency and safety of the operation. If failures do occur on a particular trial section, provision should be made so that the failure can be controlled, and the mining geometry modified accordingly, without jeopardizing the safety or efficiency of the mine operation.

All significant failures should be completely and accurately documented so that back analyses can be carried out to help assess the rock mass strength for design.

9.8 CLEANING BERMS AND SCALING

With due considerations of efficiency and safety, benches should be adequately scaled to minimize rockfalls. Debris buildups may require cleanup at a later stage in certain areas. Appropriate berms should be kept relatively free of excessive buildup of rockfall, ravelling and slide material to maintain adequate catchments. Such berms, if possible, should be accessible from both ends so that access will not be lost if a failure occurs.

9.9 SUMMARY OF RECOMMENDATIONS FOR ONGOING WORK RELATED TO PIT DESIGN

The following summarizes many of the aspects discussed earlier pertaining to ongoing work that should be considered by the mine in terms of stability and design of slopes in the pit.

(i) Geologic Structural Mapping

Because of the complex geology and importance of the geological structure to slope design, detailed geologic structural mapping should be carried out on a reasonably continuous basis as mining proceeds. This information should be compared to the existing information and should be used to determine if any slope design modifications are required as mining proceeds. All geological structures, most particularly major faults and shears, should be carefully mapped and described. This would help to correlate major geological structures and to update important information on faults

which have already been mapped and described. The ultimate objective should be to establish an appropriate engineering geologic data storage and retrieval system such that local design problems can be analyzed on a rational basis. The computer programs available on the mine should assist greatly in this regard.

(ii) Documentation and Back Analysis of Slope Failures

Documentation and back analysis of slope failures should be carried out to obtain additional information on rock mass shear strength, shear strength of discontinuities and general behaviour of slope forming materials.

(iii) Trial Slopes and Trial Blasts

A program of trial slopes and trial blasts should be considered to evaluate the proposed bench and overall slope geometry as well as the blasting procedures to be used in the pit. In conjunction with the above work, an analysis of bench breakback could be carried out to compare the designed and "as constructed" slope geometry, thus evaluating the design and effects of control blasting and other remedial measures.

(iv) Monitoring Slopes

Slopes should be monitored for horizontal and vertical movement at appropriate intervals, depending on the degree and nature of the movement. Carefully installed ground control points would probably suffice. Also, a periodic visual inspection of the pit crest should be carried out to determine visible signs of movement.

Consideration could also be given to utilizing the dowels (or possibly rockbolts) as movement monitoring devices. If some of these artificial support members were ungrouted and installed sufficiently deep, movement could be measured directly or change in tensioning could be observed. In either case, evidence of movement would be known.

(v) Piezometer Installations and Monitoring

As described above, piezometers should be installed in strategic locations to monitor groundwater pressures and to assess the need for groundwater depressurization or additional hydrogeological studies.

9.10 PERSONNEL FOR CONTROL OF SLOPE DESIGN AND REMEDIAL MEASURES

The stability and integrity of the south wall depends on careful excavation and installation of remedial measures as discussed above. In order to insure a high degree of accuracy and acceptable results from the remedial measures the work should be carefully monitored. It is suggested that a qualified technician or engineer be utilized to organize and control all remedial work. His duties would be as follows:

(i) supervise installation of grouted dowels and dowel pullout tests, if required
(ii) supervise installation of drainholes, piezometers and drainage ditches
(iii) plan and evaluate trial blasts and trial slopes
(iv) carry out detailed geological mapping, document slope failures, back analyze slope failures and carry out slope monitoring, as required

(v) establish a movement monitoring system utilizing dowels if required

(vi) evaluate design on a regular basis and carry out appropriate modifications based on results of field performance of slopes

10. ACKNOWLEDGEMENTS

The authors acknowledge with thanks Messrs D. Wolff, E. Brachmanski, H. Rich and G. Winter for assistance and cooperation throughout the project. Thanks are also extended to J. Allen, N. Atkinson, A. Horsbough and P. Wragg of the mine for day to day assistance with field work.

for D.R. PITEAU & ASSOCIATES LIMITED

Douglas R. Piteau, P.Eng.

Dennis C. Martin, P.Eng.

Eric J. Byres

April 30, 1982

Distribution of Final Report:

R.B. Mining Pty Ltd. - 3 copies
D.R. Piteau & Associates Limited - 1 copy

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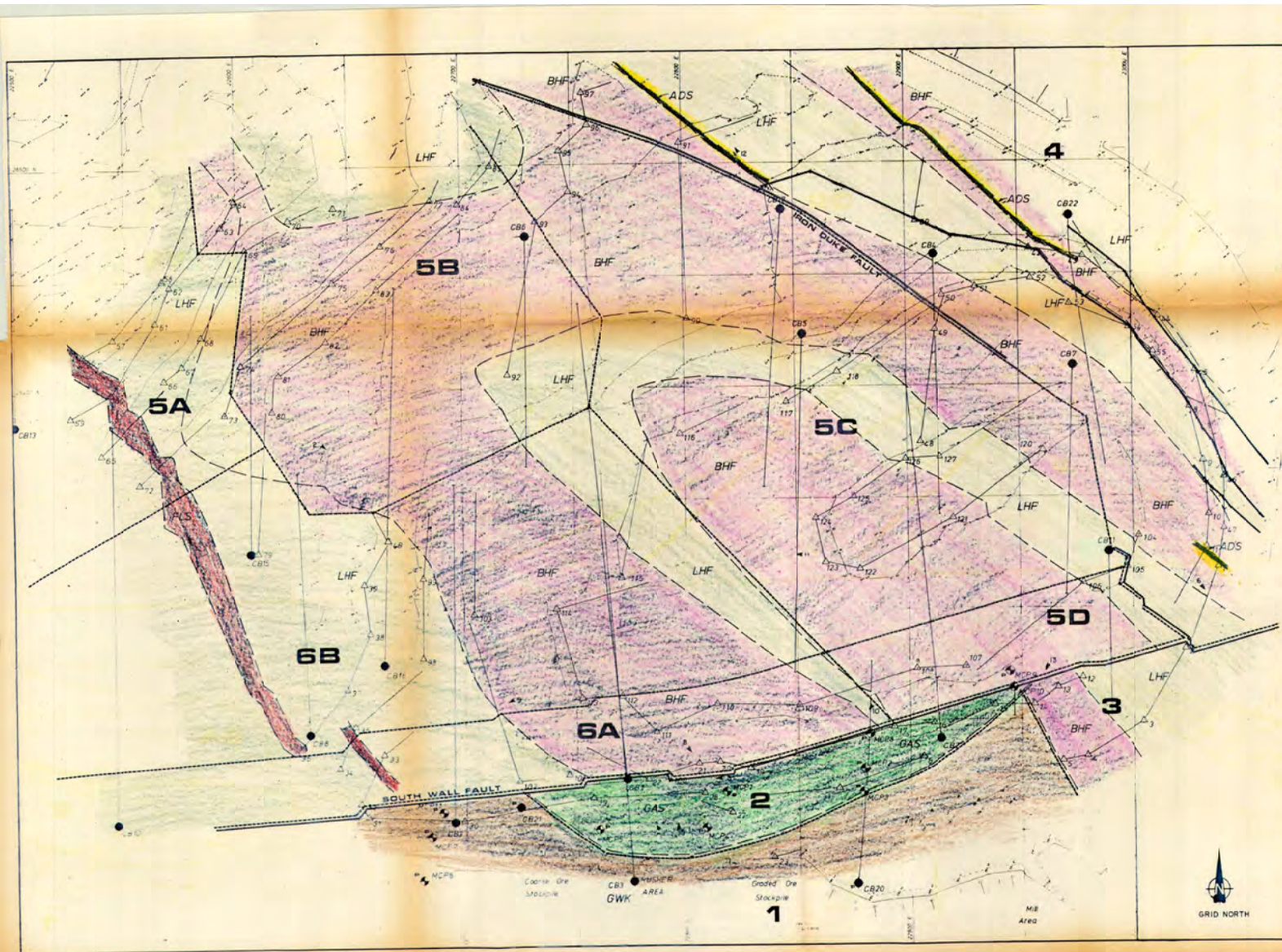
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LEGEND

- FELS — FELSITE and related coarse grained quartz - porphyry intrusive dykes
- ADS — ANDESITE and related intermediate fine grained intrusive rocks which occur as small dykes
- LHF — LAMINATED HORNFELS and related hard, grey, highly silicified, laminated rocks derived from micaceous siltstones
- BHF — BANDED HORNFELS and related hard, highly silicified rocks with quartz banding, augens, and related features
- GWK — SILICEOUS GREYWACKE and related moderately silicified argillaceous rocks with chert and quartz stringers
- GAS — GREEN ARGILLACEOUS SCHIST and related non-siliceous, argillaceous rocks
- BST — BLACK SLATE and related thinly laminated, well developed slates

SYMBOLS

- Geological Contact
- Fault
- Structural Domain boundary
- Structural Domain number — 6A
- Crest and toe of bench with elevation
- Detailed line mapping traverse: number and location
- Number and location of percussion drillhole — MCP7
- Number and location of diamond drillhole — CB21
- Drillhole with piezometers installed
- Number, location, and direction of photographs
- Label for Joint Set on lower hemisphere projection — A

NOTE

Contour values on lower hemisphere equal area projections are expressed as percent of the total weight occurring in a 1.0 percent area of the plot.

SCALE

GRID NORTH

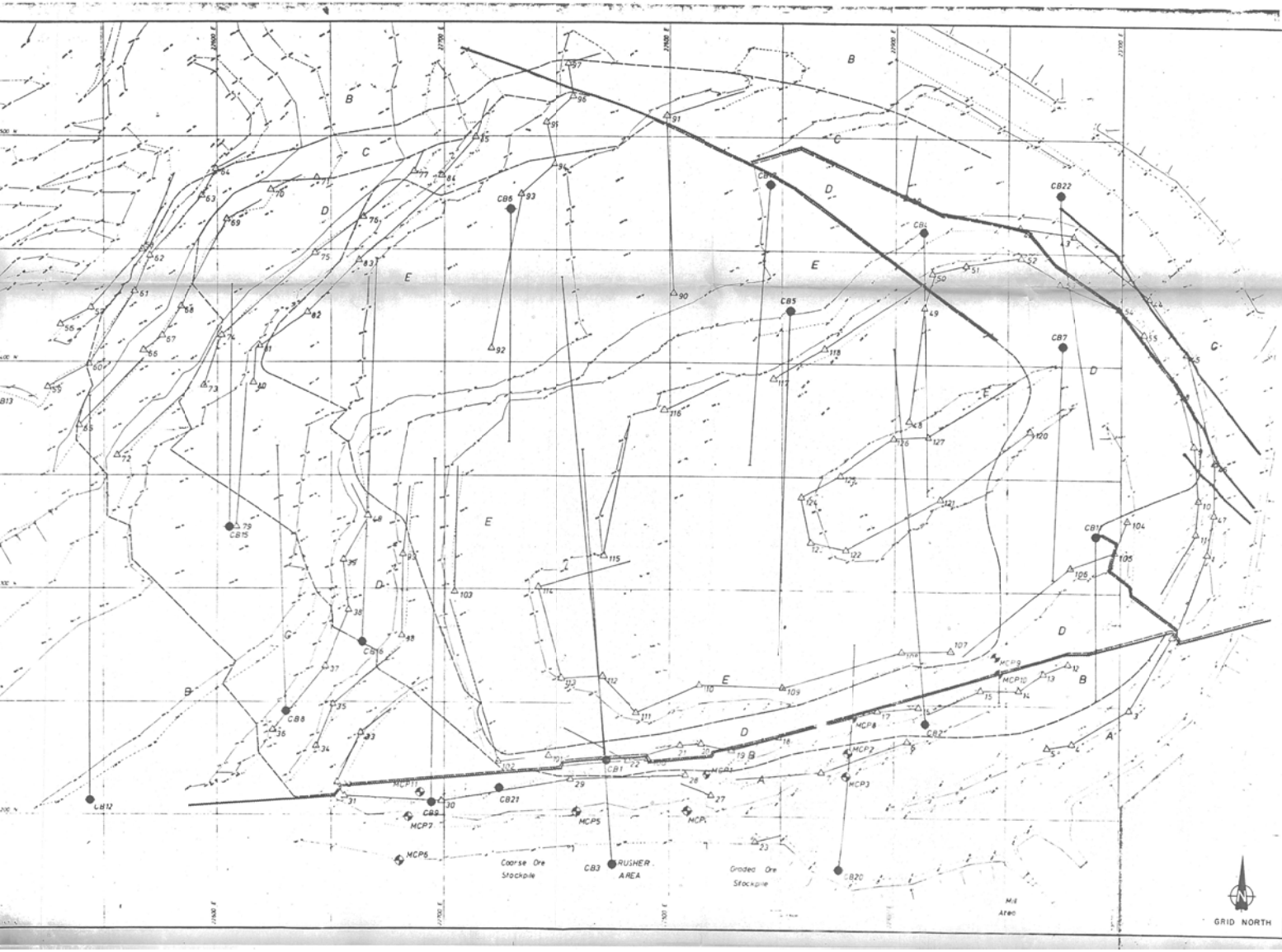
FIG. 1

R.B. MINING PTY. LTD.
MT. CARBINE MINE
GEOTECHNICAL STUDIES

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

STRUCTURAL GEOLOGY AND ENGINEERING GEOLOGY IN THE OPEN PIT

BY EB | DCM | DATE MAR 82 | JOB NO. 81-358



LEGEND

A	EXTREMELY WEATHERED ROCK : Weathering and oxidation has reduced rock to soil with relic structures
B	HEAVILY WEATHERED ROCK : Weathering throughout rock with a significant reduction in rock strength
C	MODERATELY WEATHERED ROCK : Weathering and oxidation along joints and through intact rock with little reduction in rock strength
D	SLIGHTLY WEATHERED ROCK : Weathering and oxidation along joints only with no effect on intact rock strength
E	UNWEATHERED ROCK

SYMBOLS

Estimated boundary of weathered zone

Fault

Structural Domain boundary

Structural Domain number 6A

Crest and toe of bench with elevation

Detailed line mapping traverse : number and location 47

Number and location of percussion drillhole MCP7

Number and location of diamond drillhole CB21

Drillhole with piezometers installed P

Number, location, and direction of photographs

SCALE 0 10 20 30 40 50 60 70 80 90 100 metres

FIG. 2

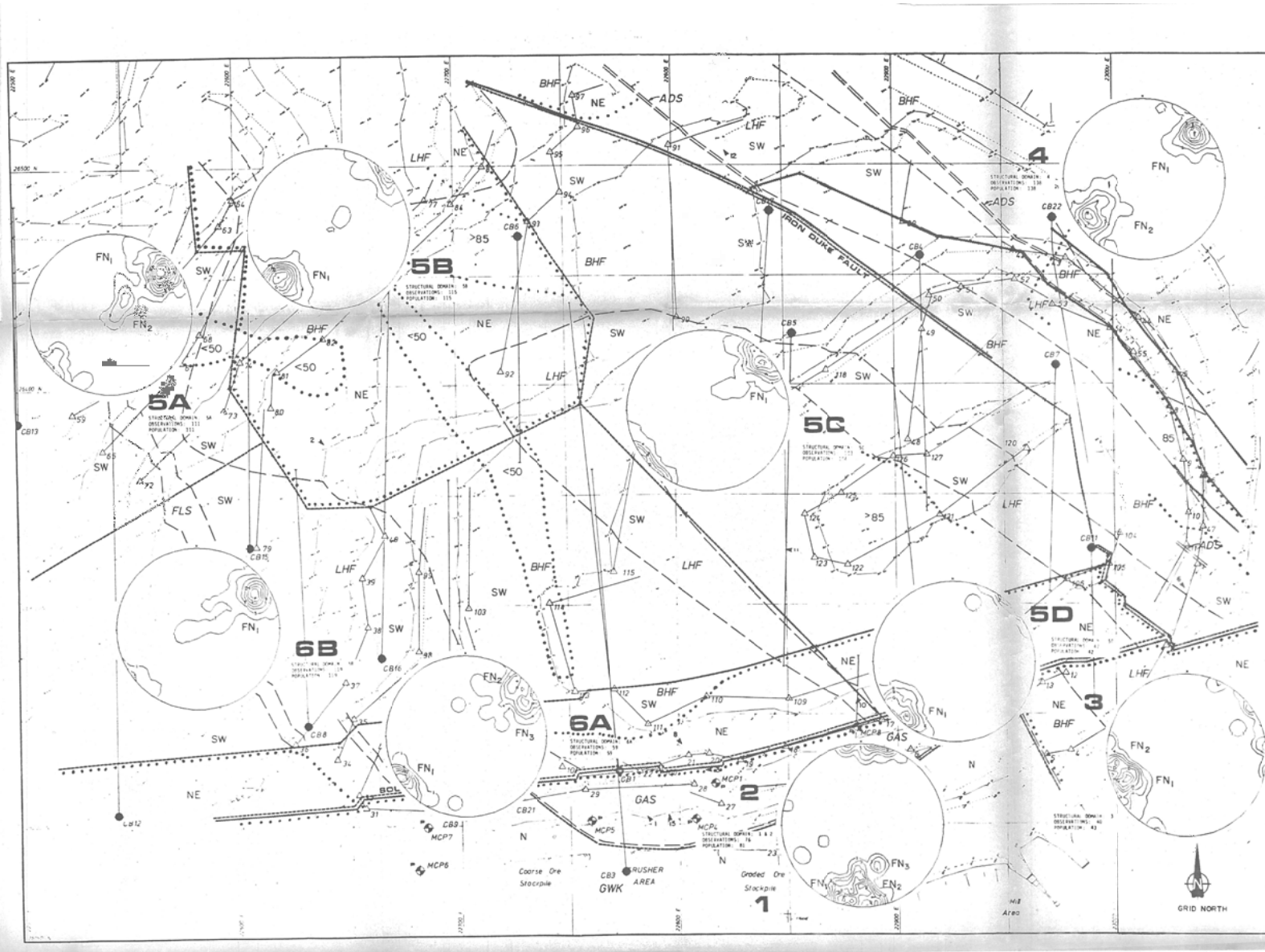
R.B. MINING PTY. LTD.
MT. CARBINE MINE
GEOTECHNICAL STUDIES

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

DISTRIBUTION OF WEATHERING

DCM EB FEB 82

APPROVED D.T.S.M. JOB NO. 81-358



LEGEND

NE	Foliation dip 50 NE - 85 NE
>85	Foliation dip 85 NE - 85 SW
SW	Foliation dip 50 SW - 85 SW
<50	Foliation dip less than 50 SW or NE
N	Foliation dip 45 N - 90 N

SYMBOLS

- Boundary of area with similar foliation dip
- Geological Contact
- Fault
- Structural Domain boundary
- Structural Domain number — 6A
- Crest and toe of bench with elevation
- Detailed line mapping traverse: number and location — 47
- Number and location of percussion drillhole — MCP7
- Number and location of diamond drillhole — CB21
- Drillhole with piezometers installed
- Number, location, and direction of photographs — 6
- Label for Joint Set on lower hemisphere projection — A

NOTE

Contour values on lower hemisphere equal area projections are expressed as percent of the total weight occurring in a 1.0 percent area of the plot.

0 10 20 30 40 50 60 70 80 90 100 metres

SCALE

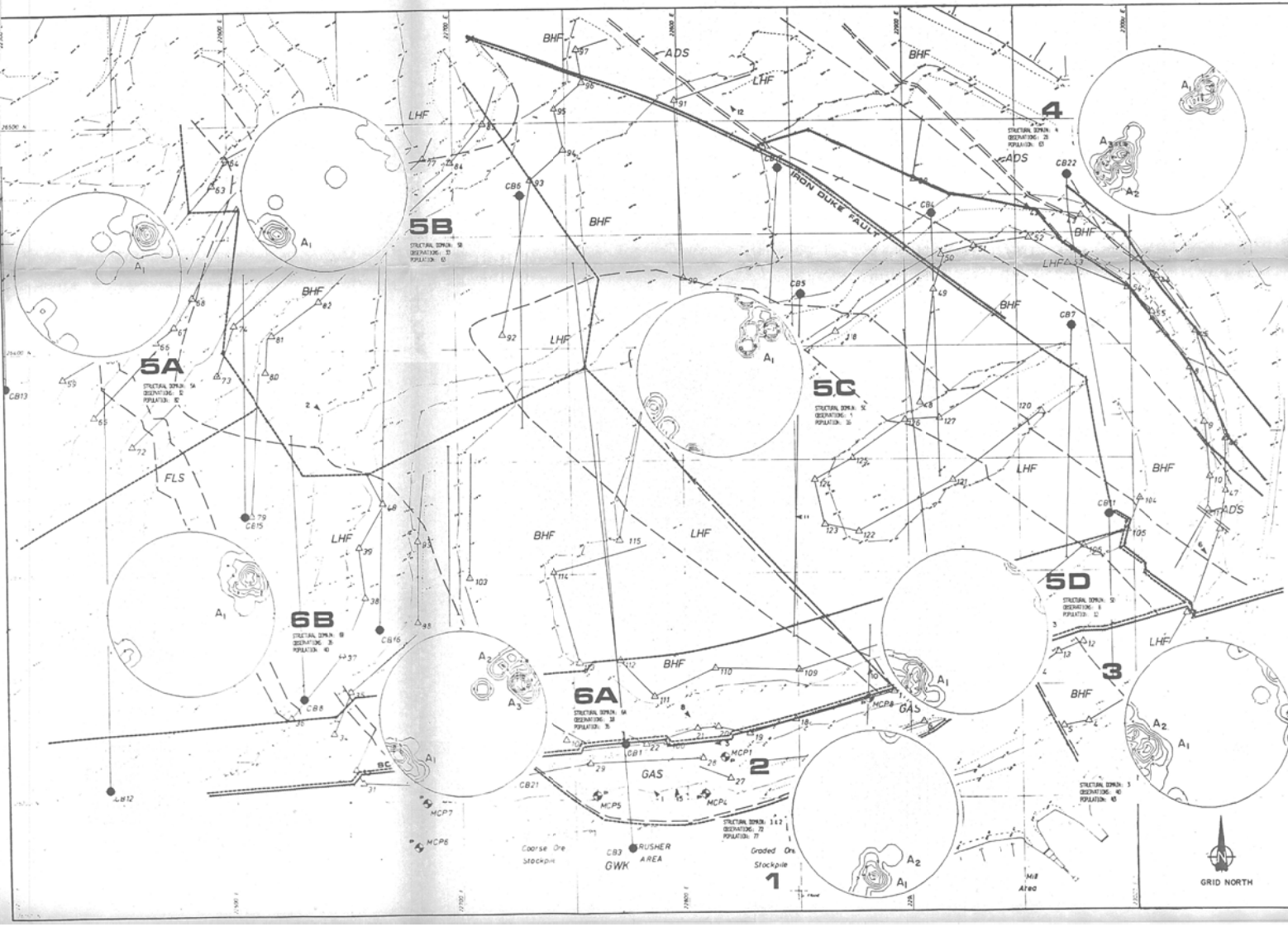
FIG. 3

R. B. MINING PTY. LTD.
MT. CARBINE MINE
GEOTECHNICAL STUDIES

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

DISTRIBUTION OF FOLIATION IN THE OPEN PIT

BY EB DCM DATE MAR 82
APPROVED JOB NO 81-358



LEGEND

FLS	FELSITE and relicted coarse grained quartz – porphyry intrusive dykes
ADS	ANDESITE and related intermediate fine grained intrusive rocks which occur as small dykes
LHF	LAMINATED HORNFELS and related hard, grey, highly silicified, laminated rocks derived from micaceous siltstones
BHF	BANDED HORNFELS and related hard, highly silicified rocks with quartz banding, augens, and related features
GWK	SILICEOUS GREYWACKE and related moderately silicified argillaceous rocks with chert and quartz stringers
GAS	GREEN ARGILLACEOUS SCHIST and related non-siliceous, argillaceous rocks
BST	BLACK SLATE and related thinly laminated, well developed slates

SYMBOLS

- Geological Contact
- Fault
- Structural Domain boundary
- Structural Domain number — 6A
- Crest and toe of bench with elevation
- Detailed line mapping traverse: number and location — 47
- Number and location of percussion drillhole — MCP7
- Number and location of diamond drillhole — CB21
- Drillhole with piezometers installed
- Number, location, and direction of photographs — 6
- Label for Joint Set on lower hemisphere projection — A

NOTE

Contour values on lower hemisphere equal area projections are expressed as percent of the total weight occurring in a 1.0 percent area of the plot.

0 10 20 30 40 50 60 70 80 90 100 metres

SCALE

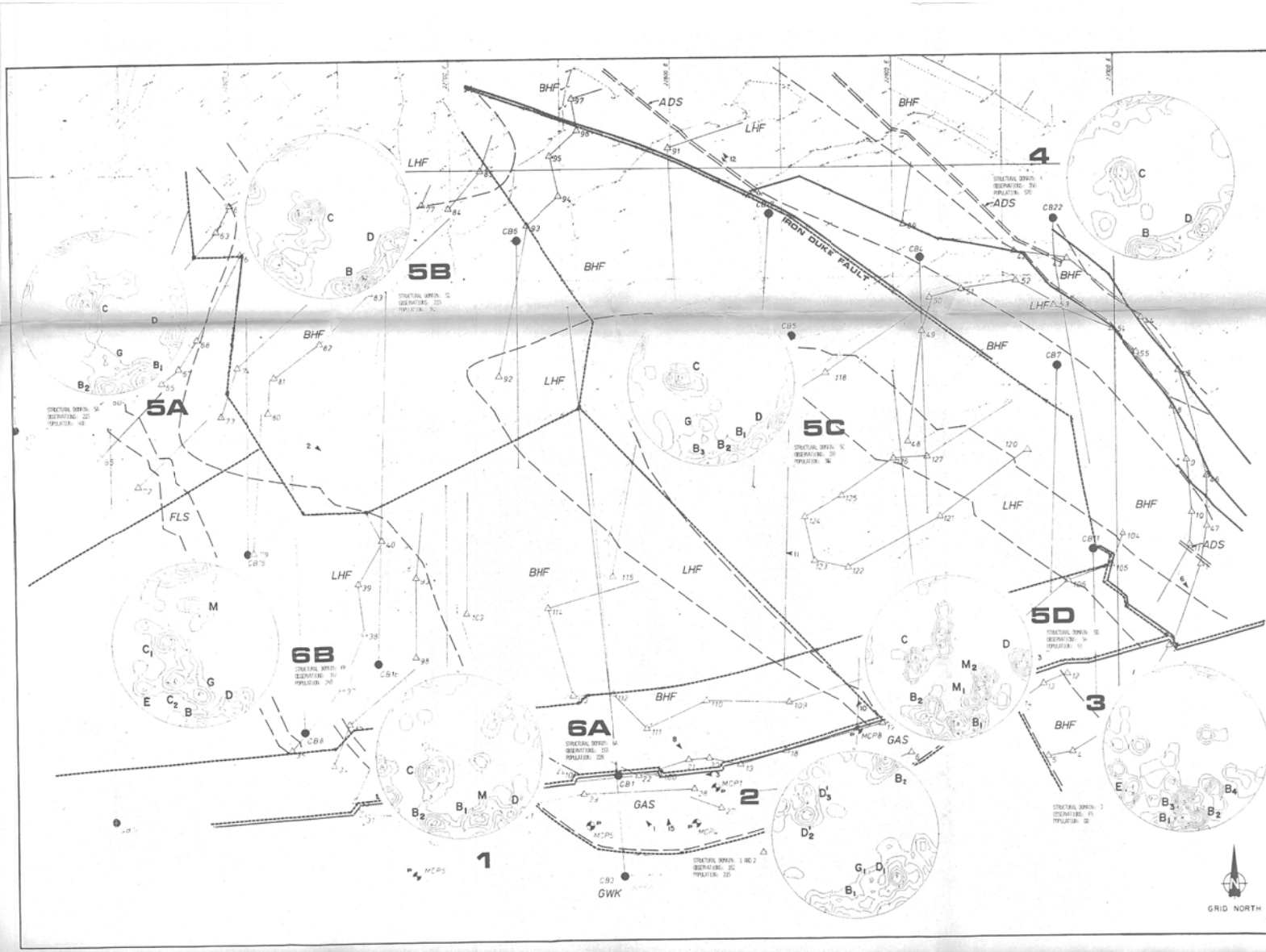
FIG. 4

R. B. MINING PTY. LTD.
MT. CARBINE MINE
GEOTECHNICAL STUDIES

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

DISTRIBUTION OF FOLIATION JOINTS IN THE OPEN PIT

BY EB DCM DATE MAR 82
APPROVED JOB NO 81-358



LEGEND

FLS	FELSITE and related coarse grained quartz – porphyry intrusive dykes
ADS	ANDESITE and related intermediate fine grained intrusive rocks which occur as small dykes
LHF	LAMINATED HORNFELS and related hard, grey, highly silicified, laminated rocks derived from micaceous siltstones
BHF	BANDED HORNFELS and related hard, highly silicified rocks with quartz banding, augens, and related features
GWK	SILICEOUS GREYWACKE and related moderately silicified argillaceous rocks with chert and quartz stringers
GAS	GREEN ARGILLACEOUS SCHIST and related non-siliceous, argillaceous rocks
BST	BLACK SLATE and related thinly laminated, well developed slates

SYMBOLS

Geological Contact

Fault

Structural Domain boundary

Structural Domain number — 6A

Crest and toe of bench with elevation

Detailed line mapping traverse: number and location — 47

Number and location of percussion drillhole — MCP7

Number and location of diamond drillhole — CB21

Drillhole with piezometers installed

Number, location, and direction of photographs — 6

Label for Joint Set on lower hemisphere projection — A

NOTE

Contour values on lower hemisphere equal area projections are expressed as percent of the total weight occurring in a 1.0 percent area of the plot.

0 10 20 30 40 50 60 70 80 90 100 metres

SCALE

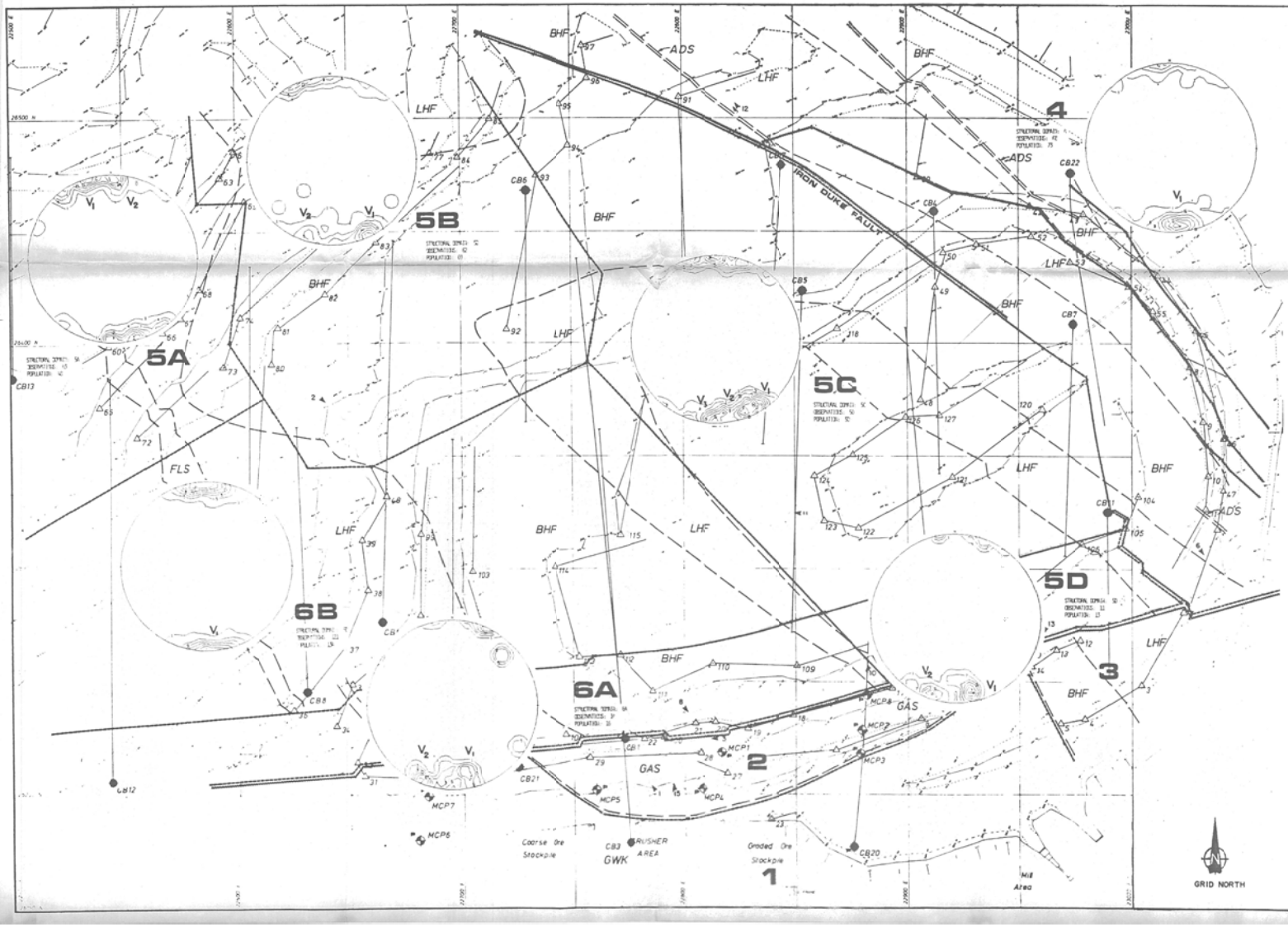
FIG. 5

R. B. MINING PTY. LTD.
MT. CARBINE MINE
GEOTECHNICAL STUDIES

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

DISTRIBUTION OF JOINTS IN THE OPEN PIT

BY: DCM EB
APPROVED: D. Tapp
DATE: MAR. 82
JOB NO: 81-358



LEGEND

FLS	FELSITE and related coarse grained quartz – porphyry intrusive dykes
ADS	ANDESITE and related intermediate fine grained intrusive rocks which occur as small dykes
LHF	LAMINATED HORNFELS and related hard, grey, highly silicified, laminated rocks derived from micaceous siltstones
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GAS	GREEN ARGILLACEOUS SCHIST and related non-siliceous, argillaceous rocks
BST	BLACK SLATE and related thinly laminated, well developed slates

SYMBOLS

- Geological Contact
- Fault
- Structural Domain boundary
- Structural Domain number — 6A
- Crest and toe of bench with elevation
- Detailed line mapping traverse: number and location — 47
- Number and location of percussion drillhole — MCP7
- Number and location of diamond drillhole — CB21
- Drillhole with piezometers installed
- Number, location, and direction of photographs — 6
- Label for Joint Set on lower hemisphere projection — A

NOTE

Contour values on lower hemisphere equal area projections are expressed as percent of the total weight occurring in a 1.0 percent area of the plot.

10 0 10 20 30 40 50 60 70 80 90 100 metres

SCALE

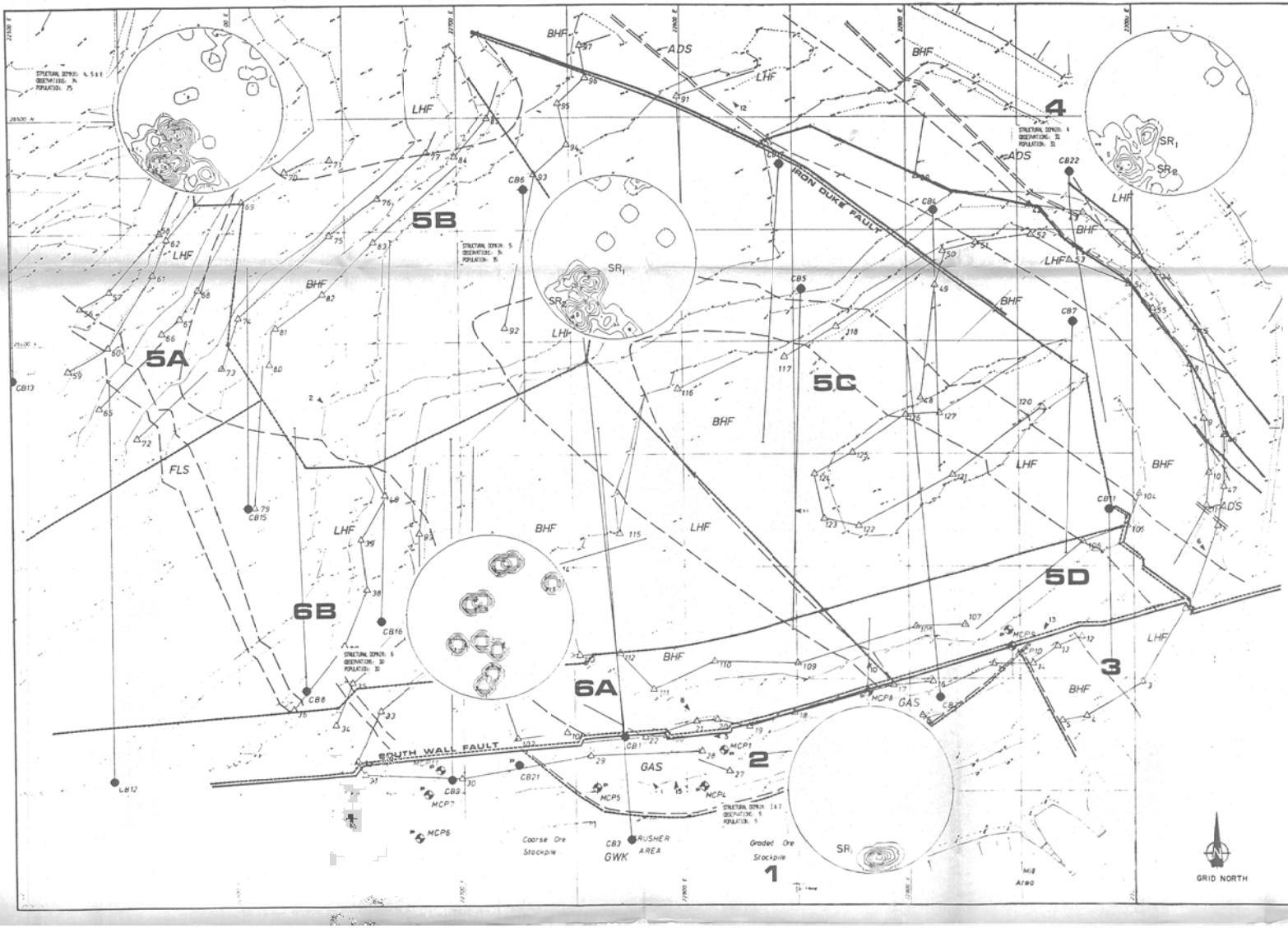
FIG. 6

R. B. MINING PTY. LTD.
MT. CARBINE MINE
GEOTECHNICAL STUDIES

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

DISTRIBUTION OF VEINS IN THE OPEN PIT

BY: EB DCM
DATE: MAR 82
APPROVED:
JOB NO: 81-356



LEGEND

FLS	FELSITE and related coarse grained quartz – porphyry intrusive dykes
ADS	ANDESITE and related intermediate fine grained intrusive rocks which occur as small dykes
LHF	LAMINATED HORNFELS and related hard, grey, highly silicified, laminated rocks derived from micaceous siltstones
BHF	BANDED HORNFELS and related hard, highly silicified rocks with quartz banding, augens, and related features
GWK	SILICEOUS GREYWACKE and related moderately silicified argillaceous rocks with chert and quartz stringers
GAS	GREEN ARGILLACEOUS SCHIST and related non-siliceous, argillaceous rocks
BST	BLACK SLATE and related thinly laminated, well developed slates

SYMBOLS

Geological Contact

Fault

Structural Domain boundary

Structural Domain number — 6A

Crest and toe of bench with elevation

Detailed line mapping traverse: number and location — 47

Number and location of percussion drillhole — MCP7

Number and location of diamond drillhole — CB21

Drillhole with piezometers installed

Number, location, and direction of photographs — 6

Label for Joint Set on lower hemisphere projection — A

NOTE

Contour values on lower hemisphere equal area projections are expressed as percent of the total weight occurring in a 1.0 percent area of the plot.

10 0 10 20 30 40 50 60 70 80 90 100 metres

SCALE

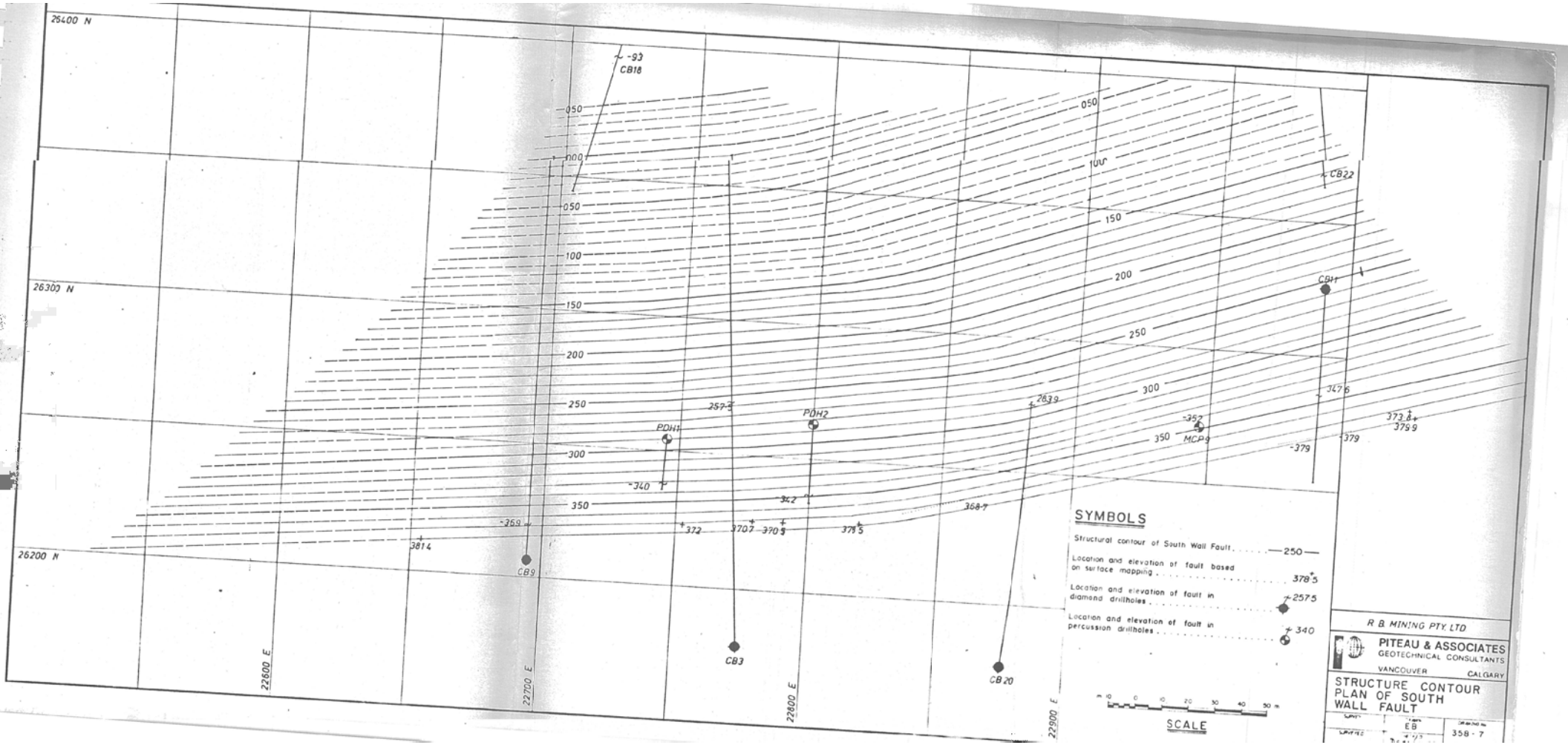
FIG. 7

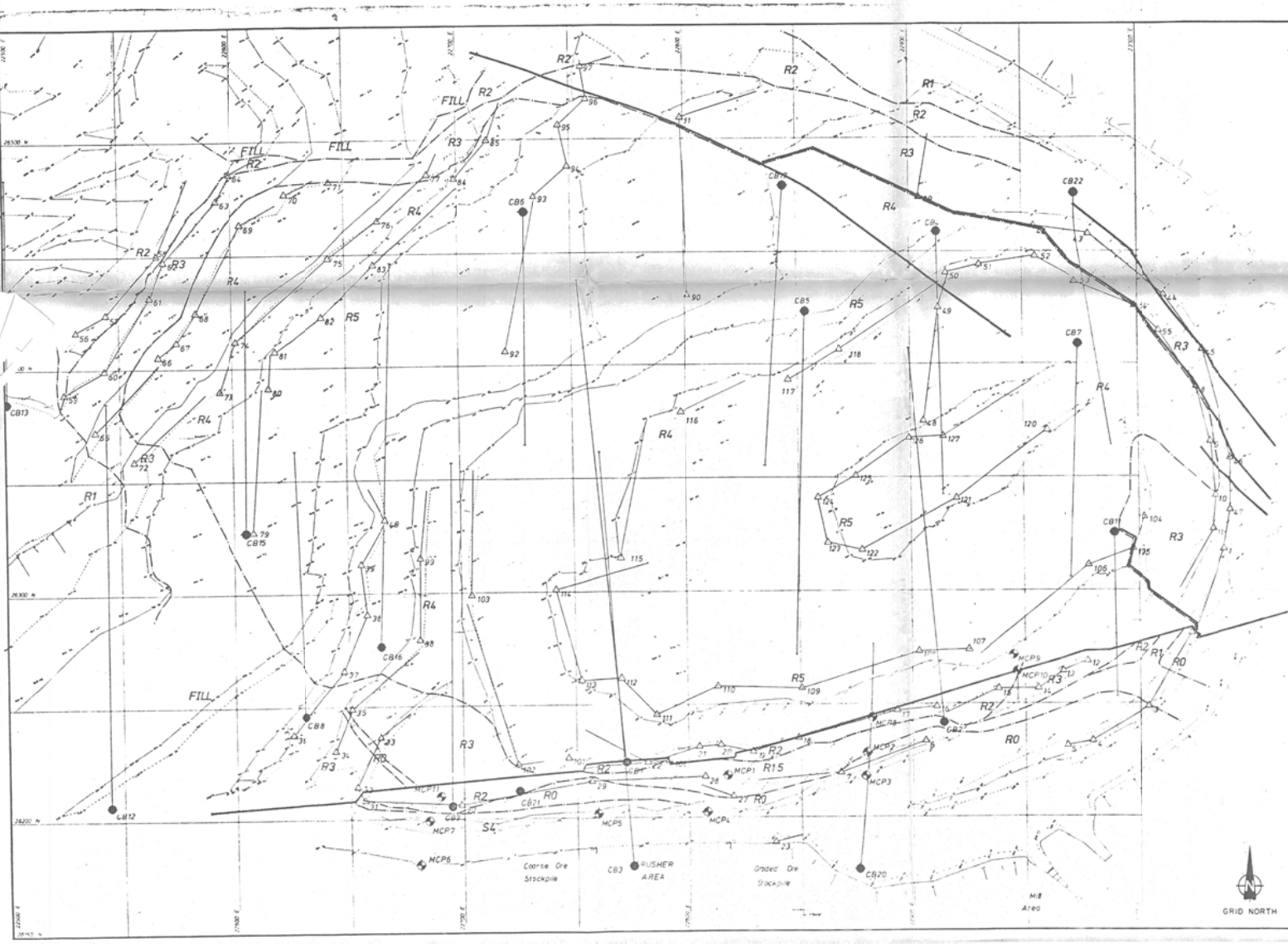
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MT. CARBINE MINE
GEOTECHNICAL STUDIES

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

DISTRIBUTION OF FAULTS AND SHEARS IN THE OPEN PIT

BY EB | DCM | DATE MAR 82 | APPROVED | JOB NO 81-358


26400 N
26300 N
26200 N
22600 E
22700 E
22800 E
22900 E
CB18
CB22
CB11
CB9
CB3
CB20
PDH1
PDH2
MCP9
-93
050
000
050
100
150
200
250
300
350
100
150
200
250
300
350
257.2
263.9
347.6
352
373.8
375.9
379
379
340
342
368.7
369
372
370.7
370.9
375.5
381.4
SYMBOLS
Structural contour of South Wall Fault 250
Location and elevation of fault based on surface mapping 378.5
Location and elevation of fault in diamond drillholes 257.5
Location and elevation of fault in percussion drillholes 340
SCALE
R B MINING PTY LTD
PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER
CALGARY
STRUCTURE CONTOUR PLAN OF SOUTH WALL FAULT
EB
358 - 7



LEGEND

		ESTIMATED COMPRESSIVE STRENGTH kg/cm²	UNCONFINED STRENGTH psi
S1	VERY SOFT: EASILY PENETRATED SEVERAL INCHES BY FIST	<0.25	<3.5
S2	SOFT: EASILY PENETRATED SEVERAL INCHES BY THUMB	0.25-0.5	3.5-7
S3	FIRM: CAN BE PENETRATED SEVERAL INCHES BY THUMB WITH MODERATE EFFORT	0.5-1.0	7-14
S4	STIFF: READILY INDENTED BY THUMB BUT PENETRATED ONLY WITH GREAT EFFORT	1.0-2.0	14-28
S5	VERY STIFF: READILY INDENTED BY THUMBNAIL	2.0-4.0	28-56
S6	HARD: INDENTED WITH DIFFICULTY BY THUMBNAIL	>4.0	>56
R0	EXTREMELY SOFT ROCK: INDENTED BY THUMBNAIL	2.0-7.0	28-100
R1	VERY SOFT ROCK: CRUMBLES UNDER FIRM BLOW WITH POINT OF GEOLOGICAL PICK. CAN BE PEELED BY POCKET KNIFE	7.0-70	100-1000
R2	SOFT ROCK: CAN BE PEELED BY POCKET KNIFE WITH DIFFICULTY; SHALLOW INDENTATIONS MADE BY FIRM BLOW OF GEOLOGIC PICK	70-280	1000-4000
R3	AVERAGE ROCK: CANNOT BE SCRAPED OR PEELED WITH POCKET KNIFE; SPECIMEN CAN BE FRACTURED WITH SINGLE FIRM BLOW OF HAMMER END OF GEOLOGICAL PICK	280-560	4000-8000
R4	HARD ROCK: SPECIMEN REQUIRES MORE THAN ONE BLOW WITH HAMMER END OF GEOLOGICAL PICK TO FRACTURE IT	560-1,120	8000-16,000
R5	VERY HARD ROCK: SPECIMEN REQUIRES MANY BLOWS OF HAMMER END OF GEOLOGICAL PICK TO FRACTURE IT	1,120-2240	16,000-32,000

SYMBOLS

Estimated boundary between rock hardness zones

Fault

Structural Domain boundary

Structural Domain number — 6A

Crest and toe of bench with elevation

Detailed line mapping traverse: number and location — 47

Number and location of percussion drillhole — MCP7

Number and location of diamond drillhole — CB21

Drillhole with piezometers installed — P

Number, location, and direction of photographs — 6

SCALE 0 10 20 30 40 50 60 70 80 90 100 metres

FIG. 9

R.B. MINING PTY. LTD.
MT CARBINE MINE
GEOTECHNICAL STUDIES

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

DISTRIBUTION OF ROCK HARDNESS

BY DCM EB APPROVED D. Piteau DATE MAR 82 JOB No. BI-358

JOB NUMBER

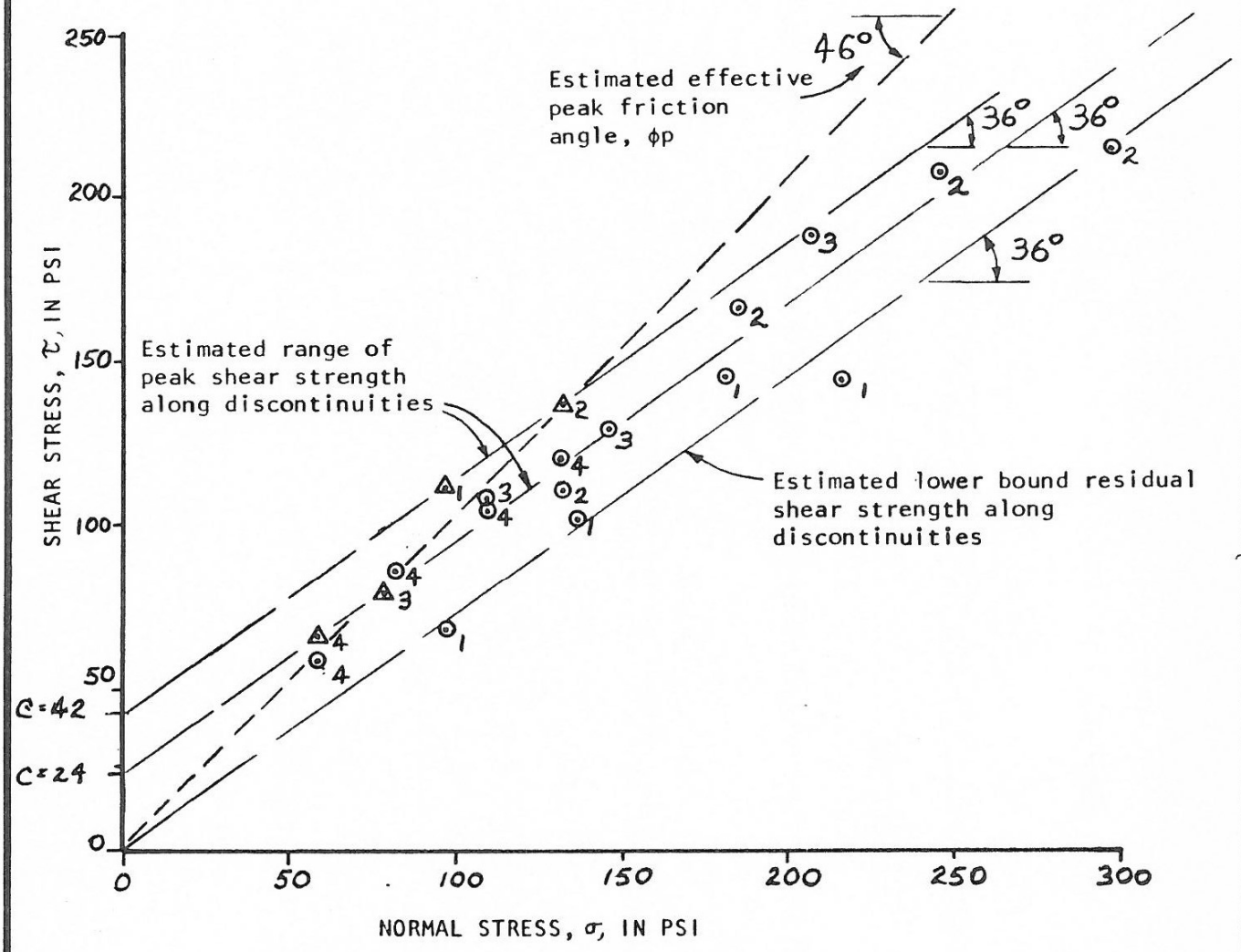
SAMPLE DESCRIPTION AND LOCATION

1 Natural joint: CB20 (64m)
2 Rough foliation joint: CB20 (104m)
3 Foliation joint: CB21 (38m)
4 Weathered joint: CB21 (4m)

SYMBOLS

Peak shear strength for initial test run △2

Residual shear strength for test run ⊙2



NOTE: Shear tests were carried out with a direct shear testing machine using standard testing techniques

FIG. 10

R.B. MINING PTY LIMITED
MT. CARBINE MINE
SLOPE STABILITY STUDIES

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

SHEAR STRENGTH OF DISCONTINUITIES

BY: D.C.M.
DATE: MAR/82
APPROVED: D. Piteau
DWG:

JOB NUMBER 81-358

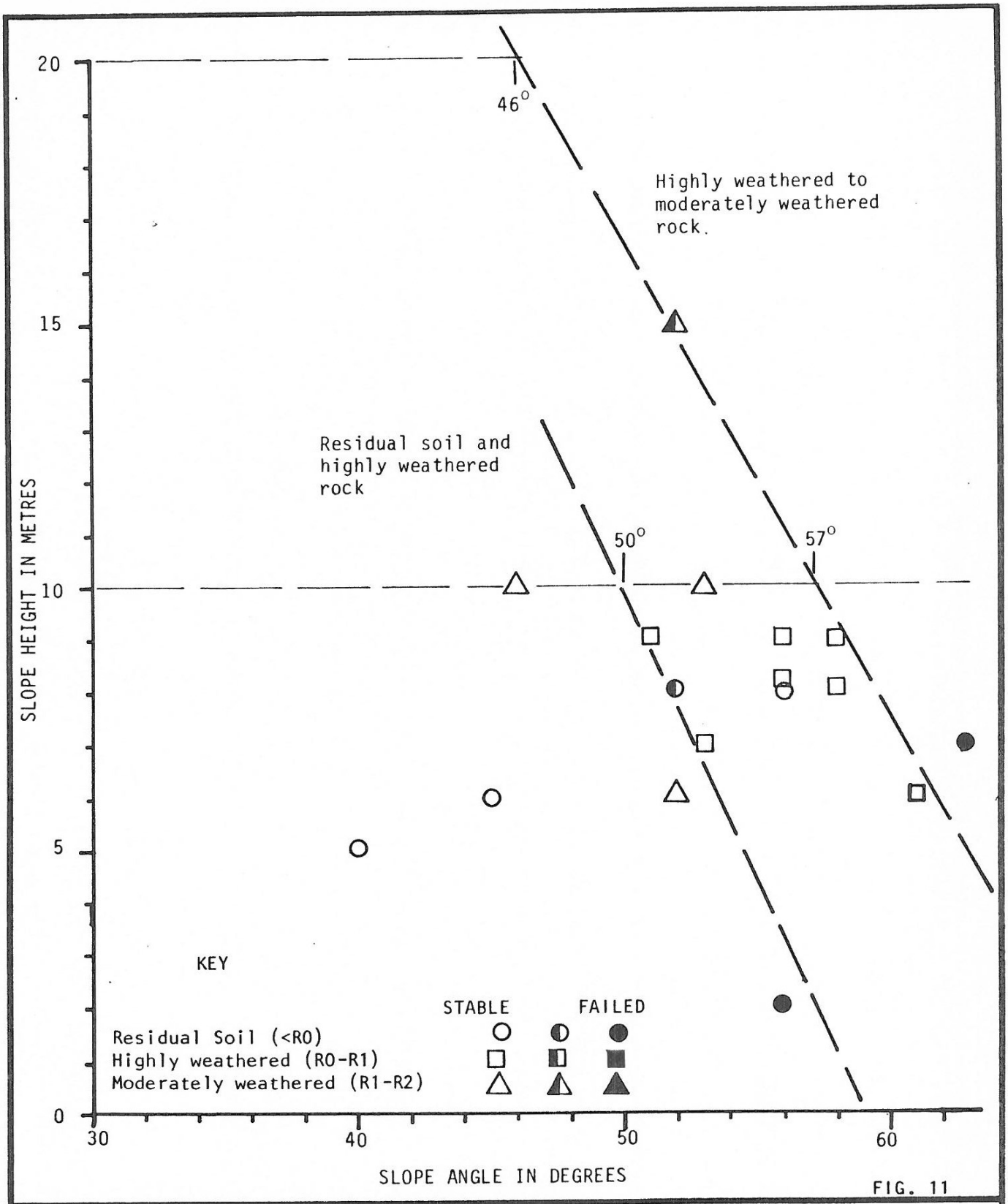


FIG. 11

R.B. MINING PTY LIMITED
MT. CARBINE MINE
SLOPE STABILITY STUDIES

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

DOCUMENTATION OF ROAD CUT SLOPES IN THE MT. CARBINE AREA

BY:	DATE:
DCM	MAR/82
APPROVED:	DWG:
	358-10

JOB NUMBER 81-358

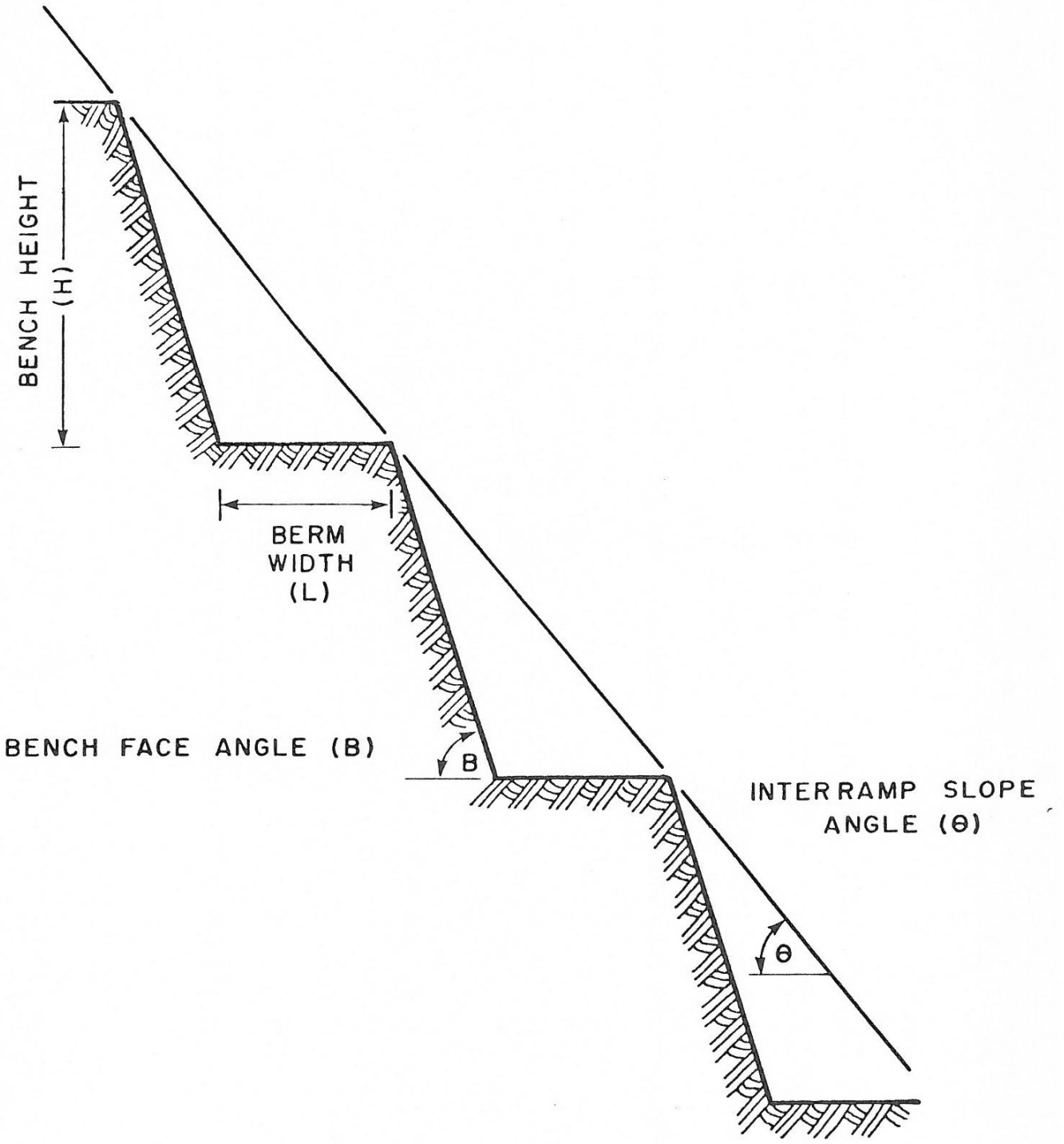


FIG. 12

R.B. MINING PTY LTD
MT. CARBINE MINE
GEOTECHNICAL STUDIES

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

SLOPE GEOMETRY PARAMETERS USED IN SLOPE DESIGN

BY	DATE:
A.F.S. / V.G.	MAR/82
APPROVED	DWG:
D. Piteau	358-12

JOB NUMBER 81-358

GEOPLN - LOWER HEMISPHERE EQUAL AREA PROJECTION OF PLANES

PROJECT: MOUNT CARBINE
DATE: MARCH 82
STRUCTURAL DOMAIN: ALL PIT

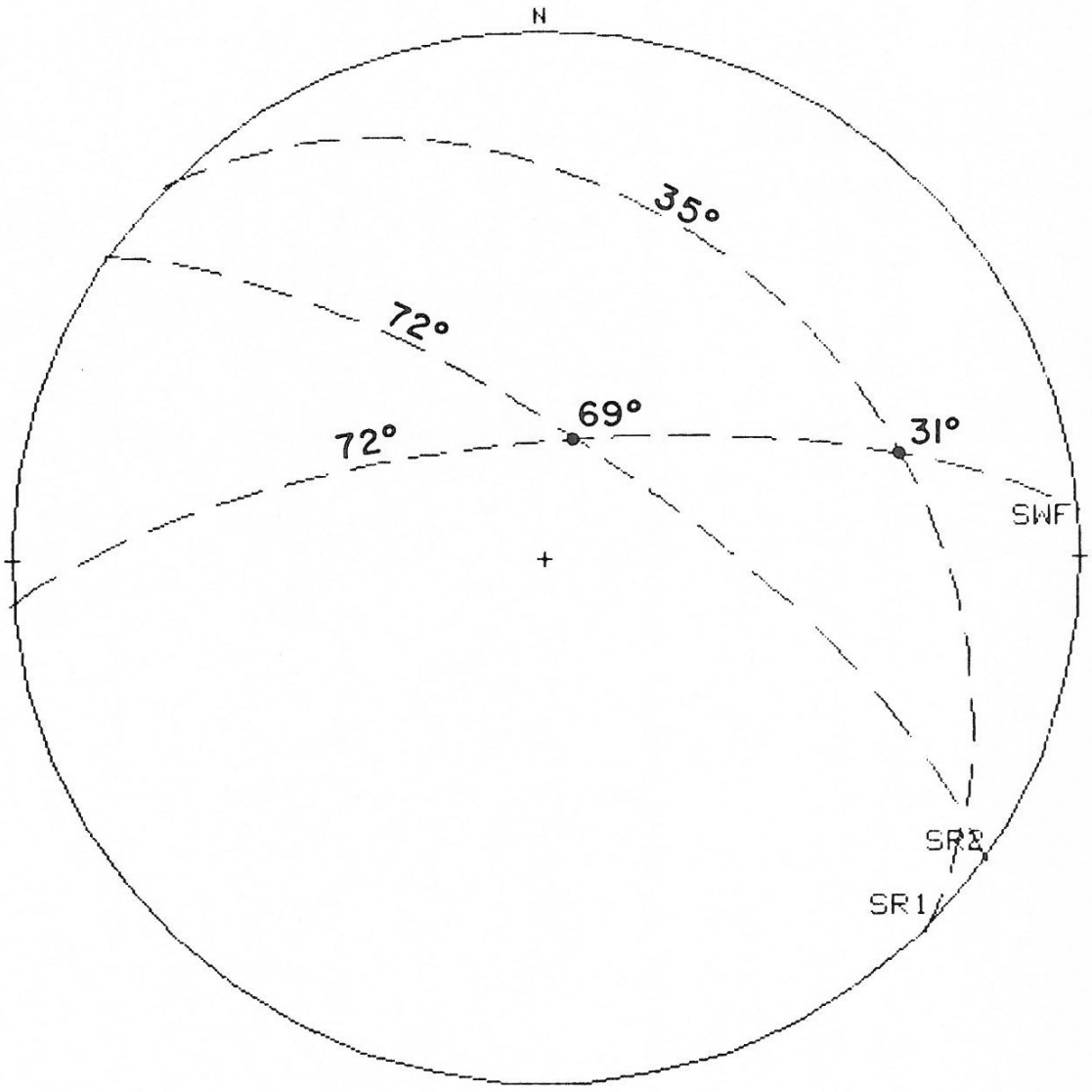
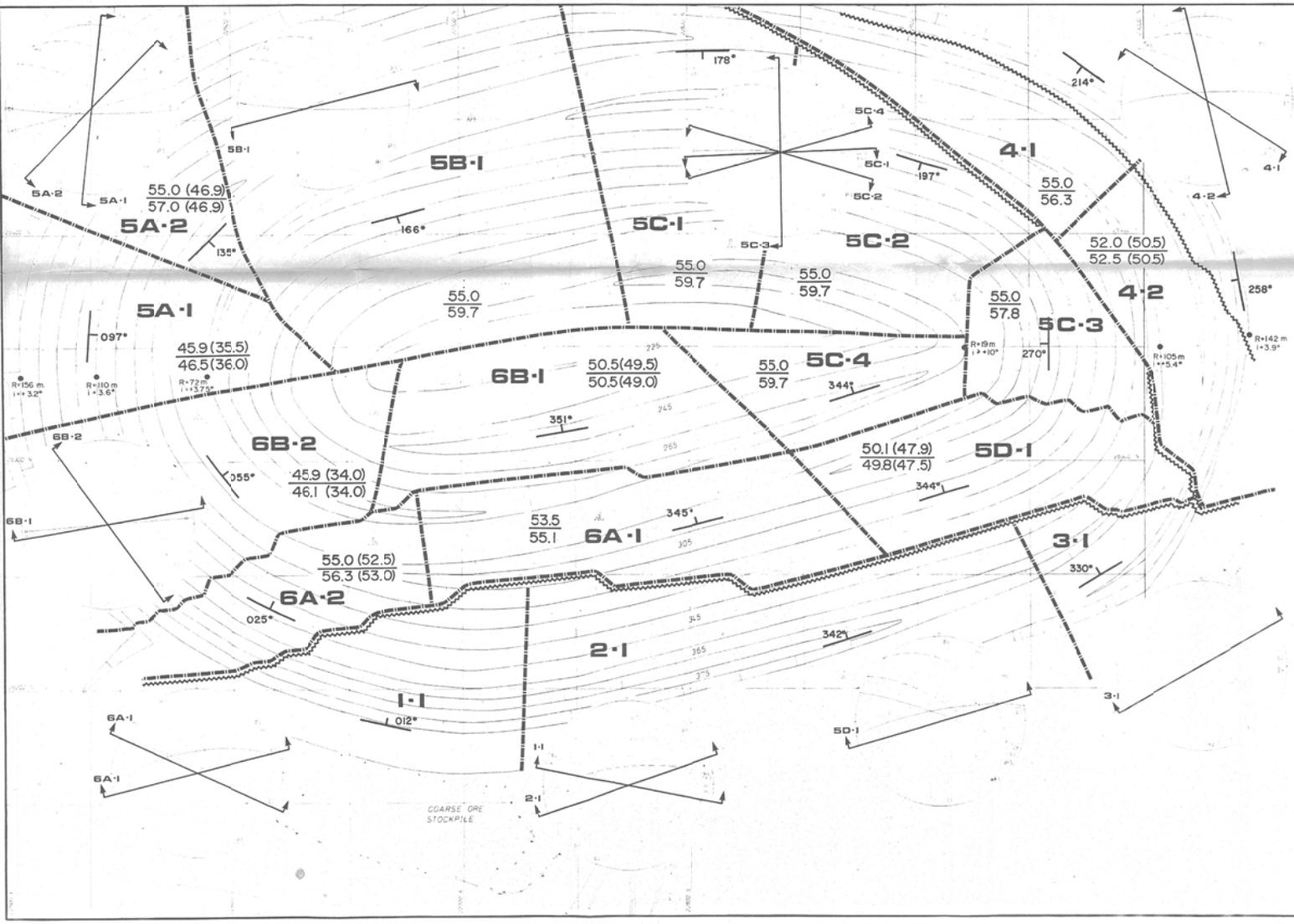


FIG. 13

R.B. MINING PTY LTD MT. CARBINE MINE GEOTECHNICAL STUDIES		PITEAU & ASSOCIATES GEOTECHNICAL CONSULTANTS VANCOUVER CALGARY
LOWER HEMISPHERE EQUAL AREA PROJECTIONS OF PLANES REPRESENTING PEAK ORIENTATION OF FAULT AND SHEAR SETS IN THE OPEN PIT	BY: D.C.M.	DATE: MAR/82
	APPROVED:	DWG: 358-B



SYMBOLS

Design Sector boundary

Design Sector number — 6B-1

Orientation and dip direction of final pit wall — 175°

Lower hemisphere equal area projection of peak attitude of discontinuity set used in the stability analysis

Approximate trend and dip direction of proposed final pit wall on equal area projection for Design Sector considered — 6A-1

Optimum interramp slope angle for Design Sectors with and without adequate groundwater depressurization — Bench height = 20m: 55.0 (469); Bench height = 30m: 57.0 (47.2)

Location of measurement of plan radius of curvature (R) and radius of curvature increment (i) — R=125m i=+5.4°

Crest, toe, and elevation of benches on the proposed final pit (Plan 5A ; July 1980) — 265

NOTES

1. Design sector boundaries are based on structural domain boundaries and boundaries of straight slope segments
2. Results of kinematic statistical analyses were not used for design of slopes in Design Sectors 1-1, 2-1 and 3-1. Separate design of slopes and remedial measures for individual benches south of the South Wall Fault are discussed in Section 8.7.

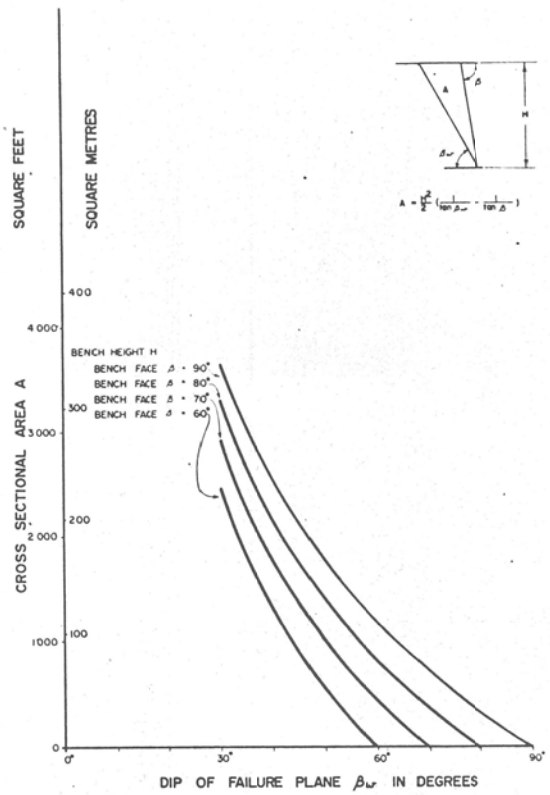
0 20 40 60 80 100 metres

SCALE

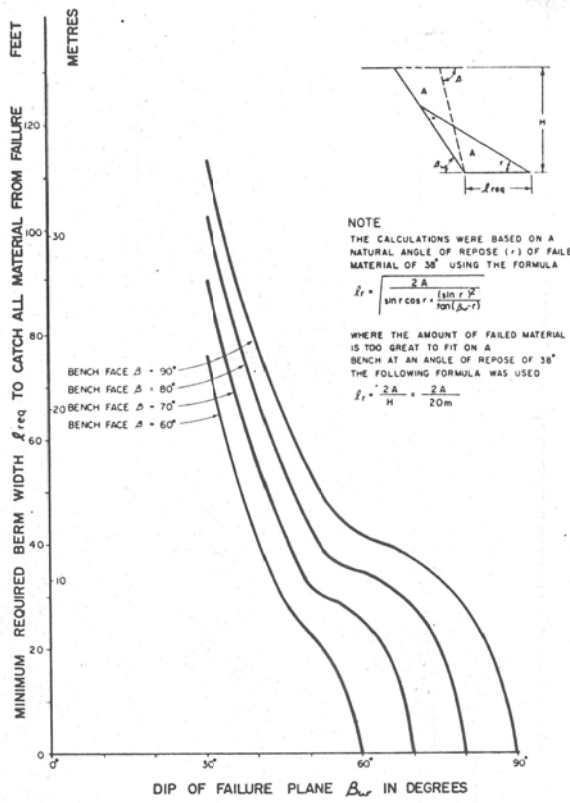
GRID NORTH

FIG. 14

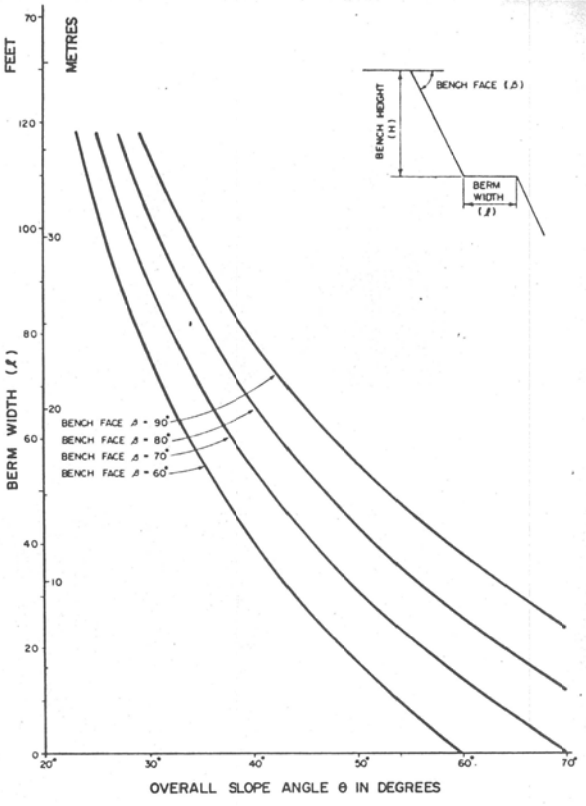
CB MINING PTY LIMITED MT CARBINE MINE GEOTECHNICAL STUDIES	PITEAU & ASSOCIATES GEOTECHNICAL CONSULTANTS VANCOUVER CALGARY
DISTRIBUTION OF DESIGN SECTORS AND KINEMATICALLY POSSIBLE FAILURE MODES	BY EB; DCM; APPROVED; DATE MAR 82; JOB 358-14



a) VARIATION OF CROSS SECTIONAL AREA WITH DIP OF FAILURE PLANE FOR FAILURES INVOLVING A SINGLE 20m (65.6 ft.) HIGH BENCH



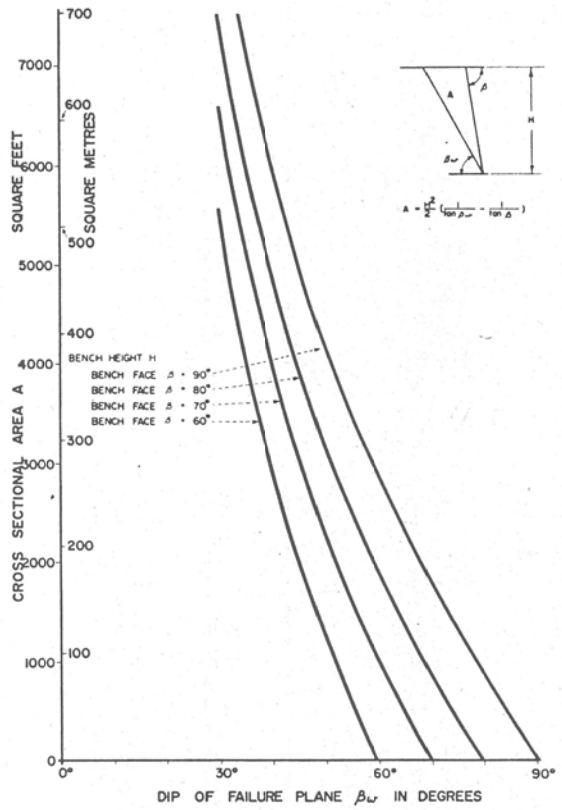
b) VARIATION OF BERM WIDTH REQUIRED TO CATCH FAILED MATERIAL WITH DIP OF FAILURE PLANE FOR FAILURES INVOLVING A SINGLE 20m (65.6 ft.) HIGH BENCH.



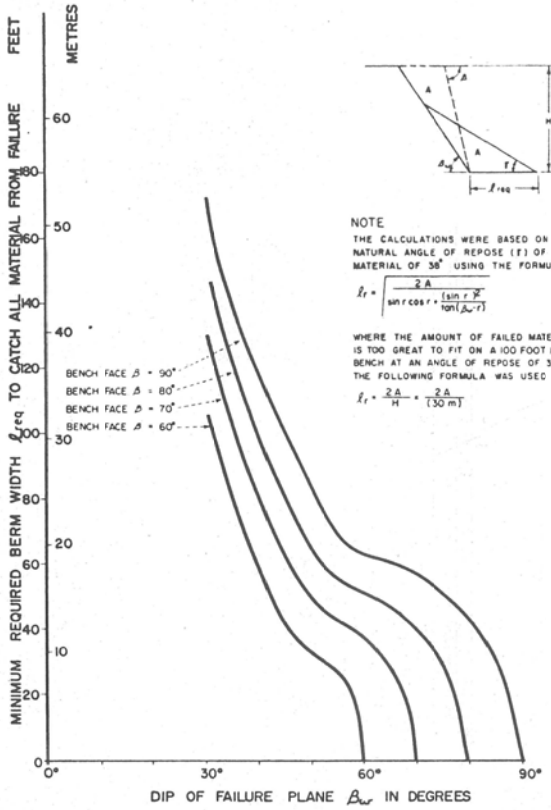
c) GEOMETRIC RELATIONSHIP OF OVERALL SLOPE ANGLE, BERM WIDTH AND BENCH FACE FOR SINGLE 20m (65.6 ft.) HIGH BENCHES

FIG. 15

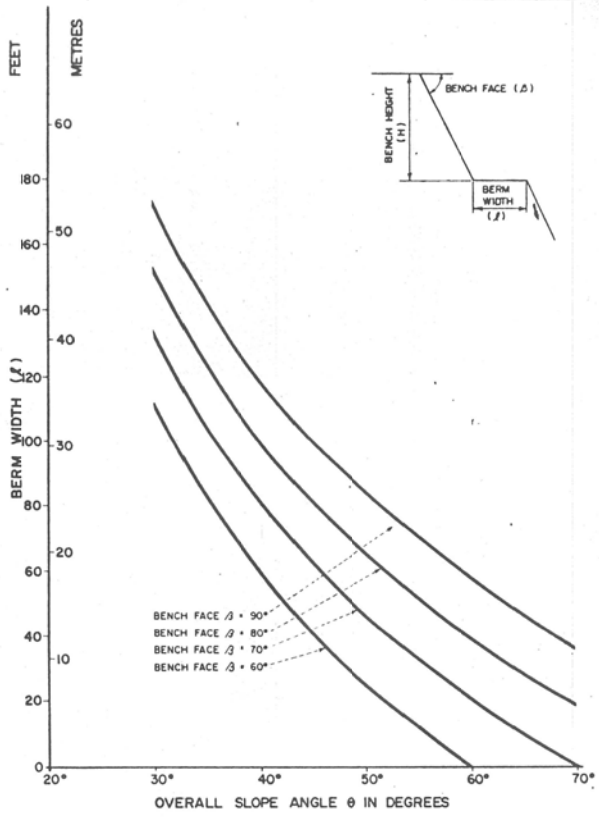
RB MINING PTY LIMITED MT. CARBINE MINE GEOTECHNICAL STUDIES	PITEAU & ASSOCIATES GEOTECHNICAL CONSULTANTS VANCOUVER CALGARY	
INTERRELATIONSHIP OF SLOPE GEOMETRY AND FAILURE GEOMETRY FOR 20m (65.6 ft.) HIGH BENCHES	BY BST	DATE 04-82
	APP.	DWG. 358-15



a) VARIATION OF CROSS SECTIONAL AREA WITH DIP OF FAILURE PLANE FOR FAILURES INVOLVING A SINGLE 30 METRE HIGH BENCH



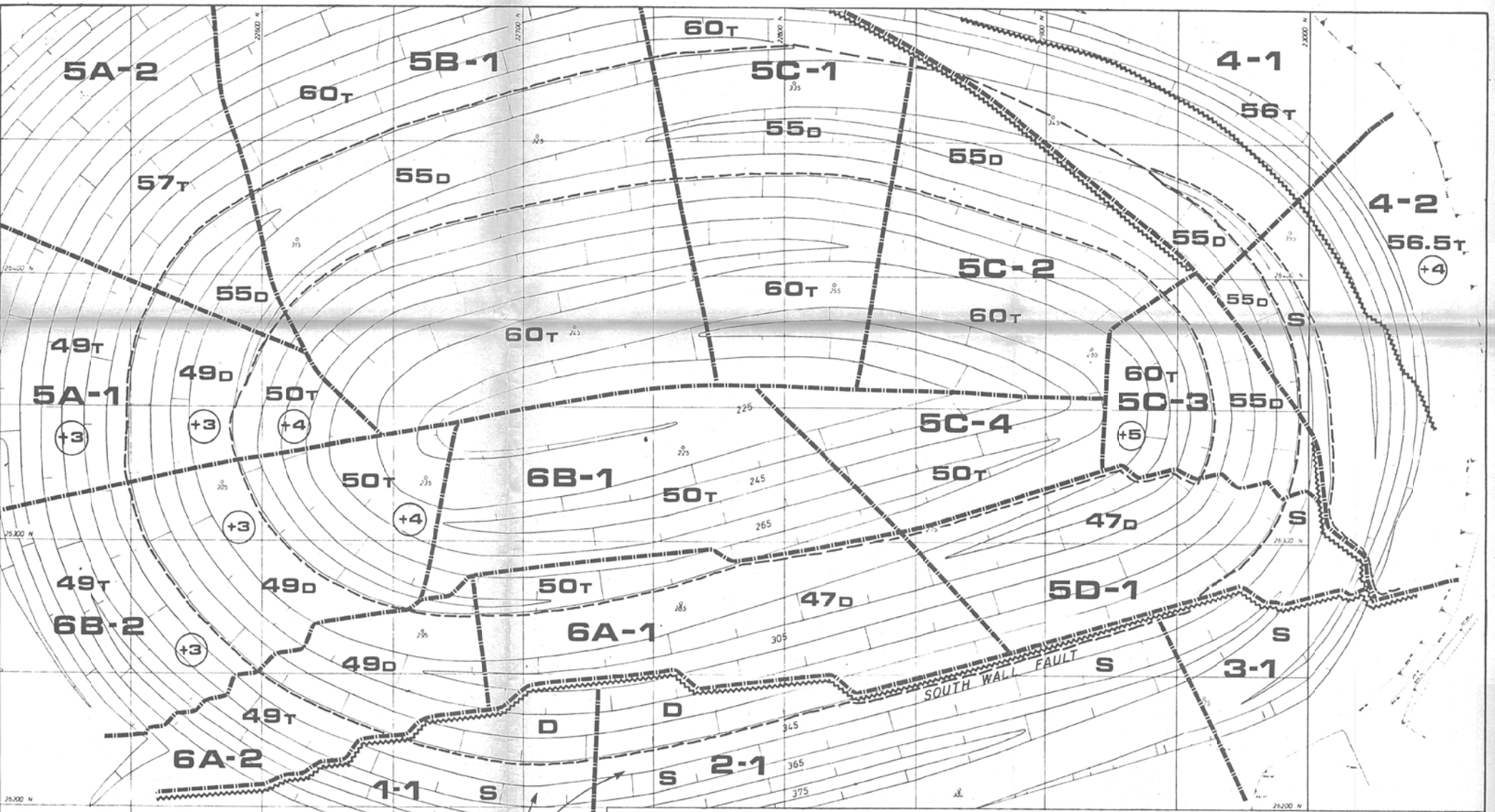
b) VARIATION OF BERM WIDTH REQUIRED TO CATCH FAILED MATERIAL WITH DIP OF FAILURE PLANE FOR FAILURES INVOLVING A SINGLE 30 METRE HIGH BENCH



c) GEOMETRIC RELATIONSHIP OF OVERALL SLOPE ANGLE, BERM WIDTH AND BENCH FACE FOR 30 METRE HIGH BENCHES

FIG. 16

R B MINING PTY LIMITED MT CARBINE MINE GEOTECHNICAL STUDIES	PITEAU & ASSOCIATES GEOTECHNICAL CONSULTANTS VANCOUVER CALGARY	
INTERRELATIONSHIP OF SLOPE GEOMETRY AND FAILURE GEOMETRY FOR 30 METRE HIGH BENCHES	BY BST JSP CHKD	DATE 04-82
	APP. JP	DWG 358-16



AREA SOUTH OF THE SOUTH WALL FAULT HAS SEPARATE DESIGN AND REMEDIAL MEASURES AS SUMMARIZED IN FIG. 19

COARSE ORE STOCKPILE

SYMBOLS

Boundary of Design Sector

Design Sector Number, 6B-1

Boundary of area with similar recommended bench height

Recommended interramp slope angle and bench height for slopes with adequate groundwater depressurization (D= 20m high benches ; T= 30m high benches.) 60T

Area where single 10m high benches are recommended for access to the South Wall S

Recommended increase in slope angle included due to effects of plan radius of curvature (+5)

NOTE

Slope angles are recommended for interramp slopes north of the South Wall Fault. The recommended slope geometry and remedial measures for each Design Sector are summarized in Table IX.

10 0 10 20 30 40 50 60 70 80 90 100 metres

SCALE

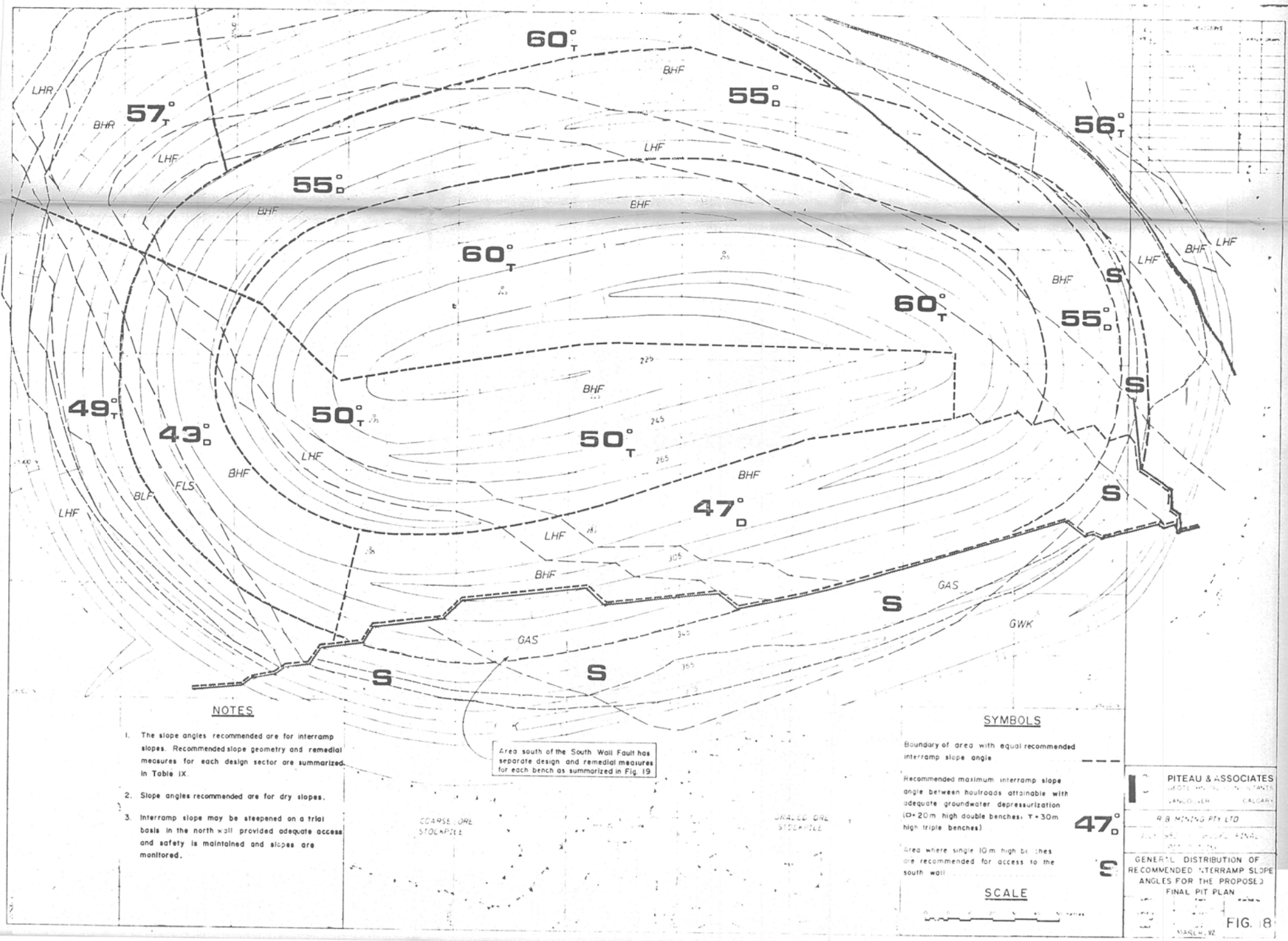
FIG. 17

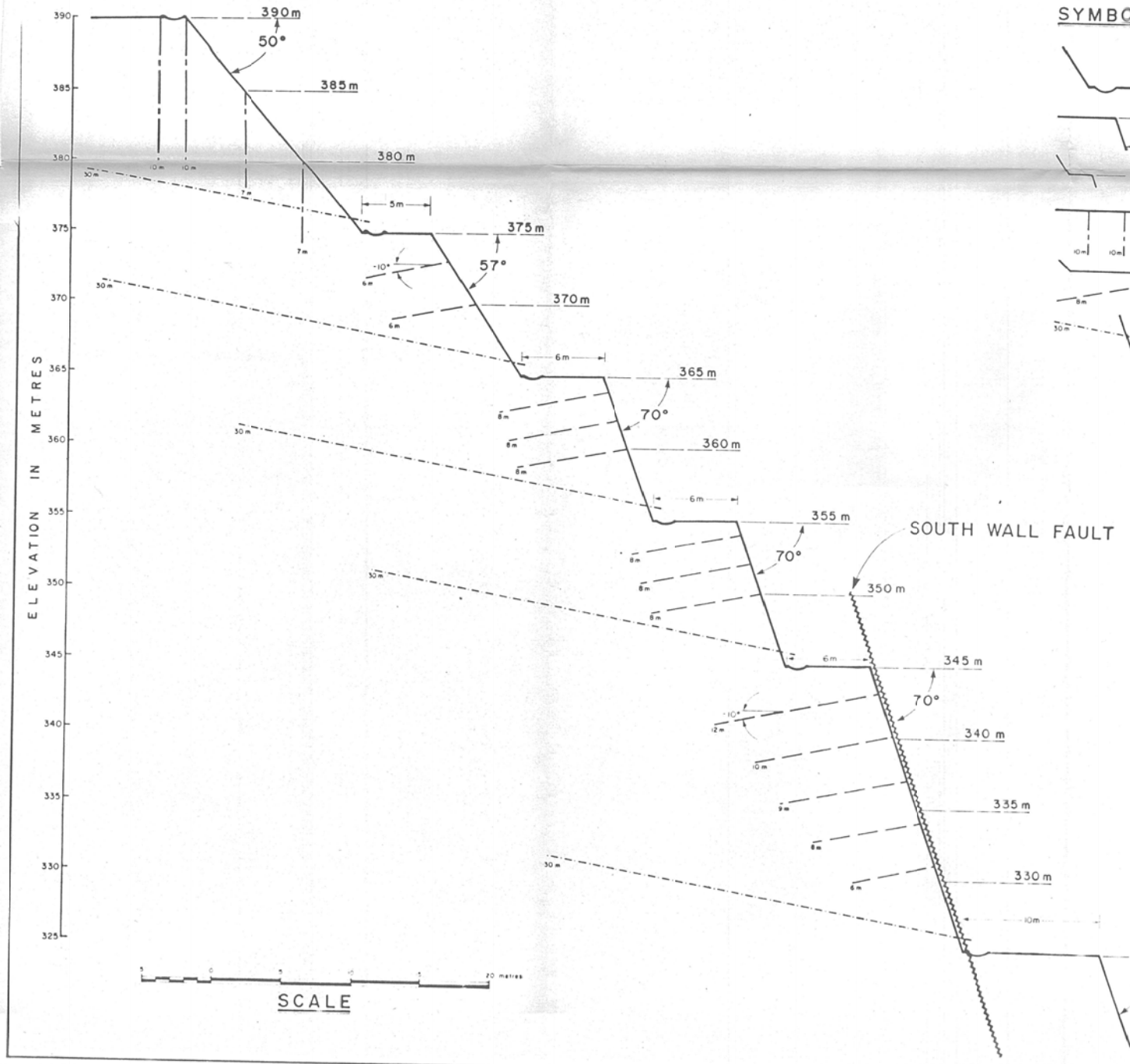
R B MINING PTY LIMITED
MT CARBINE MINE
GEOTECHNICAL STUDIES

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

RECOMMENDED INTERRAMP SLOPE DESIGN IN INDIVIDUAL DESIGN SECTORS

BY	DATE
DCM	MAR 82
APPROVED	DWG
	358-18


60° T
55° D
57° T
56° T
55° D
60° T
60° T
55° D
49° T
43° D
50° T
50° T
47° D
LHR
BHR
LHF
BHF
BLF
FLS
GAS
GWK
S
NOTES
1. The slope angles recommended are for interramp slopes. Recommended slope geometry and remedial measures for each design sector are summarized in Table IX.
2. Slope angles recommended are for dry slopes.
3. Interramp slope may be steepened on a trial basis in the north wall provided adequate access and safety is maintained and slopes are monitored.
Area south of the South Wall Fault has separate design and remedial measures for each bench as summarized in Fig. 19
SYMBOLS
Boundary of area with equal recommended interramp slope angle
Recommended maximum interramp slope angle between haulroads attainable with adequate groundwater depressurization (D = 20m high double benches; T = 30m high triple benches)
47° D
Area where single 10m high benches are recommended for access to the south wall
S
SCALE
COARSE ORE STOCKPILE
CRUSHED ORE STOCKPILE
PITEAU & ASSOCIATES
R.B. MINING PTY LTD
GENERAL DISTRIBUTION OF RECOMMENDED INTERRAMP SLOPE ANGLES FOR THE PROPOSED FINAL PIT PLAN
MARCH, 92
FIG. 18



SYMBOLS

RECOMMENDED SLOPE GEOMETRY SOUTH OF SOUTH WALL FAULT

RECOMMENDED BENCH FACE ANGLE

RECOMMENDED LEVEL OF EACH EXCAVATION LIFT TO BE USED FOR INSTALLING REMEDIAL MEASURES

RECOMMENDED LOCATION AND LENGTH IN METRES OF FULLY GROUTED VERTICAL DOWELS

RECOMMENDED LOCATION AND LENGTH IN METRES OF FULLY GROUTED INCLINED CABLE DOWELS

RECOMMENDED LOCATION AND LENGTH IN METRES OF SUBHORIZONTAL DRAINHOLES AND DRAINAGE DITCH

NOTES

1. SLOPE DESIGN IS FOR AREA SOUTH OF SOUTH WALL FAULT ON SECTION 22,700 E. RECOMMENDED DESIGN SHOULD BE APPLIED SOUTH OF FAULT ONLY. SLOPE DESIGN FOR AREA NORTH OF FAULT IS GIVEN IN FIG. 18.
2. RECOMMENDED DESIGN ASSUMED SLOPES ARE EXCAVATED BY RIPPING OR OTHER NON EXPLOSIVE EXCAVATION METHODS TO MAINTAIN COHESION IN THE ROCK MASS.
3. SLOPES SHOULD BE CAREFULLY MAPPED AND MONITORED DURING EXCAVATION. EXTENT OF REMEDIAL MEASURES MAY BE VARIED DEPENDING ON ACTUAL CONDITIONS ENCOUNTERED DURING EXCAVATION.
4. SPACING OF ALL DOWELS IS ASSUMED TO BE 3m TO INSURE ADEQUATE SUPPORT AND ACCEPTABLE DISTRIBUTION OF SUPPORT IN THE SLOPE. INCLINED DOWELS ABOVE 345m ELEVATION ARE REQUIRED TO HAVE A MINIMUM DESIGN LOAD OF 200 kN (20 TONNE). INCLINED DOWELS BELOW 345m ELEVATION ARE REQUIRED TO HAVE A MINIMUM DESIGN LOAD OF 500 kN (50 TONNE).

FIG. 19

R. B. MINING PTY. LTD.
MT. CARBINE MINE
GEOTECHNICAL STUDIES

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

RECOMMENDED SLOPE DESIGN AND REMEDIAL MEASURES FOR SLOPES SOUTH OF THE SOUTH WALL FAULT

DCM EB FEB 82

81-358

TABLE I

SUMMARY OF CHARACTERISTICS OF WEATHERED ROCKS

SOUTH OF THE SOUTH WALL FAULT

ASSUMED ELEVATION FOR DESIGN (m)	DESCRIPTION	DEGREE OF WEATHERING*	AVERAGE ROCK HARDNESS*	ESTIMATED AVERAGE UNCONFINED COMPRESSIVE STREGHTH (MPa)	AVERAGE DEPTH (m)
above 375	Fill and extremely weathered residual soil	A	S4 to RO	0.19 to 0.69	10.5
365 to 375	Highly weathered schists and greywackes	B	R1	5.6	7.0
355 to 365	Moderately weathered schists and greywackes	C	R2	6.9	9.5
below 355	Slightly weathered to unweathered schists and greywackes	D and E	>R3	27.5	-

* Note: A description of Degree of Weathering and Rock Hardness is given in Figs. 2 and 9.

TABLE III

ORIENTATION OF FAULT AND SHEAR SETS

IN THE OPEN PIT

STRUCTURAL DOMAIN	TOTAL POP.	SHEAR SET SR1			SHEAR SET SR2		
		DIP DIRECTION	DIP	%	DIP DIRECTION	DIP	%
1, 2 & 3	9	355	72	>35			
4	31	043	33	11	038	70	19
5	35	047	37	14	032	73	13
6	10	-	-	-	-	-	-
4, 5 & 6	75	045	35	11	035	72	12

NOTES: 1. Orientation is given in terms of dip direction and dip of the peak or average orientation of the discontinuity set.

2. Percent refers to the percent concentration with one percent area of the lower hemisphere for the peak or average orientation of the population.

TABLE IV

SUMMARY OF UNCONFINED COMPRESSIVE STRENGTH[1]

ROCK TYPE[2]	ESTIMATED AVERAGE HARDNESS	DRILLHOLE	DEPTH (m)	UNIAXIAL COMPRESSION TESTS[3] UCS (MPa)	UNIAXIAL COMPRESSION TESTS[3] AVERAGE UCS (MPa)	POINT LOAD INDEX TESTS UCS PARALLEL SCHISTOSITY (MPa)	POINT LOAD INDEX TESTS UCS NORMAL TO SCHISTOSITY (MPa)	
Fill and residual soil (A)	S4 to RO	-	- -	-	-	-		
Highly weathered schist and greywacke (B)	R1	CB20	24.0	7.04	5.6	-	-	
			26.1	4.60				
			28.5	4.53				
			28.7	6.01				
		CB3	16.8	-	-	5.76	-	*
Moderately weathered schist and greywacke (C)	R2	CB20	-	6.48	10.44	-	-	
		CB21	4.0	14.4				
Unweathered greywacke (D to E)	R3 to R4	CB20	51.0 to 56.0	-	-	-	93.4	
		CB20	77.0 to 81.0	-	-	29.0	59.8	
		CB3	54.3 to 60.4	-	-	-	54.0	*
Unweathered schistose greywacke (D to E)	R3 to R4	CB20	122.0 to 127.0	-	-	28.1	73.4	
		CB20	131.0 to 137.0	-	-	3.7	91.2	*
Unweathered hornfels (D to E)	R4 to R5	CB3	71.0 to 77.13	-	-	-	62.4	

NOTES: 1. Laboratory tests were carried out in November, 1981 at James Cook University, Townsville, under the supervision of Dr. H. Bock. Test results indicated by an asterisk (*) were carried out by Piteau & Associates.

2. Degree of Weathering is classified by letters A to E as summarized in Fig. 2.

3. Unconfined compressive strength is abbreviated as UCS

TABLE V

SUMMARY OF BACK ANALYSIS RESULTS FOR SLOPES

IN WEATHERED ROCK AND RESIDUAL SOIL

SOUTH OF THE SOUTH WALL FAULT

SLOPE HEIGHT (m)	DRY SLOPE	MAXIMUM SLOPE ANGLE FOR F = 1.2	
		MODERATE GROUNDWATER	HIGH GROUNDWATER
10	60	58	47
15	48	40	31
20	41	29	25

NOTES:
1. Analyses were carried out using design charts.
2. Analyses results are based on a factor angle of 24° and a mass cohesion C' of 40 kPa.
3. It is anticipated that slopes 20m in height would contain significantly stronger rock in the toe area. Hence, somewhat steeper slope angles could be appropriate for 20m high slopes.

TABLE VI

SUMMARY OF
BACK ANALYSIS RESULTS
FOR PLANE FAILURE IN ARGILLACEOUS SCHIST
ON THE SOUTH WALL

1. SLOPE GEOMETRY AND STRENGTH PARAMETERS

- Slope Height H = 10m
- Slope Angle B = 80^o
- Friction Angle = 36^o
- Failure Surface Dip, $_p$ = 47^o

2. CALCULATION OF REQUIRED COHESION FOR SLOPE ANGLE OF 80^o

Factor of Safety	Cohesion Required, kPa Without Tension Crack	With Tension Crack
1.0	16	20
1.2	26	33
1.5	42	51

3. CALCULATION OF ANCHOR FORCES REQUIRED FOR VARIOUS SLOPE ANGLES ON A 10m HIGH BENCH FOR COHESION OF 10 kPa

Bench Face Angle (o)	Total Anchor Force Required kN/m	Equivalent Number of Rows of Grouted Dowels 200 kN (20 Tonne) Dowels at 3m Spacing	500 kN (50 Tonne) Dowels at 5m Spacing
50	0	-	-
60	81	2	1
70	186	3	2
80	262	4	3

NOTES: 1. Calculations are for horizontal dowels. Dowels inclined at -10^o would require higher anchor forces.

2. Sufficient number of rows of dowels are required to obtain acceptable distribution of support in the slope.

TABLE VII

SUMMARY OF GROUTED DOWELS AND PULLOUT TEST RESULTS

DOWEL NO.	LOCATION			ORIENTATION		LENGTH (m)	GROUTED LENGTH (m)	ESTIMATED ROCK HARDNESS[1]	LOCATION IN FINAL WALL	JACK FORCE AT FAILURE (TONNES)[2]
	NORTHING (m)	EASTING (m)	ELEVATION (m)	DIP DIRECTION (°)	INCLINATION (°)					
1	26226.6	22887.1	380.8	160	-30	10	10	R0	1st Bench	67
2	26202.8	22804.3	389.7	183	-30	10	10	S5	Top	48*
3	26212.8	22862.3	384.8	172	-30	20	20	R0	Top	64
4	26216.6	22856.2	381.2	171	-30	20	20	1.5	1st Bench	70
5	26212.9	22837.2	381.5	171	-30	10	10	R1	1st Bench	77
6	26215.3	22807.8	380.5	189	-30	10	10	R1	1st Bench	71
7	26228.4	22958.4	379.5	159	-30	20	10	R0	1st Bench	76
8	26241.1	22874.2	371.0	174	-30	10	10	R2	2nd Bench	71
9	26246.1	22899.1	370.7	181	-30	20	20	R2	2nd Bench	76
10	26255.9	22954.6	370.9	173	-30	10	10	R3	2nd Bench	78

NOTES: 1. An explanation of rock hardness provided on the legend Fig. 2.
2. In each test failure was due to cable failure and not ground failure.
3. Anchor did not fail: Jack Failure prevented completion of test on this anchor.

TABLE VIII

SUMMARY OF HYDROGEOLOGICAL INFORMATION

DRILLHOLE				INSTALLATION[2]	ROCK TYPE[3]	DEGREE OF WEATHERING	POCKET LENGTH (m)	TIP ELEVATION (m)	ELEVATION OF RECORDED STATIC WATER LEVELS (m)		HYDRAULIC CONDUCTIVITY BASED ON FALLING HEAD TESTS (m/sec)	COMMENTS
NUMBER[1]	LOCATION	COLLAR ELEVATION (m)	INCLINATION (o)						LOW[4] (DRY SEASON)	HIGH[5] (WET SEASON)		
MCP1	26218.7N 22817.5E	378.8	90	P1	GAS	E	3.0	346.8	361.34	365.85	-	Seals may be inadequate.
				P2	GAS	E	2.0	357.3	361.37	365.86	1.0×10^{-7}	Seals may be inadequate.
				S1	GAS	C	-	367.3	dry	dry	-	
MCP2	26228.5N 22880.0E	379.3	90	P1	GAS	E	3.0	347.3	359.95	364.94	5.5×10^{-10}	
				P2	GAS	E	2.0	358.3	360.73	365.01	3.4×10^{-8}	
				S1	GAS	C	-	368.3	dry	dry	-	
MCP3	26218.3N 22879.3E	383.4	90	P1	GWK	E	3.0	349.4	360.07	364.87	3.8×10^{-7}	Seals may be inadequate.
				P2	GWK	E	3.0	355.4	360.04	364.69	1.8×10^{-7}	Seals may be inadequate.
				S1	GWK	B & C	-	371.9	dry	dry	-	
MCP4	26202.7N 22808.0E	389.6	90	P1	GWK	E	4.6	352.9	361.09	364.73	-	Seals may be inadequate
				S1	GAS	C	-	370.1	dry	dry	-	
MCP5	26202.4N 22759.8E	389.3	90	P1	GWK	E	3.0	355.8	360.60	363.67	1.6×10^{-8}	
MCP6	26180.3N 22680.1E	385.3	90	P1	GWK	D & E	3.0	348.3	359.92	361.73	2.6×10^{-7}	Seals may be inadequate.
MCP7	26199.3N 22684.2E	385.7	90	P1	GWK	E	3.0	350.9	359.77	361.98	4.9×10^{-8}	
MCP8	26244.7N 22882.4E	368.9	90	P1	GAS	E	2.0	347.9	360.22	364.98	3.0×10^{-7}	Test results may have been affected by caving.
MCP9	26271.4N 22945.6E	369.2	90	P1	GWK	E	3.1	334.5	359.49	364.58	1.0×10^{-8}	
				P2	GAS	E	2.0	345.6	354.75	362.05	5.9×10^{-8}	
				S1	LHF	E	-	354.2	dry	358.17	-	
MCP11	26210.3N 22689.6E	378.8	90	P1	GWK	E	3.0	343.8	359.58	362.62	2.3×10^{-9}	
				P2	GWK	C & D	2.2	357.1	360.95	363.96	4.1×10^{-8}	
CB20	26176.3N 22875.9E	382.8	45	P1	Fault Gouge	E	7.0	282.6	348.93	346.74	4.1×10^{-10}	Test results may have been affected by drilling mud.
				P2	GWK	B & D	6.0	352.1	358.65	360.43	4.8×10^{-9}	Test results may have been affected by drilling mud.
				P3	GWK	A	6.0	366.5	dry	dry	-	
CB21	26210.3N 22689.6E	378.8	90	P1	GWK	E	4.0	310.8	360.05	363.63	7.1×10^{-10}	Test results may have been affected by drilling mud.
				P2	GWK	D & E	4.6	356.0	359.75	362.02	2.7×10^{-10}	Test results may have been affected by drilling mud.

NOTES. 1. MCP1 to MCP11 refers to 165mm diameter percussion drillholes and CB20 and CB21 refers to 76mm to 96mm diameter diamond drillholes.

2. Installations are given as type and number where P = sealed piezometer and S = open standpipe.

3. A description of the symbols for the various rock types is given in Fig. 1. Explanation of weathering categories is given in Fig. 2.

4. Low static water levels listed were recorded on November 6, 1981 for all drillholes, except MCP4, MCP5, MCP6, MCP7, MCP11 and CB20, which were recorded on December 3, 1981.

5. High static water levels listed were recorded on February 3, 1982 for all drillholes.

TABLE X

AVERAGE BREAKBACK OF BENCH CRESTS IN HORNFELS ROCK

AREA OF THE OPEN PIT	STRUCTURAL DOMAIN	AVERAGE BREAKBACK AT CREST OF 10m HIGH BENCH (m)	EQUIVALENT BREAKBACK ANGLE (°)	COMMENTS
North Wall	5B, 5C	3.42	71	
West Wall	5A, 6B	4.50	66	
South Wall (north of South Wall Fault)	5D, 6A	4.88	64	
East Wall	4	2.45	76	Slopes in this area were excavated by controlled blasting techniques

NOTE: The average breakback was calculated from measurement of distance between bench toes and crests for selected locations on the current mining plan (October 1981)

STRUCTURAL DOMAIN	FOLIATION					FOLIATION JOINTS JOINT SET A					JOINTS																	VEINS				
												JOINT SET B				JOINT SET C				JOINT SET D				MISCELLANEOUS JOINT SETS							
	POPULATION	SET	DIP DIRECTION	DIP	%	POPULATION	SET	DIP DIRECTION	DIP	%	POPULATION	SET	DIP DIRECTION	DIP	%	SET	DIP DIRECTION	DIP	%	SET	DIP DIRECTION	DIP	%	SET	DIP DIRECTION	DIP	%	POPULATION	SET	DIP DIRECTION	DIP	%
1 & 2	81	FN1 FN2 FN3	010 002 342	85 63 44	19 15 6	15	A1 A2	001 005	62 45	>35 10	215	B1 B2	352 203	74 88	4 7	-	-	-	-	D1' D2' D3'	316 114 131	59 51 67	7 5 4	G1	340	48	3	-	-	-	-	-
3	43	FN1 FN2	067 083	67 77	21 18	43	A1 A2	067 083	67 77	21 18	88	B1 B2 B3 B4	004 354 002 328	78 74 52 45	10 9 10 6	-	-	-	-	-	-	-	-	E1	051	76	5	-	-	-	-	-
4	138	FN1 FN2	228 056	72 75	16 12	63	A1 A2 A3	225 060 062	67 69 46	16 16 17	570	B1	003	80	7	C1	105	30	7	D1	315	80	6	-	-	-	-	73	V1	358	82	35
5A	111	FN1 FN2	230 221	71 21	17 6	82	A1	229	66	33	400	B1 B2	333 359	86 83	7 6	C1	115	19	6	D1	286	80	6	G1	000	50	2	48	V1 V2	165 181	89 85	22 19
5B	115	FN1	047	77	22	63	A1 A2	047 225	69 16	36 6	342	B1	333	86	12	C1	105	18	9	D1	290	82	6	-	-	-	-	69	V1 V2	336 019	87 83	27 10
5C	104	FN1	229	80	21	16	A1	277	76	27	368	B1 B2 B3	324 344 004	80 85 89	5 6 4	C1	100	32	7	D1	299	86	6	G1	009	43	3	50	V1 V2 V3	331 339 001	79 84 88	17 17 15
5D	42	FN1	041	80	26	12	A1	049	72	>35	91	B1 B2	354 025	72 67	8 5	C1	084	33	7	D1	275	78	8	M1 M2	326 300	50 41	9 7	13	V1 V2	350 020	79 84	>35 31
6A	59	FN1 FN2 FN3	056 823 239	85 83 73	19 13 14	35	A1 A2 A3	057 220 245	83 65 70	18 14 24	228	B1 B2	343 021	70 76	6 6	C1	060	36	5	D1	320	82	4	M1	328	62	4	4	V1 V2	351 024	69 84	6 28
6B	119	FN1	239	71	29	40	A1	235	73	32	243	B1	176	88	6	C1 C2	092 031	32 41	5 6	D1	327	77	4	G1 E1 M1	356 050 172	50 72 40	4 3 3	134	V1	356	90	78

NOTES

1. Orientation is given in terms of dip direction and dip of the peak or average orientation of the discontinuity set.
2. Percent refers to the percent concentration in a one percent area of the lower hemisphere for the peak or average orientation of the population.

TABLE II

R B MINING PTY LIMITED
MT. CARBINE MINE
GEOTECHNICAL STUDIES

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

ORIENTATION OF DISCONTINUITY SETS IN THE OPEN PIT

BY DCM | DATE MAR 82
APPROVED | DWG 358-T2

DESCRIPTION OF DESIGN SECTORS					MAIN MODES OF SLOPE FAILURE WHICH CONTROL SLOPE STABILITY	STABILITY ANALYSIS RESULTS FOR KINEMATICALLY POSSIBLE FAILURE MODES[1,2]								OPTIMUM INTERRAMP SLOPE DESIGN FOR DRY SLOPES BASED ON KINEMATIC ANALYSES RESULTS (SLOPE DESIGN FOR SLOPES WITH HIGH GROUNDWATER PRESSURES ARE GIVEN IN BRACKETS WHERE DIFFERENT)						POSSIBLE INCREASE IN SLOPE ANGLE DUE TO PLAN RADIUS OF CURVATURE (°)	RECOMMENDED INTERRAMP SLOPE DESIGN FOR DRY OR DRAINED SLOPES OR SLOPES WITH ADEQUATE GROUNDWATER DEPRESSURIZATION[4]							DESIGN SECTOR
						AVERAGE DIP OR APPARENT PLUNGE OF FAILURE FOR WORST CASE WHERE STATISTICAL ANALYSIS NOT USED		APPARENT PLUNGE OF WEDGES CORRESPONDING TO A CUMULATIVE PERCENTAGE OF 20%		APPARENT PLUNGE OF WEDGES CORRESPONDING TO THE BREAK IN THE CUMULATIVE FREQUENCY PLOT				BENCH HEIGHT = 20m			BENCH HEIGHT = 30m				BENCH HEIGHT = 20m BETWEEN 305m AND 345m ELEVATION			BENCH HEIGHT = 30 m ABOVE 345m AND BELOW 305m ELEVATION				
DESIGN SECTOR	STRUCTURAL DOMAIN	SLOPE DIP DIRECTION (°)	MAXIMUM SLOPE HEIGHT (m)	NUMBER OF HAULROADS		F=2.0	F=1.2	F=2.0	F=1.2	F=2.0 CUMUL. PERCENT	F=2.0 APPARENT PLUNGE	F=1.2 CUMUL. PERCENT	F=1.2 APPARENT PLUNGE	OPTIMUM BENCH FACE ANGLE (°)	TOTAL BERM WIDTH[3] (m)	INTERRAMP SLOPE ANGLE (°)	OPTIMUM BENCH FACE ANGLE (°)	TOTAL BERM WIDTH[3] (m)	INTERRAMP SLOPE ANGLE (°)		BENCH FACE ANGLE (°)	BERM WIDTH (m)	INTERRAMP SLOPE ANGLE (°)	BENCH FACE ANGLE (°)	BERM WIDTH (m)	INTERRAMP SLOPE ANGLE (°)	REMEDIAL MEASURES AND COMMENTS[5,6,7]	
1-1	1 and 2	012	85	-	Rotational failure in weathered rocks at pit crest. Wedge failures formed by combination of joints of Joint Set A and Joint Set D.	40°	(44°)	58°	54°	15	53°	10	56°	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Statistical analysis and design techniques were not used in Design Sectors 1-1, 2-1 and 3-1 because slope stability is controlled by rotational failure in weathered rocks as well as kinematically possible failure modes. Slope design and remedial measures in this area are discussed in section 8.7.	1-1
2-1	1 and 2	342	85	-	Rotational failure in weathered rocks at pit crest. Plane failures along joints of Joint Set A and Joint Set G.	47	(47)	50	50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		2-1
3-1	3	330	30	1	Rotational failure in weathered rock at pit crest. Plane failure along joints of Joint Set B.	44	(44)	44	44	6	44	6	44	-	-	-	-	-	-	-	-	-	-	-	-	-	-		3-1
4-1	4	214	60	1	Plane failure along joints of Joint SetA. Wedge failures formed by combination of joints of Joint Set A and Joint Set D.	(69)	(69)	69	69	-	-	-	-	80	10.5	55.0	80	14.7	56.3	-	80	10.5	55	80	14.7	56		4-1
4-2	4	258	60	1	Wedge failure formed by combination of joints of Joint Set A and Joint Sets B.	52	56	(52)	(58)	-	-	-	-	80 (70)	12.1 (16.5)	52.1 (50.5)	70 (70)	23.0 (24.7)	52.5 (50.5)	+4°	80	10.5	55	80	14.4	56.5	Slope angle of 55° is recommended for 20m high benches to provide access to the south wall. Drainholes may be required to control groundwater pressures.	4-2
5A-1	5A	097	170	2	Wedge failures formed by combination of joints, faults, shears and veins.	27	42	(36)	(46)	-	-	22	66	70 (70)	19.1 (28.0)	45.9 (35.5)	70 (70)	28.9 (41.4)	46.1 (36.0)	+3°	70	17.4	49	70	26.1	49	Slopes below 305m elevation could be increased to 50° based on increased effects of plan radius of curvature. Horizontal drainholes may be required.	5A-1
5A-2	5A	135	170	1	Wedge failures formed by combination of joints, faults, shears and veins.	34	70	(47)	(70)	-	-	-	-	80 (70)	10.5 (18.7)	55.0 (46.9)	80 (70)	14.2 (28.1)	57.0 (46.9)	-	80	10.5	55	80	19.5	57	Horizontal drainholes may be required in specific areas on benches to control groundwater pressures in the slope.	5A-2
5B-1	5B	166	260	2	Wedge failures formed by combination of joints, faults, shears and veins.	59	76	(75)	76	12	(74)	-	-	80	10.5	55.0	80	12.2	59.7	-	80	10.5	55	80	12.0	60		5B-1
5C-1	5C	178	260	2	Wedge failures formed by combination of joints, faults, shears and veins.	57	80	(79)	(80)	23	79	-	-	80	10.5	55.0	80	12.2	59.7	-	80	10.5	55	80	12.0	60		5C-1
5C-2	5C	197	120	2	Wedge failures formed by combination of joints, faults, shears and veins.	77	77	(84)	(84)	-	-	-	-	80	10.5	55.0	80	12.2	59.7	-	80	10.5	55	80	12.0	60		5C-2
5C-3	5C	270	100	1	Wedge failure formed by combination of joints, faults, shears and veins.	68	68	(71)	(71)	-	-	-	-	80	10.5	55.0	80	13.6	57.8	+5	80	10.5	55	80	12.0	60	Maximum slope angles of 55° are recommend for 20m high benches in this design sector to insure reliable access to the south wall.	5C-3
5C-4	5C	344	50	1	Wedge failures formed by combination of joints, faults, shears and veins.	43	43	(74)	(74)	18	74	17	74	80	10.5	55.0	80	12.2	59.7	-	70	16.7	50	70	25.3	50	Maximum interramp slopes of 50° are recommended below 305m elevation due to sensitive nature of slope in this area and possible requirements for remedial measures.	5C-4
5D-1	5D	344	100	2	Wedge failures formed by combination of joints, faults, shears and veins.	26	40	(48)	(51)	-	-	-	-	70 (70)	16.7 (18.1)	50.1 (47.9)	70 (70)	25.4 (27.5)	49.8 (47.5)	-	70	18.7	47	N/A	N/A	N/A	20m high benches and maximum interramp slope angles of 47° are recommended above the haulroad (300m elevation) in Design Sectors 5D-1 and 6A-1 due to the sensitive nature of the slope and possible requirements for remedial measures. Horizontal drainholes may be required.	5D-1
6A-1	6A	345	60	1	Wedge failures formed by combination of joints, faults, shears and veins.	47	53	(64)	(64)	20	65	20	66	80	11.3	53.5	70	20.9	55.1	-	70	18.7	47	70	25.3	50		6A-1
6A-2	6A	025	120	1	Wedge failures formed by combination of joints, faults, shears and veins.	34	36	(59)	(69)	25	70	16	68	80 (80)	10.5 (12.0)	55.0 (52.2)	80 (70)	14.7 (22.6)	56.3 (53.0)	-	70	17.4	49	70	26.1	49	Interramp slope angles of 49° are recommend in this design sector for blending of slope designs between adjacent design sectors. Horizontal drainholes may be required.	6A-2
6B-1	6B	351	50	1	Plane failure along joints of Joint Set G1. Wedge failures formed by combination of joints, faults, shears and veins.	47	49	(50)	(52)	-	-	-	-	70 (70)	16.5 (17.1)	50.5 (49.5)	70 (70)	24.7 (26.1)	50.5 (49.0)	-	N/A	N/A	N/A	70	25.3	50	Same as comments for Design Sector 5C-4. Horizontal drainholes may be required.	6B-1
6B-2	6B	055	170	2	Wedge failures formed by combination of joints, faults, shears and veins.	27	40	(34)	(46)	-	-	-	-	70 (70)	19.1 (30.7)	45.9 (34.0)	70 (70)	28.9 (44.4)	46.1 (34.0)	+3°	70	17.4	49	70	26.1	49	Slopes below 305m elevation could be increased to 50° based on increased effects of plan radius of curvature. Horizontal drainholes may be required.	6B-2

NOTES

1. Analyses results are presented for F=2.0 and F=1.2 which relate to undewatered and dry, drained or dewatered slopes respectively.
2. The dip or apparent plunge which is considered to control slope stability is circled for both undewatered (F=2.0) and drained (F=1.2) conditions in each design sector.
3. Total berm width is calculated based on berm width required to catch failed material with consideration of anticipated breakback of bench crests.
4. Feasibility of using 30m high benches should be verified by assessment of trial slopes.
5. Control blasting is recommended in all areas of the final slope to ensure minimal disturbance to the rock and maintain cohesion in the slope.
6. If control blasting is not adequate or undue failures occur in certain areas, grouted dowels may be required to ensure the integrity of haulroads or other critical installation.
7. Remedial measures are recommended to control groundwater and surface water. Sealed drainage ditches graded berms and horizontal drainholes are recommended in critical areas as required. If adequate groundwater control is not obtained using drainholes additional hydrogeological studies may be required.

TABLE IX

R. B. MINING PTY LIMITED
MT. CARBINE MINE
GEOTECHNICAL STUDIES

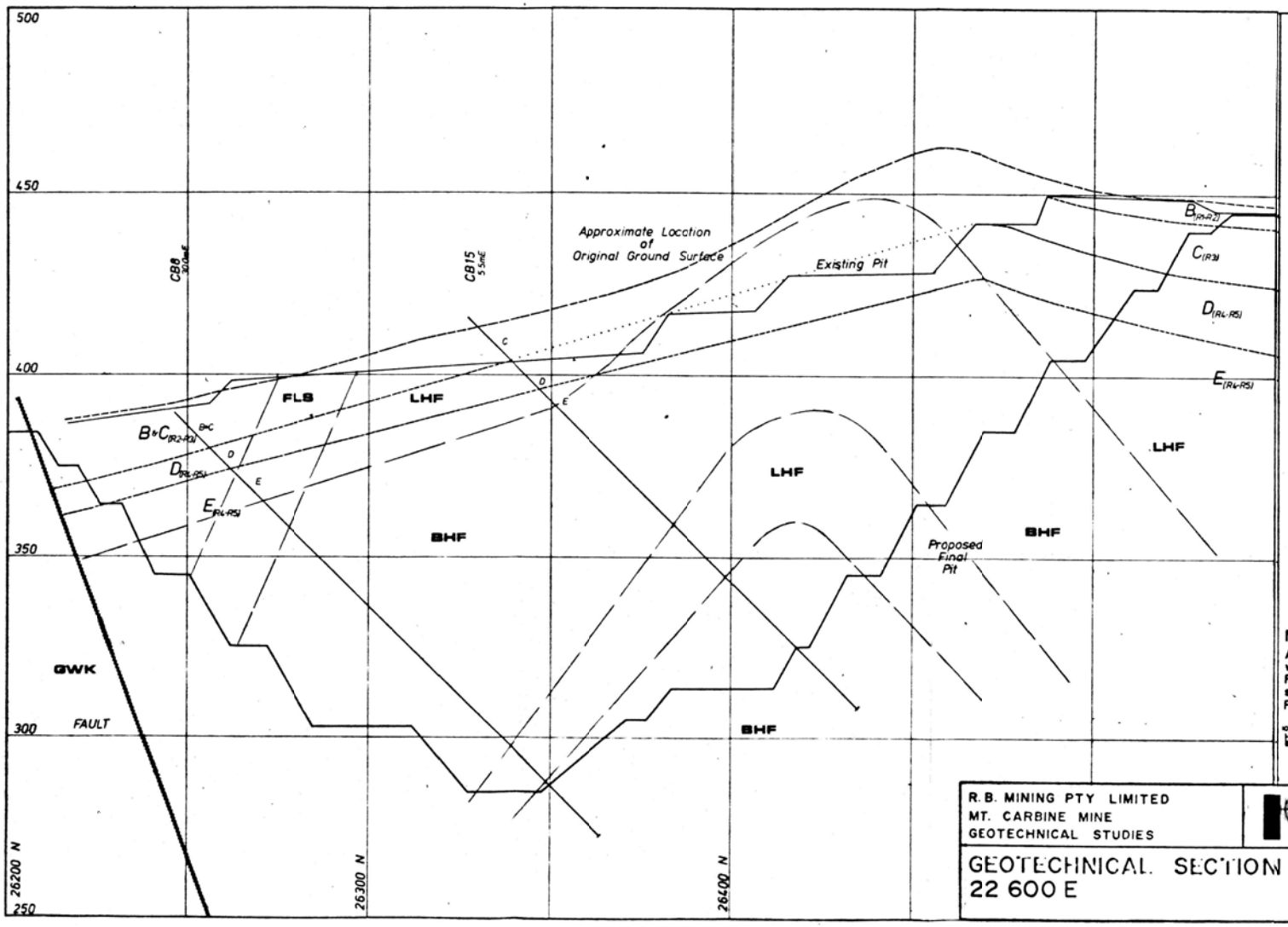
PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

SUMMARY OF SLOPE INFORMATION, STABILITY ANALYSIS RESULTS AND SLOPE DESIGN RECOMMENDATIONS FOR DESIGN SECTORS

BY: D C M
DATE: MAR 82
APPROVED:
DWG: 358-20

APPENDIX A

GEOTECHNICAL SECTIONS



SYMBOLS

Geological contact

Boundary of weathered zones Defined & assumed

Number & location of drillholes showing piezometer installations (•), standpipe installations (•), and piezometric levels for dry & wet seasons — CB21, SI, PI

Proposed location of final pit wall

Estimated piezometric surface

NOTE:
An explanation of rock types, weathering, & hardness is given in Figs. 1, 2, & 9. An explanation of symbols on this drawing is given in Figs. 1 & A-1.

-40 -30 -20 -10 0 10 20 30 40 50 m
SCALE

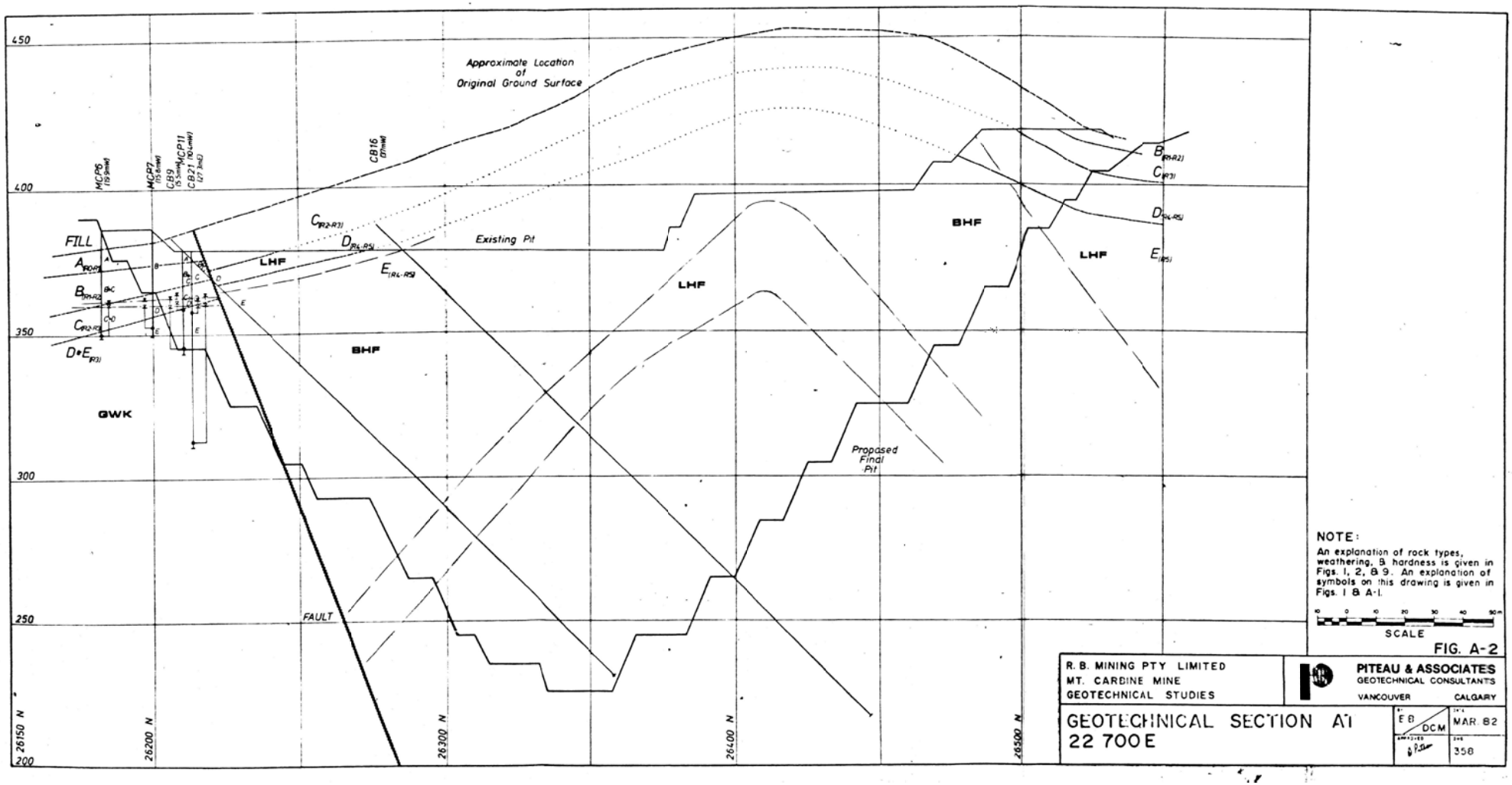
FIG. A-1

R.B. MINING PTY LIMITED
MT. CARBINE MINE
GEOTECHNICAL STUDIES

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

GEOTECHNICAL SECTION A1
22 600 E

EB / DCM	MAR. 82
APPROVED	358



NOTE:
An explanation of rock types, weathering, & hardness is given in Figs. 1, 2, & 9. An explanation of symbols on this drawing is given in Figs. 1 & A-1.

SCALE

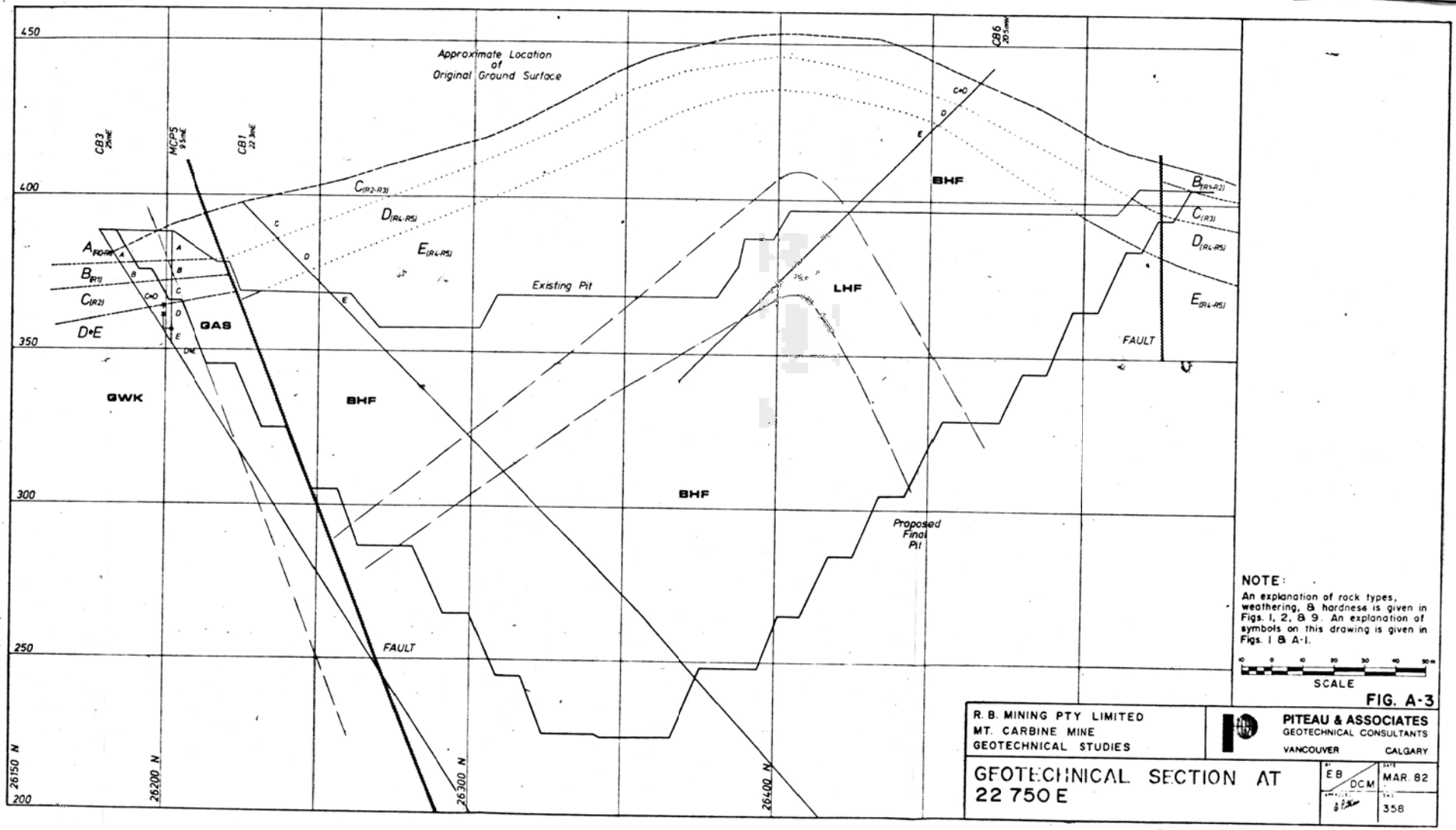
FIG. A-2

R. B. MINING PTY LIMITED
MT. CARBINE MINE
GEOTECHNICAL STUDIES

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

GEOTECHNICAL SECTION A1
22 700E

BY: EB / DCM
DATE: MAR. 82
APPROVED:
JOB: 358



NOTE:
An explanation of rock types, weathering, & hardness is given in Figs. 1, 2, & 9. An explanation of symbols on this drawing is given in Figs. 1 & A-1.

SCALE

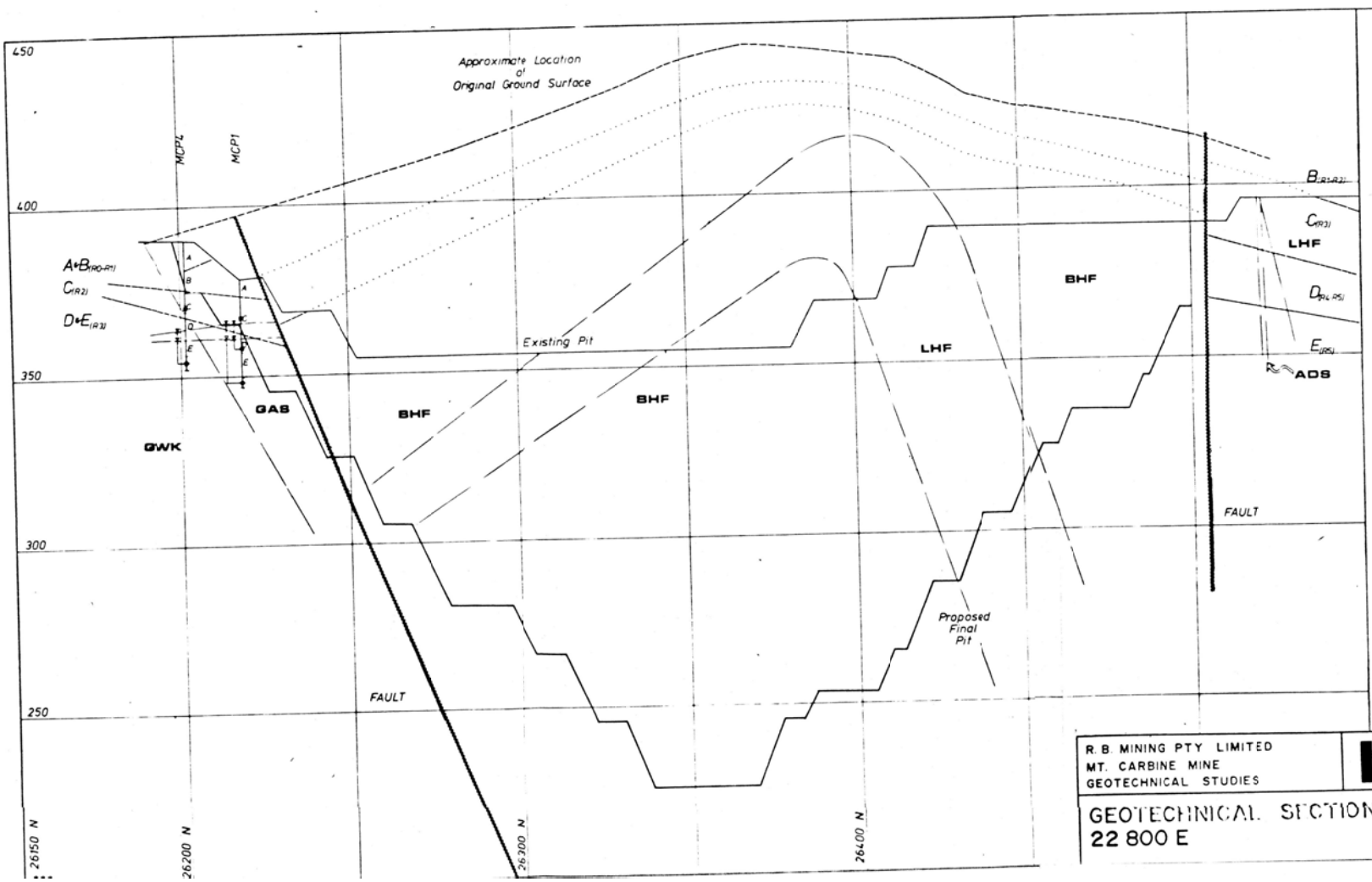
FIG. A-3

R. B. MINING PTY LIMITED
MT. CARBINE MINE
GEOTECHNICAL STUDIES

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

GEOTECHNICAL SECTION AT 22 750 E

BY: E.B / DCM
DATE: MAR. 82
JOB: 358



NOTE:
An explanation of rock types, weathering, & hardness is given in Figs. 1, 2, & 9. An explanation of symbols on this drawing is given in Figs. 1 & A-1.

SCALE

FIG. A-4

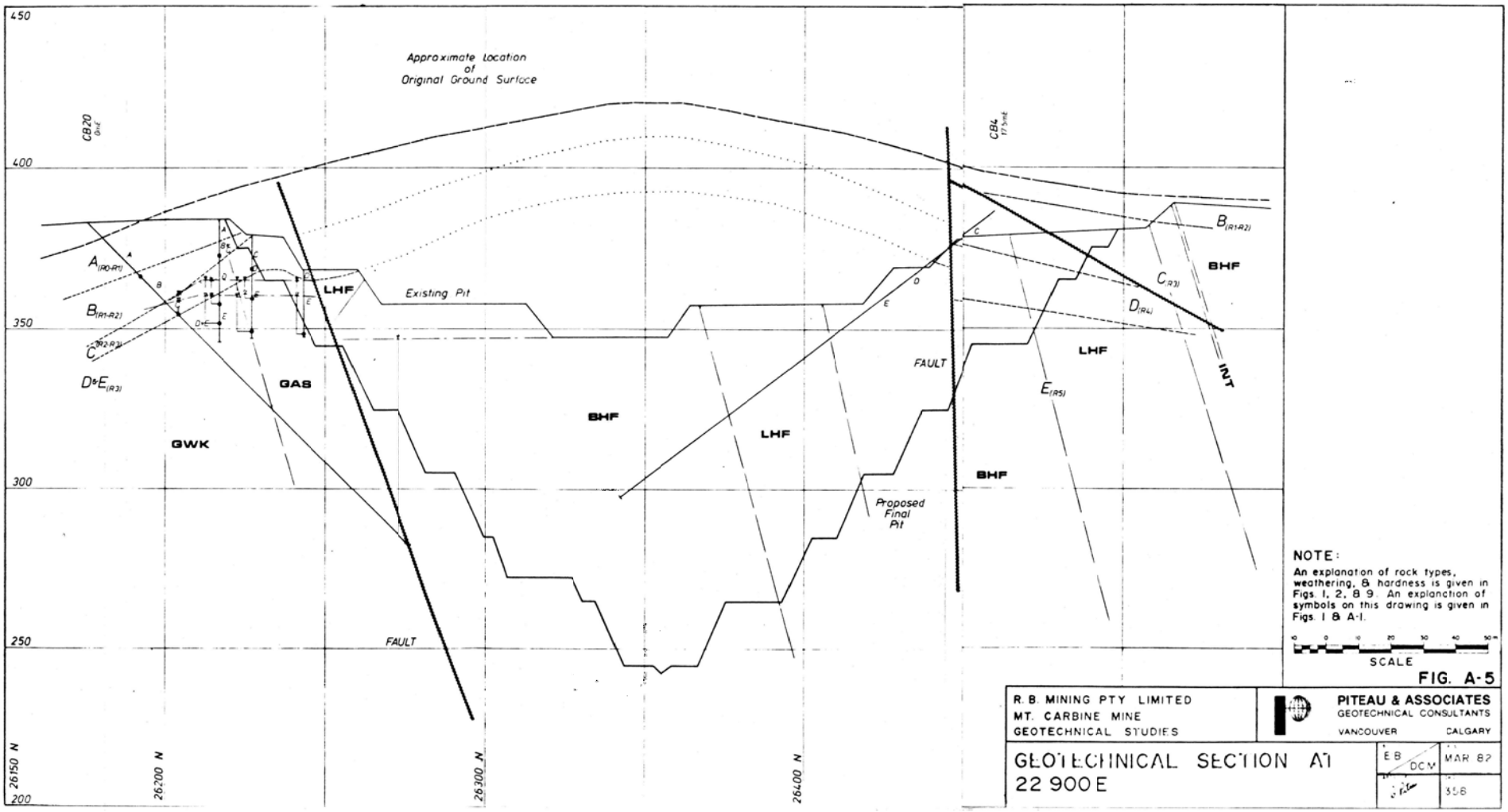
R.B. MINING PTY LIMITED
MT. CARBINE MINE
GEOTECHNICAL STUDIES

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

GEOTECHNICAL SECTION AT 22 800 E

EB DCM MAR 82

358



NOTE:
An explanation of rock types, weathering, & hardness is given in Figs. 1, 2, & 9. An explanation of symbols on this drawing is given in Figs. 1 & A-1.

SCALE

FIG. A-5

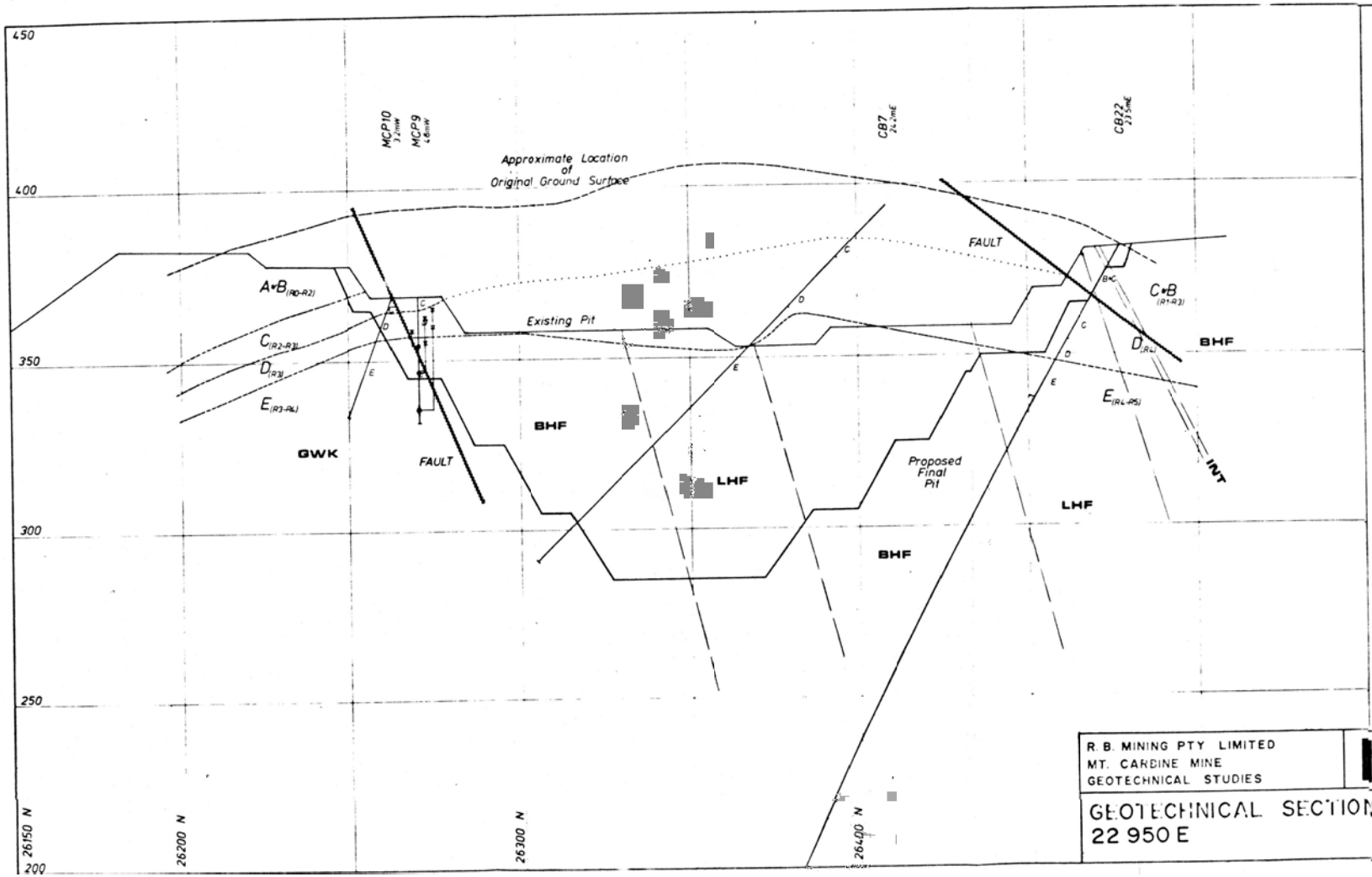
R.B. MINING PTY LIMITED
MT. CARBINE MINE
GEOTECHNICAL STUDIES

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

GEOTECHNICAL SECTION A1
22 900 E

E.B. DCM MAR 82

356



NOTE:
An explanation of rock types, weathering, & hardness is given in Figs. 1, 2, & 9. An explanation of symbols on this drawing is given in Figs. 1 & A-1.

SCALE

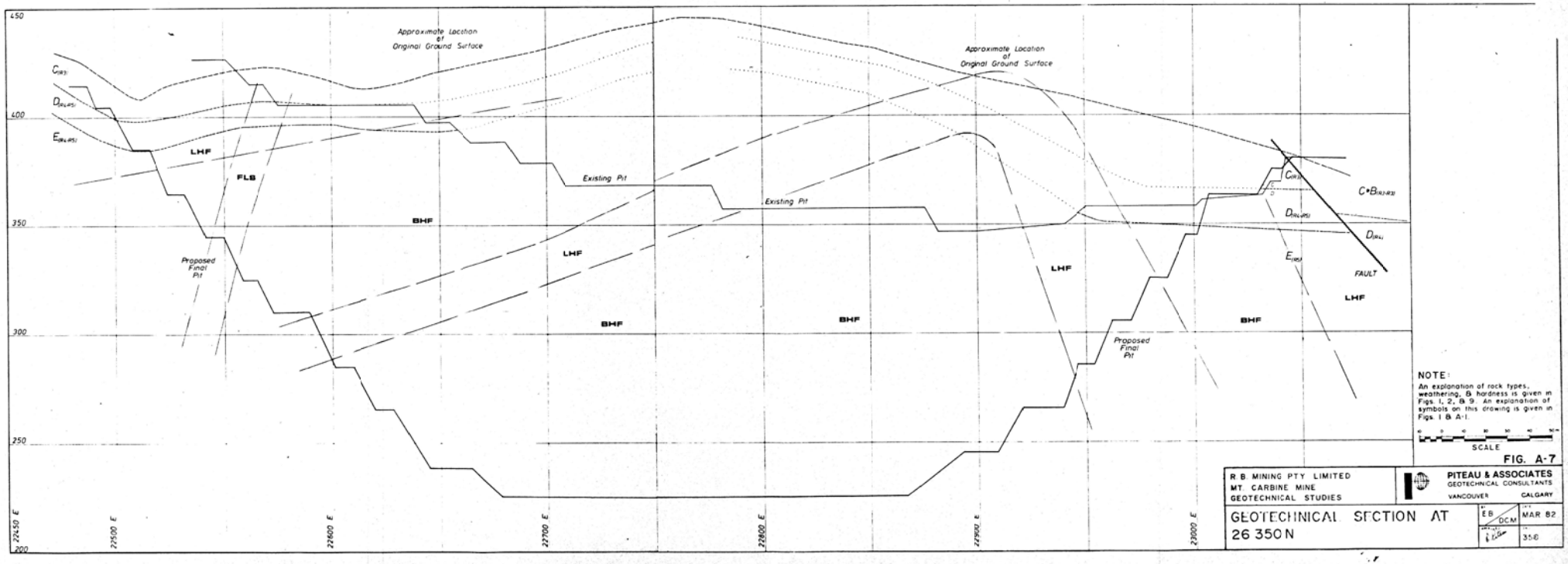
FIG. A-6

R. B. MINING PTY LIMITED
MT. CARBINE MINE
GEOTECHNICAL STUDIES

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

GEOTECHNICAL SECTION AT 22 950 E

E B / DCM	MAR 82
	358



NOTE:
An explanation of rock types, weathering, & hardness is given in Figs. 1, 2, & 9. An explanation of symbols on this drawing is given in Figs. 1 & A-1.

SCALE

FIG. A-7

R.B. MINING PTY. LIMITED
MT. CARBINE MINE
GEOTECHNICAL STUDIES

PITEAU & ASSOCIATES
GEOTECHNICAL CONSULTANTS
VANCOUVER CALGARY

GEOTECHNICAL SECTION AT 26 350 N

BY EB/DCM | DATE MAR 82
APPROVED | No. 356

APPENDIX B

PERCUSSION DRILL LOGS

DRILLING REPORT

DRILL ROTATION
24 RPM

CO-ORDINATES
26218.7 N
22817.5 E
378.8 RL

HOLE No. MCP - 1
PROJECT MT. CARBINE
LOCATION SOUTH 375
JOB No. 81 - 358
DATE 12.09.81

DRILLING DATA

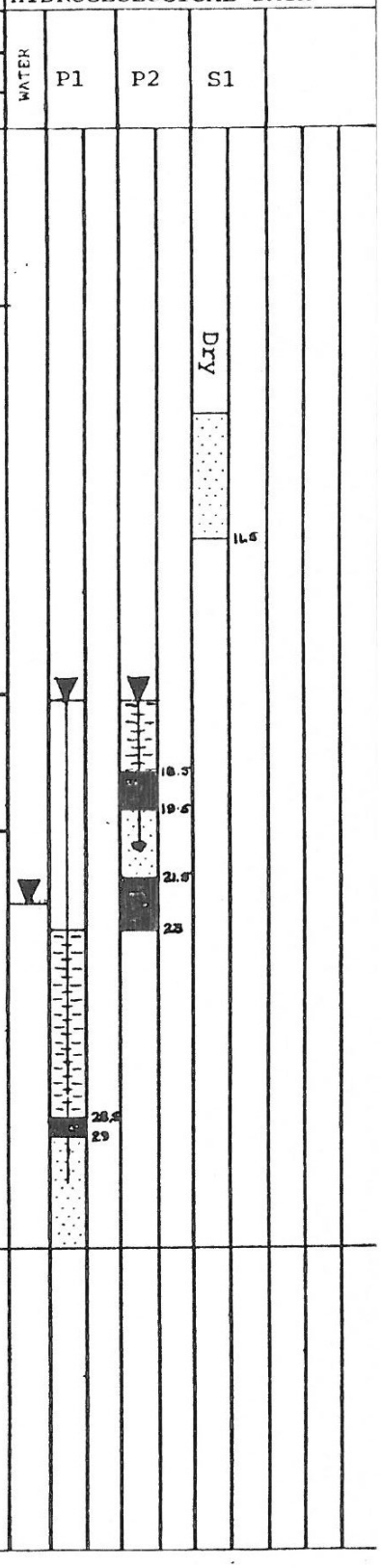
CLIENT

Elevation Ground/Collar

Water Level

DEPTH IN METERS	DOWN PRESSURE	TIME FOR 2m RUN	RQI	SAMPLE LOCATION	WEATHERING	DESCRIPTION OF MATERIAL
2	100	-			A	On to 5m - Moderately to highly weathered schistose chips
4		130		X		
6		95			C	5m to 16m - Moderately weathered schistose chips - Chip surfaces weathered but rock unaltered
8		135		X		
10		140				
12		160		X		
14		150				
16		180		X		
18		120			D	16m to 20m - Slightly weathered laminated schist
20		140		X		
22		195			E	20m to 32m - Unweathered laminated schist with quartz fragments
24		190		X		
26	O	170				
28		190		X		
30		220				
32		210		X		END OF HOLE
34						
36						
38						
0						

HYDROGEOLOGICAL DATA



DRILLING REPORT

DRILL ROTATION 24 RPM	CO-ORDINATES 26228.5 N 22880.0 E 379.3 RL	HOLE No. MCP - 2 PROJECT MT. CARBINE LOCATION SOUTH 375 JOB No. 81 - 358 DATE 12.09.81

CLIENT

Elevation Ground/Collar

Water Level

DRILLING DATA

DEPTH IN METERS	DOWN PRESSURE	TIME FOR 2m RUN	FQI	SAMPLE LOCATION	WEATHERING
2	100	90			
4		105		X	C
6		90			
8		100		X	
10		90			
12		95		X	D
14		102			
16		145		X	
18		153			
20	500	146		X	
22		195			E
24		180		X	
26	0	170			
28		192		X	
30		218			
32		200		X	
34					
36					
38					
40					

DESCRIPTION OF MATERIAL

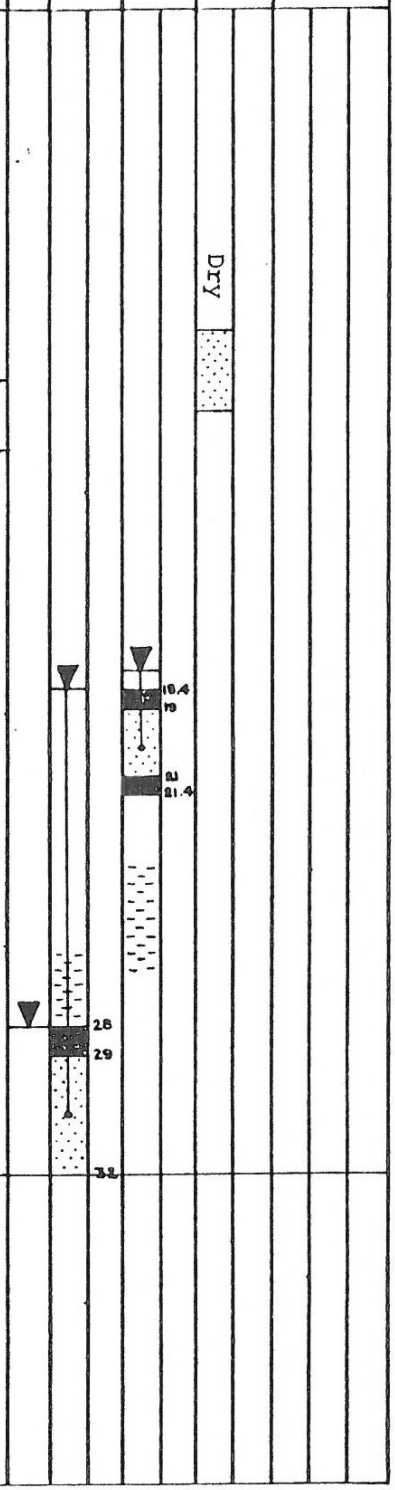
0m - 10m - Moderately weathered laminated schist.
- Strength Affected.

10m to 12m - Slightly weathered laminated schist

12m to 32m - Unweathered grey laminated schist.
- Unsilicified

END OF HOLE

HYDROGEOLOGICAL DATA



DRILLING REPORT

DRILL ROTATION	CO-ORDINATES	HOLE No. MCP - 3
24 RPM	26218.3 N 22879.3 E 383.4 RL	PROJECT MT. CARBINE LOCATION SOUTH 385 JOB No. 81 - 358 DATE 12.09.81

CLIENT

Elevation Ground/Collar

Water Level

DRILLING DATA						DESCRIPTION OF MATERIAL	HYDROGEOLOGICAL DATA
DEPTH IN METERS	DOWN PRESSURE	TIME FOR 2m RUN	RQI	SAMPLE LOCATION	WEATHERING		WATER / P1 / P2 / S1
2	100	90				0m to 6m - Yellow brown fine grained powder - A few chips - Extremely weathered	
4		130		X	A		
6		93					
8		157		X X	B + C	6m to 12m - Moderately weathered siliceous laminated rock chips - Green	S1: Dry
10		124		X			
12		105		X		12m to 22m - As above but slightly weathered	
14	500	105					
16		104		X			
18		147			D	19m - Moderately weathered seam, 0.2m wide	
20		137		X			
22	100	225					
24		214		X		22m to 36m - Slightly weathered to unweathered finely laminated chips of green siliceous rock	P2: 23.4, 26, 28, 29
26		250					
28		262		X			
30		223			E		P1: 31, 34
32		250		X			
34		220					
36		235		X		END OF HOLE	
38							
40							

DRILLING REPORT

DRILL ROTATION
24 RPM

CO-ORDINATES
26202.7 N
22808.0 E
389.6 RL

HOLE No. MCP - 4
PROJECT MT. CARBINE
LOCATION SOUTH 385 CREST
JOB No. 81 - 358
DATE 12.09.81

CLIENT

Elevation Ground/Collar

Water Level

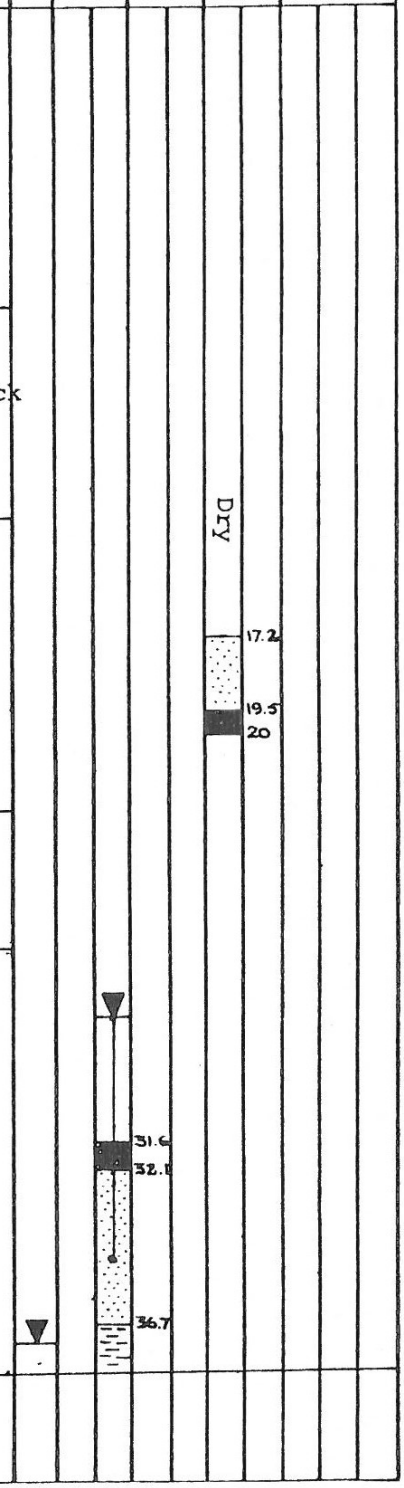
DRILLING DATA

HYDROGEOLOGICAL DATA

DEPTH IN METERS	DOWN PRESSURE	TIME FOR 2m RUN	RQI	SAMPLE LOCATION	WEATHERING	DESCRIPTION OF MATERIAL
2	100	75			A	0m to 8m - Extreme to highly weathered schistose rock - Yellow-brown
4		64		X	+	- Areas of both siliceous and nonsiliceous rock
6		67			B	
8		61		X		
10		90				8m to 14m - Highly weathered siliceous and non-siliceous schistose rock
12		104		X	B	
14		113				
16		104		X		14m to 22m - Moderate to slightly weathered schistose rock - Varying degrees of silicification
18		116			C	
20		115		X		
22	0	181				
24		184		X	D	22m to 26m - Grey laminated cherty rock - Similar to LHR
26		180				
28		345		X		26m to 38m - Unweathered green slightly laminated cherty rock with quartz chips - Similar to MCP-3 and GHR
30		266				
32		230		X	D + E	
34		180				
36		205				
38		180				END OF HOLE
40						

HYDROGEOLOGICAL DATA

WATER	P1	P2	S1
			DRY



Sheet ____ of ____

DRILLING REPORT

DRILL ROTATION

24 RPM

CO-ORDINATES

26202.4 N
22759.8 E
389.3 RL

HOLE No.	MCP-5
PROJECT	MT. CARBINE
LOCATION	SOUTH 385 CREST
JOB No.	81-358
DATE	12.9.81

CLIENT

Elevation Ground/Collar

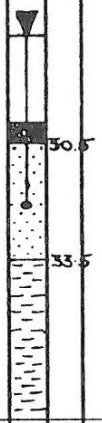
Water Level

DRILLING DATA

HYDROGEOLOGICAL DATA

DEPTH IN METERS	DOWN PRESSURE	TIME FOR 2m RUN	RQI	SAMPLE LOCATION	WEATHERING	DESCRIPTION OF MATERIAL
2	100	81				Om to 10m - Extremely weathered reddish brown chips. - Not identifiable
4		105		X		
6		71			A	
8		155		X		
10		165				
12		95		X		10m to 16m - Highly weathered schistose rock. - Not very siliceous
14		107			B	
16		119		X		
18		117				16m to 24m - Moderately to highly weathered siliceous rock chips
20		119		X	C	
22		102				
24		116		X		
26		105				24m to 30m - Moderate to slight weathered grey green siliceous chips
28		117			D	
30		118		X		
32	0	177		X		30m to 38m - Unweathered grey green siliceous rock chips - Less silicified than other rocks
34		160			E	
36		151				
38		142		X		
40						END OF HOLE

WATER	P1	P2	S1



Sheet ---------- of ----------

DRILLING REPORT

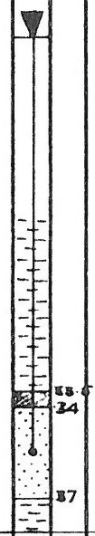
DRILL ROTATION	24 RPM
CO-ORDINATES	26180.3 N 22680.1 E 385.3 RL
HOLE No.	MCP-6
PROJECT	MT. CARBINE
LOCATION	COARSE ORE STOCKPILE
JOB No.	81-358
DATE	12.9.81
CLIENT	
Elevation Ground/Collar	
Water Level	

DRILLING DATA

DEPTH IN METERS	DOWN PRESSURE	TIME FOR 2m RUN	RQI	SAMPLE LOCATION	WEATHERING	DESCRIPTION OF MATERIAL
2						0m to 5m - Rock fill - Clay used to stabilize hole
4						
6						
8	100	77				5m to 14m - Highly weathered schist mixed with chips of host rock. - Sample probably erroneous due to fill
10		75		X	A	
12		85				
14		70		X		
16		88		X		14m to 26m - Moderatley to strongly weathered green argillite schist
18		77			B	
20		97		X	+ C	
22		82				
24		92		X		
26		115				
28		89		X		26m to 35.5m - Moderately to slightly laminated schistose rock. - Only slightly siliceous
30		?			D	
32		104		X		
34		95				
36		105			D + E	35.5m to 37.5m - Slightly weathered siliceous laminted chips.
38		90				END OF HOLE
40						

HYDROGEOLOGICAL DATA

WATER	P1	P2	S1



Sheet ____ of ____

DRILLING REPORT

DRILL ROTATION	20 RPM
CO-ORDINATES	26199.3 N 22684.2 E 385.7 RL
HOLE No.	MCP-7
PROJECT	MT. CARBINE
LOCATION	SOUTH WEST 385 CREST
JOB No.	81-358
DATE	13.9.81
CLIENT	
Elevation Ground/Collar	
Water Level	

DEPTH IN METERS	DOWN PRESSURE	TIME FOR 2m RUN	RQI	SAMPLE LOCATION	WEATHERING	DESCRIPTION OF MATERIAL
2	0	78				0m to 5m - Rock Fill
4		75				
6		100			B	5m to 16m - Highly weathered siliceous rock in very small fragments
8		95		X		
10		64				
12		94		X		
14		90				
16		70		X		
18		89			C	16m to 25m - Moderately weathered siliceous rock. - 5% white quartz
20		113				
22		105				
24		107		X		
26	200	105			D	25m to 30m - Slightly weathered laminated siliceous - A few quartz fragments with sulfide min.
28		135		X		
30		213				
32		198		X	E	30m to 37m - Unweathered siliceous cherty rock - Laminated blue-grey. - 5% quartz with sulfides
34		195				
36		203				
				X		END OF HOLE
38						
40						

HYDROGEOLOGICAL DATA

WATER	P1	P2	S1



DRILLING REPORT

DRILL ROTATION

CO-ORDINATES
26244.7 N
22882.4 E
368.9 RL

HOLE No.	MCP - 8
PROJECT	MT. CARBINE
LOCATION	SOUTH 365
JOB No.	81-358
DATE	13.9.81

CLIENT

Elevation Ground/Collar

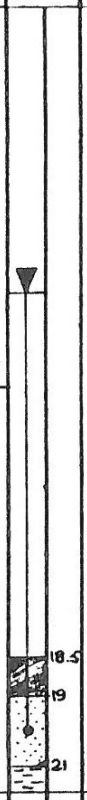
Water Level

DRILLING DATA

HYDROGEOLOGICAL DATA

DEPTH IN METERS	DOWN PRESSURE	TIME FOR 2m RUN	RQI	SAMPLE LOCATION	WEATHERING	DESCRIPTION OF MATERIAL
2	200	83			C + D	0m to 4m - Slightly to Moderately grey schist
4		90		X		
6		104				4m to 21.5m - Unweathered grey to schistose chips with pyrite. - Slightly siliceous
8		130		X		
10		100				
12		105		X		
14		146			E	
16		145		X		
18		140				
20		135		X		
22		140				END OF HOLE
24						
26						
28						
30						
32						
34						
36						
38						
40						

WATER: 2.5 gpm



DRILLING REPORT

DRILL ROTATION

CO-ORDINATES
26271.4 N
22945.6 E
369.2 RL

HOLE No.	MCP - 9
PROJECT	MT. CARBINE
LOCATION	SOUTH 365 —
JOB No.	81-358
DATE	13-9-81

CLIENT

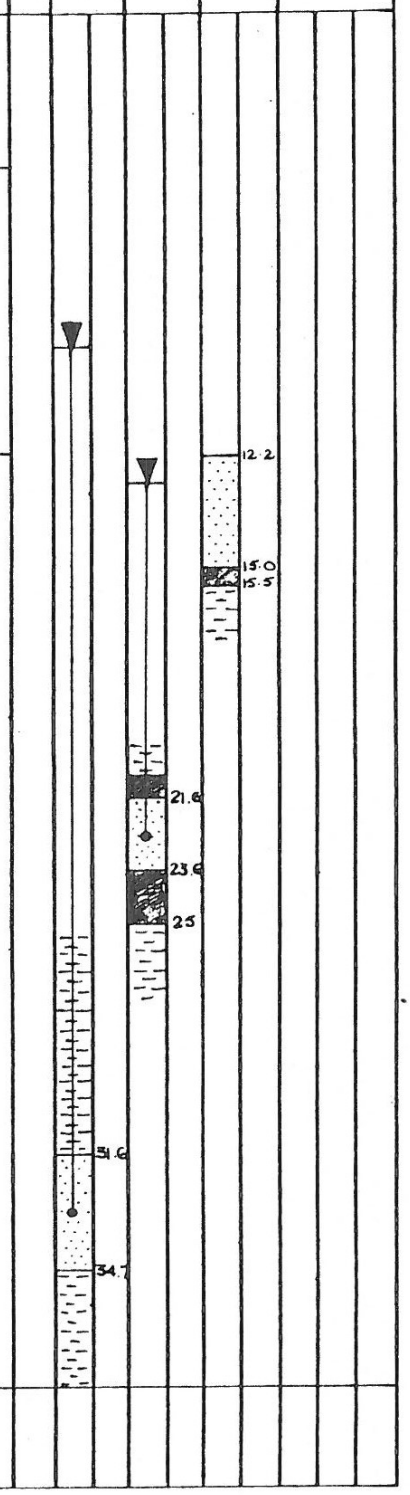
Elevation Ground/Collar

Water Level

DRILLING DATA

HYDROGEOLOGICAL DATA

DEPTH IN METERS	DOWN PRESSURE	TIME FOR 2m RUN	RQI	SAMPLE LOCATION	WEATHERING	DESCRIPTION OF MATERIAL
2	200	-				
		180			C	0m to 4m - Moderately weathered laminated Host rock
4				X		
		174				
6						4m to 12m - Slightly weathered laminated to massive greenish Host rock
		194				
8				X	D	
		173				
10						
	100	160				
12				X		
		150				12m to 38m - Hard grey siliceous horfels rock
14						
		185				
16				X		
		153				17.5m - Rods drop 0.1m - Fault?
18						
		153				
20				X		
		180				
22						
		170				
24				X	E	
		164				
26						
		196				
28				X		
		180				
30						
		185				
32				X		
		198				
34						
		190				
36						
		100				
38				X		END OF HOLE
40						



DRILLING REPORT

DRILL ROTATION 24 - 26 RPM	CO-ORDINATES 26264.1 N, 22946.9 E, 368.9 RL	HOLE No. MCP-10
		PROJECT MT. CARBINE
BEARING: 180° INCL: 70°		LOCATION SOUTH 365
		JOB No. 81-358
		DATE 13-9-81

CLIENT

Elevation Ground/Collar

Water Level

DRILLING DATA						DESCRIPTION OF MATERIAL	HYDROGEOLOGICAL DATA				
DEPTH IN METERS	DOWN PRESSURE	TIME FOR 2m RUN	RQI	SAMPLE LOCATION	WEATHERING		WATER	P1	P2	S1	
2	200	120				0m to 5m - Moderately weathered siliceous rock					
		155			C						
4				X							
		133				5m to 14m - Grey to black siliceous Host rock. - Unweathered					
6											
		134									
8				X							
		-			E						
10											
		148									
12				X							
		148									
14											
		138				14m to 36m - Grey to black schistose rock, less cherty					
16				X							
		161									
18											
		161									
20				X							
		170									
22											
	150	167									
24				X							
		170			E						
26											
		198									
28				X							
		192									
30											
		191									
32				X							
		170									
34											
		142									
36				X		END OF HOLE					
38											
40											

DRILLING REPORT

DRILL ROTATION

CO-ORDINATES
26210.3 N
22689.6 E
378.8 RL

HOLE No.	MCP-11
PROJECT	MT. CARBINE
LOCATION	SOUTH WEST 375
JOB No.	81-358
DATE	13-9-81

CLIENT

Elevation Ground/Collar

Water Level

DRILLING DATA

HYDROGEOLOGICAL DATA

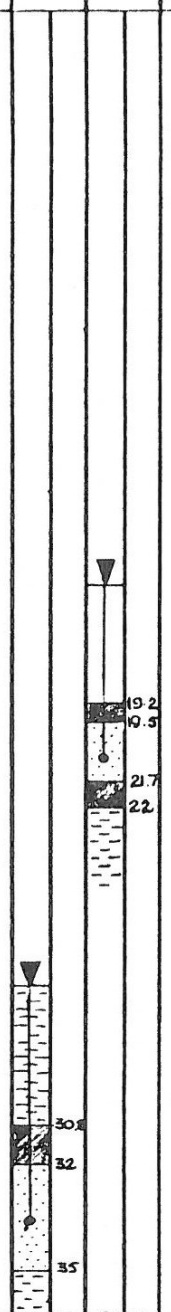
DEPTH IN METERS	DOWN PRESSURE	TIME FOR 2m RUN	RQI	SAMPLE LOCATION	WEATHERING	DESCRIPTION OF MATERIAL
2	200	58			A	0m to 4m - Highly weathered siliceous rock
		73				
4				X		
		77				4m to 16m - Moderate to highly weathered siliceous rock
6						
		74			B + C	
8				X		
		84				
10						
		88				
12				X		
		93				
14						
		125				
16				X		
		91			C + D	16m to 20m - Slightly to moderately weathered siliceous rock
18						
		132				
20				X		
		155				20m to 26m - Unweathered laminated siliceous rock
22						
		170				
24				X		
		157				
26						
		135				
28				X	E	
		128				
30						
		124				
32				X		
		119				
34						
		148				
36				X		END OF HOLE
38						
40						

WATER

P1

P2

S1



APPENDIX C

DESCRIPTION OF THE CUSUMS TECHNIQUE

Reprinted from STABILITY OF ROCK SLOPES
Thirteenth Symposium on Rock Mechanics
ASCE / Urbana, Illinois / August 30–September 1, 1971

CUMULATIVE SUMS TECHNIQUE: A NEW APPROACH TO ANALYZING JOINTS IN ROCK

By Douglas R. Piteau* and Lindsay Russell**

SYNOPSIS

The cumulative sums technique for analyzing joints in rock was developed as part of an extensive slope stability study of Nchanga pit. It was used successfully to determine the joint orientation trends, the pattern of their behavior and whether the joint information could be extrapolated to other areas in which slopes are proposed. This technique is illustrated with reference to the Nchanga study.

INTRODUCTION

The cumulative sums technique for analyzing joints in rock was developed as part of an extensive slope stability analysis of the hanging-wall of the Nchanga open pit in Zambia. This technique was used successfully to define the characteristic features of the joints, most particularly to determine the pattern of their behavior from one part of the Nchanga syncline, where the pit is situated, to the other. A description of cumulative sums technique is

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given with particular reference to the joint analysis of the Nchanga pit.

Basically, the cumulative sums technique was developed to analyze the joint trends in a more definitive manner. This technique led to a better understanding of the genetic relationship of the joints occurring within the overall synclinal structure. Ultimately, predictions were made as to whether the joint data acquired from the existing hanging-wall pit face could be extrapolated (a) to an area some 300 ft behind the existing hanging-wall face, where the final slope is to be located and (b) to areas east of the existing face, where the pit is to be extended another mile.

The Nchanga syncline is approximately one and one quarter miles wide and seven miles long. The Nchanga open pit is located in the southern half of the western limits of the syncline, which consists of a clearly defined sequence of mainly sedimentary rocks (i.e. argillite, siltstones, shale, sandstone, etc). The sediments strike roughly east-west. The south limb dips between 20^{o} N to 35^{o} N, and the north limb dips steeply to the south, forming an asymmetrical synclinal structure with an axial plane dipping steeply north. The syncline plunges between 5^{o} and 15^{o} to the west.

The overall approach to the structural analysis of the hanging-wall slopes was basically straightforward [Piteau (6)]. Discontinuities in the rock were systematically measured along over three miles of benches, using the continuous detail line survey method as described by Piteau (5). The joint data were statistically analyzed, initially using rectangular, histogram, cumulative sums and other analysis methods to determine their nature and distribution. For purposes of this discussion "joint" is meant to include any naturally-occurring structural discontinuity in the rock

mass.

CONSIDERATION OF THE ROCK MASS JOINT MODEL

An objective of the joint analyses is to obtain a schematized concept or model of the joints in the rock mass and to establish certain criteria which indicate where this model changes. Also, one seeks to establish confidence limits in areas where the model is considered to apply, regardless of whether it is in areas of extensive, limited or no sampling.

When designing open pit slopes on a rational basis, an important, if not the most important, consideration in most geological environments is the determination of the attitude, geometry and spatial distribution of the joints in the boundary of the proposed excavation. Thus, for purposes of rationally analyzing a rock slope, such a study must be dependent upon assessing three main factors, namely (1) the nature and structural arrangement of the joints; (2) the strength parameters of the joints; and (3) their relationships to possible failure surfaces. Based on this approach, the geological factors and certain geological premises are given by Piteau (4) and (5), methods of structural interpretation by Robertson (8) and mathematical theories for stability calculations by Jennings (3). This discussion deals exclusively with assessment of factor (1).

Of the three factors listed above, the first is the most important, as the two others are of little consequence if the structural interpretation, and hence the jointing model of the rock mass, does not represent the actual situation in a statistical sense. The first requirement of the model, whether it is of a physical, graphical or mathematical nature, is that it be true, and that a statistical sampling of any property will give a representative picture of the whole situation. The second is that any calculations

made for a representative portion or section of the model apply to the model as a whole.

Thus, on the basis of the jointing model, and with due consideration of the strength parameters and kinematically possible failure modes for that particular structural situation, the stability of the slope can be theoretically determined [Jennings (3)].

CONSIDERATIONS AT NCHANGA LEADING TO THE DEVELOPMENT OF THE CUMULATIVE SUMS TECHNIQUE

The present dimensions of the pit are 9,600 ft along strike, but will extend, eventually, along strike for three miles, after the extension of the pit eastwards is completed. It is presently approximately 2,500 ft wide at its present depth of 750 ft. However, it is planned to go to 1,000 ft, and possibly even to 1,200 ft depth, the result being a final width of about 3,000 ft.

The structural mapping was conducted on the hanging-wall face of the pit. The problem involved trying to determine whether the same or a different structural situation can be expected to exist in the hanging-wall slope when the final depth of 1,000 ft is achieved. The final hanging-wall slope will be at least 300 ft farther in from the existing face as the pit is advanced northwards. The existing and approximate final locations of the hanging-wall, along with some salient geological features, are shown in Fig. 1.

A print-out of the raw joint data representing greater than 3,000 joints from the hanging-wall is shown in a rectangular plot in Fig. 2. Horizontal rows indicate similar angle of dip, whereas vertical rows on the upper half and lower half of the plot indicate joints with similar direc-

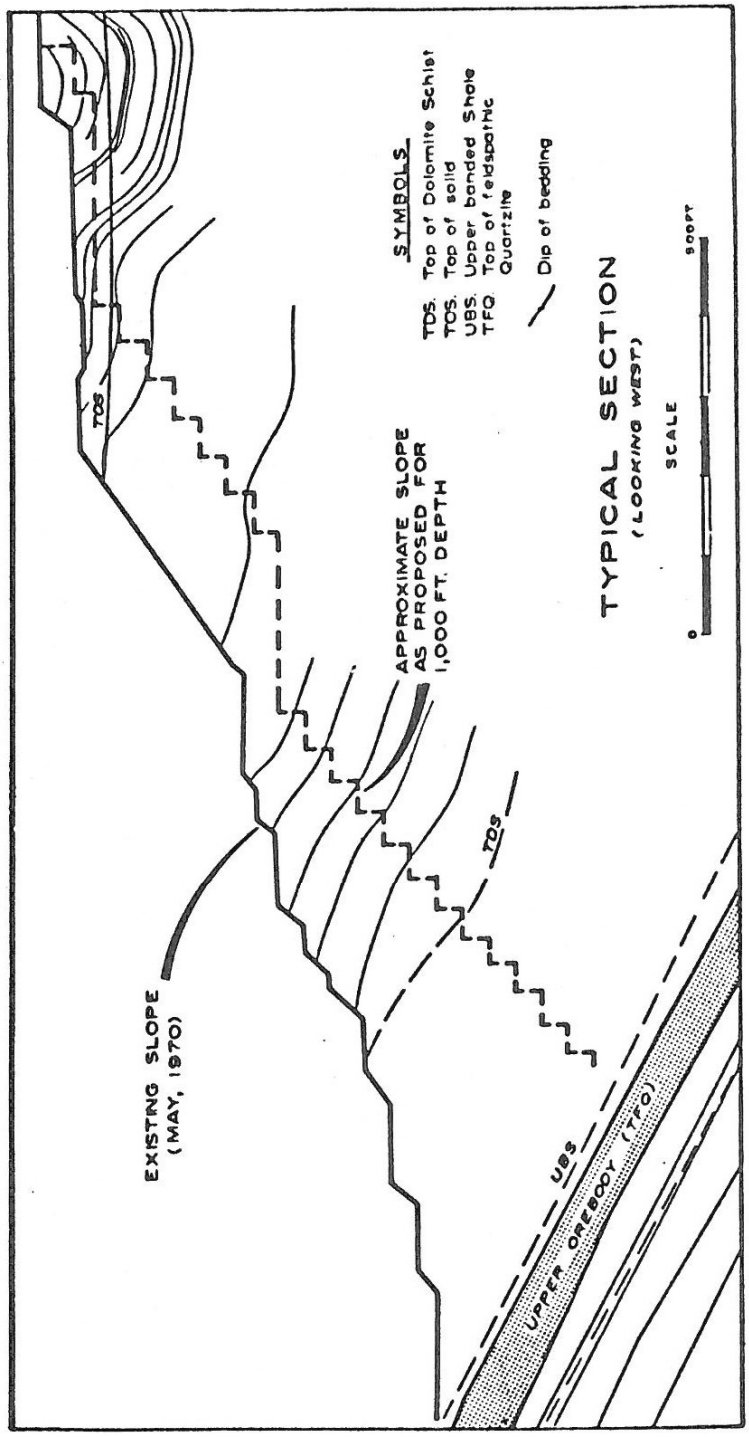


Fig. 1 Typical geological section (looking west), showing the existing and approximate final location of the Nchanga pit hanging-wall.

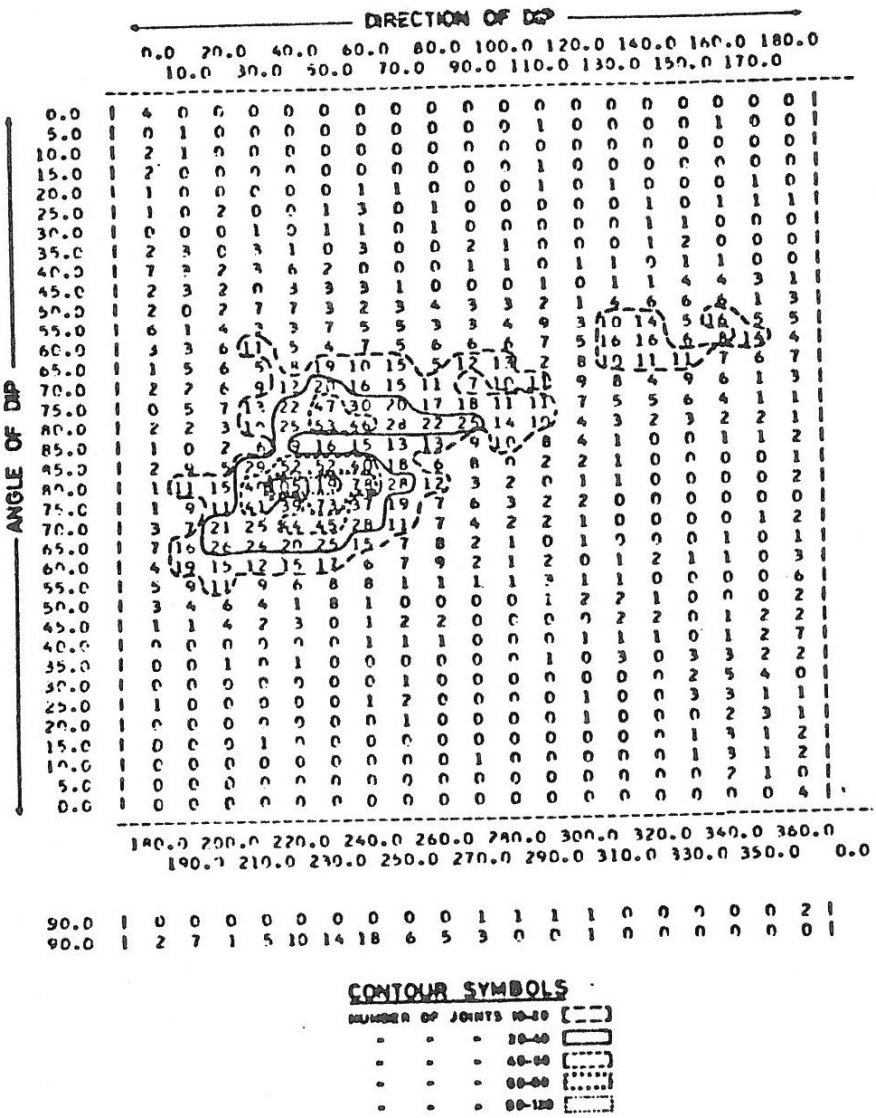


Fig. 2 Rectangular plot showing the distribution of raw joint data from Nchanga north face

tion of dip* /Robertson (8)7. It can be seen that about 70 percent of the joints are highly concentrated, occurring within a direction of dip interval of 50° (i.e. between 20° and 70°, and 200° and 250° in the upper and lower halves, respectively), and within an angle of dip interval of 55° (i.e. between 70° and 90°, and 65° and 90° in the upper and lower halves, respectively). That is, the peak concentration of these joints is centred about a strike of approximately 310°, and they dip steeply both to the northeast and southwest.

Detailed examinations of drag, monoclinal and major recumbent folds, both locally and at other points around the syncline, revealed that their axial planes were in fact striking about 300° to 310°, and not east-west, as might be expected from the approximately east-west orientation of the Nchanga syncline proper. From the results in Fig. 2 it can be seen that the peak concentration of the joints approximately parallel this tectonic fold axis.

Further study indicated that the topography of underlying basement granite dome structures to a large extent controlled the overall synclinal shape and did not control the tectonic fold process proper. For purposes of extrapolation and, ultimately, for assessing the significance of the joints with respect to slopes developed at different locations in the syncline, a more definitive knowledge of the joint behavior in regards to both dip and strike trends was required.

---

* Direction of dip of a joint is the strike plus or minus 90°, depending upon whether the joint dips in a clockwise or counter-clockwise direction.

THE CUMULATIVE SUMS TECHNIQUE

GENERAL FEATURES

Cumulative sums, or "cusums" as they are also called, have been used extensively in industrial quality control [Woodward and Goldsmith (9)]. They have also been used for studying long-term trends in natural phenomena, such as river volume flows and silt deposition [Hurst et al (2)]. As far as is known, these techniques have been applied only to series of events equally spaced in time. In the analysis of joints, however, we have used these methods to study events occurring, not in time, but in an irregular sequence in space. This analysis is sequential in that the dip or strike values of the joints are considered in the order in which they are derived along the survey line.

The cumulative sums technique provides a rapid and a precise method of determining major trends above or below a particular reference value which is selected, and for ascertaining both the magnitude and location of these variations. The main uses of such an analysis method can be summarized briefly as follows:

(a) To detect general changes in joint orientation above and below the mean level of the joint orientation data;

(b) To determine where changes in joint orientation take place in the rock mass;

(c) To determine a reliable estimate of the mean orientation of the joints at any point along the surveyed pit face;

(d) To predict the average orientation of a particular joint set, or group of joints, in other parts of the mass where information is not available.

METHOD OF COMPUTATION

Basically, the approach is simple, consisting merely of subtracting a constant quantity, which at Nchanga was taken to be the mean value of either the strike or dip, from each value of strike or dip in the series, and accumulating the differences as each additional value is introduced. Successive accumulated differences are designated the "cumulative sums" of the original sequence of joint orientation values. The resulting graph of these sums is designated the "cumulative sum joint orientation plot".

When large numbers of joints are to be analysed, it is convenient to create cusum plots by computer methods, methods to which the analysis is ideally suited. Plots on the line printer, using a width of 100 characters, have proven to be an excellent medium for this method of analysis. In order to make the plots comparable, however, it is necessary to use the same cusum range and mean for all plots.

Let us suppose that we have a series of joint strike values acquired from a continuous detail joint survey. We will denote these values by X_1, X_2, . . . X_r, recorded in that order along the pit face. From each X we subtract a reference value K, the mean strike of the joints. We then add these deviations to form a series of partial sums:

$$S_1 = X_1 - K$$

$$S_2 = (X_1 - K) + (X_2 - K) = S_1 + (X_2 - K)$$

$$S_3 = S_2 + (X_3 - K)$$

The general equation for the cumulative sums can thus be written as follows:

$$S_r = S_{r-1} + (X_r - K) = X_1 + X_2 + \ldots\ldots X_r - rK$$

S_1, S_2, S_3, ... S_r is the cumulative sum series (or cusum) of the joint strike series. The plot of S against position in the sequence (S_r vs r) is the cumulative sum joint orientation plot.

The random spacing of the joints presents no problem, so long as the position, not the distance, in the sequence is used. It does not matter if the interval between observations changes. In this computation, strike or direction of dip data must be converted so that only values from either the 0^o to 180^o or the 180^o to 360^o intervals are calculated in the same analysis.

METHOD OF INTERPRETATION

If there is no trend in the strike of the joints, some of the difference terms (X_r - K) will be positive and others negative, with the result being that the cusum will be basically constant. But, if the current or local mean strike value is slightly greater than K (the overall mean), more of the differences will be positive, and the cusum will then be a straight line or curve sloping upwards. The reverse will occur if the current mean is less than K.

The actual distance of the plotted cusum curve from the horizontal is irrelevant; the interpretation is based exclusively on the average slope of the curve. The steeper the curve, the further the mean strike of the joints within any particular location is from the mean value K. The slope of the line (and hence the amount of deviation of the current mean strike from the overall mean value) can be easily calculated. The slope of the plotted line joining, let us say, the mth point and an nth point further along in the series indicates the average difference from the reference value of all the results from X_{m+1} to X_n inclusive. The mean strike ($\bar{X}$) over any interval of the cumulative sum

joint orientation plot is given by

$$\bar{X} = K + \frac{\text{change in cumulative sum}}{\text{change in n}}$$

When conducting this type of analysis considerable care should be taken in selecting a suitable reference value (K). One important feature of this analysis method is that relatively small changes, say in the current mean value of the joint strike, will appear as clearly different slopes. However, changes from one positive value to another in the slope of the cusum plot are not nearly so discernable as a reversal of the sign of the slope, i.e. a change from a situation in which the mean strike of the joints is above the reference value, to one in which it is below. The reference value K should be chosen as a reasonable target from which the results are expected to vary. Also, erratic variations or "noise" in the data are smoothed out. This is a significant factor when looking for trends and patterns, particularly when analyzing data from natural phenomena such as joints.

This technique is best used to determine long-term trends. Interpretation becomes difficult if attempts are made to include short-duration effects.

COMPARISON WITH TIME TREND ANALYSES

Several techniques, adapted from time series analysis, have been used extensively to analyze sets of geological data which are arranged as a series in space [Harbough and Merriam (1)]. They include moving average methods, harmonic analysis, spectral analysis and auto-correlation. All but the first of these are concerned with acquiring information from rapid fluctuations present in all data.

The moving average techniques (including polynomial

trend analysis) tackle a problem similar to that discussed here. However, they assume that the underlying variations sought are continuous functions and will smooth out any sudden breaks. The analyst is presented with a plethora of results which are difficult to interpret.

In contrast, cusums are best used to highlight step changes in the underlying function, and are excellent for displaying slow cyclic variations. A comparison of cusums with other techniques used to detect slow variations is given by Hurst et al (2). It is interesting to note that the cusum of a series of equally spaced events is a convenient aid in calculating the simple moving average, particularly when a number of base lengths are to be examined.

APPLICATION OF THE CUMULATIVE SUMS ANALYSIS AT NCHANGA

METHOD OF APPROACH

All joints occurring within 30° of either side of the tectonic fold axis (which for analysis purposes was taken to be 300°) were considered in the analysis (i.e. joints with a direction of dip of 0° to 60° and 180° to 240°). In order that the joint data be representative of different parts of the pit slope, the hanging-wall was sub-divided into 14 arbitrary areas of approximately similar size going from west to east.

Analysis Using One Mean

One cusums technique consisted of analyzing the direction of dip data of all joints within the limits defined. Those joints with direction of dip of 0° to 60° were converted to 180° to 240° by adding 180° to their respective values. Thus, all joints could be analyzed together in the 180° to 240° range.

An example of the method of interpretation of the cumulative sums is shown in Fig. 3. The actual direction of dip orientations, as calculated from strike measurements in the field, are shown in Fig. 3(a). The resulting cumulative sums joint orientation plot of the raw data in Fig. 3(a) is shown in Fig. 3(b). Fig. 3(c) shows a Manhattan diagram, depicting the degree of deviation of the current mean strike above or below the overall mean strike K, according to the curves plotted in Fig. 3(b). See Fig. 4 for details of Fig. 3.

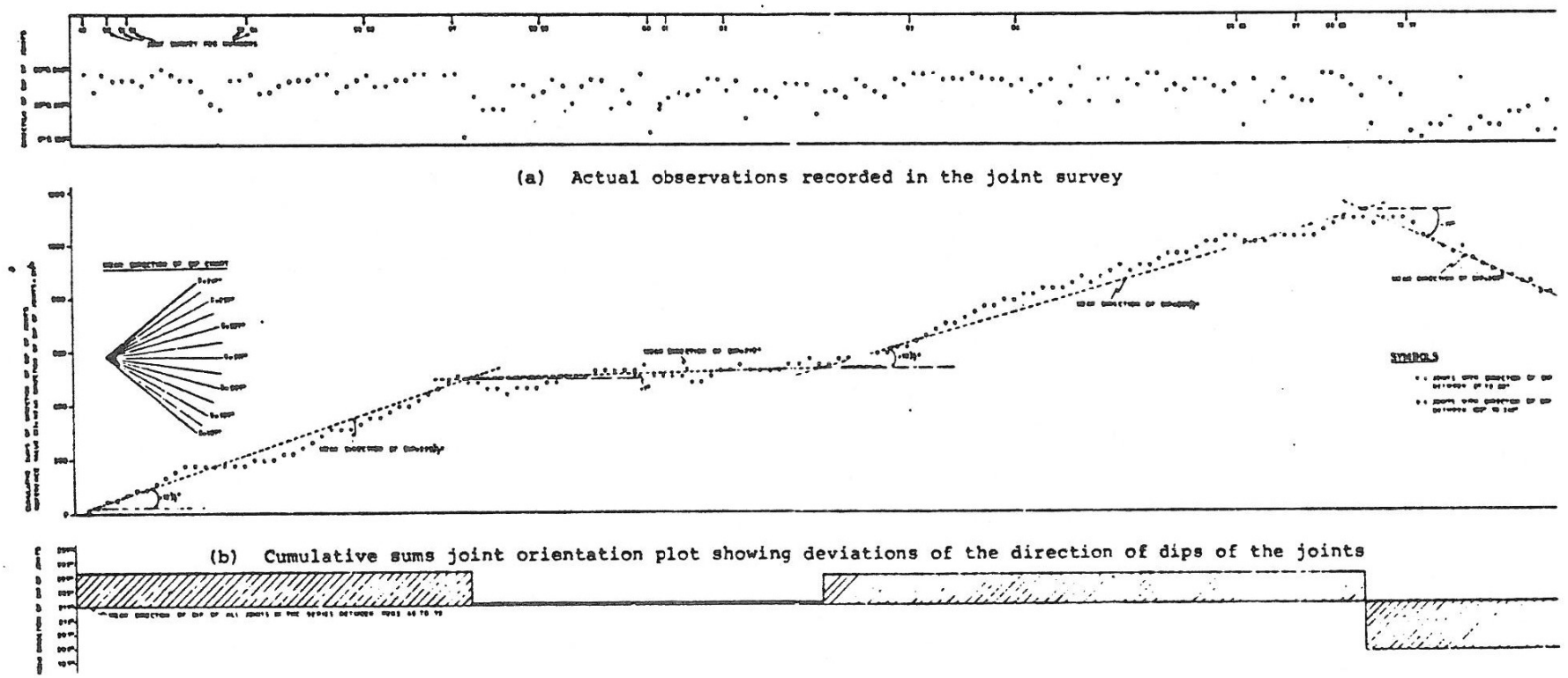
In Fig. 5, Manhattan diagrams of the cumulative sums of the analyses of the entire hanging-wall area that was surveyed, are shown. The various bench levels and subdivided areas of the hanging-wall (i.e. 1 to 14) are denoted accordingly. The bottom Manhattan diagram in Fig. 5 gives, for each of the 14 areas, the current mean deviation of the strike* of the joints about the mean. This is determined by calculating the mean deviation for all the benches occurring in a particular area.

Analysis Using Four Means

This analysis technique consisted of determining the cusums of both the direction of dip and angle of dip of the joints dipping to the northeast and of those dipping to the southwest. The respective mean direction of dip and mean angle of dip for each group were used. Hence, four K values are required, giving four cusum plots. The four K values applying to the Nchanga data are as follows:

---

* The cumulative sums plots in Fig. 3, of direction of dip data, is converted to actual strike values in Fig. 5 for purposes of clarity.



(a) Actual observations recorded in the joint survey

(b) Cumulative sums joint orientation plot showing deviations of the direction of dips of the joints

(c) Manhattan diagram showing the current mean direction of dip of the joints at progressive positions along the survey line

Fig 3 Illustration of cumulative sums technique for analysing joint direction of dip trends

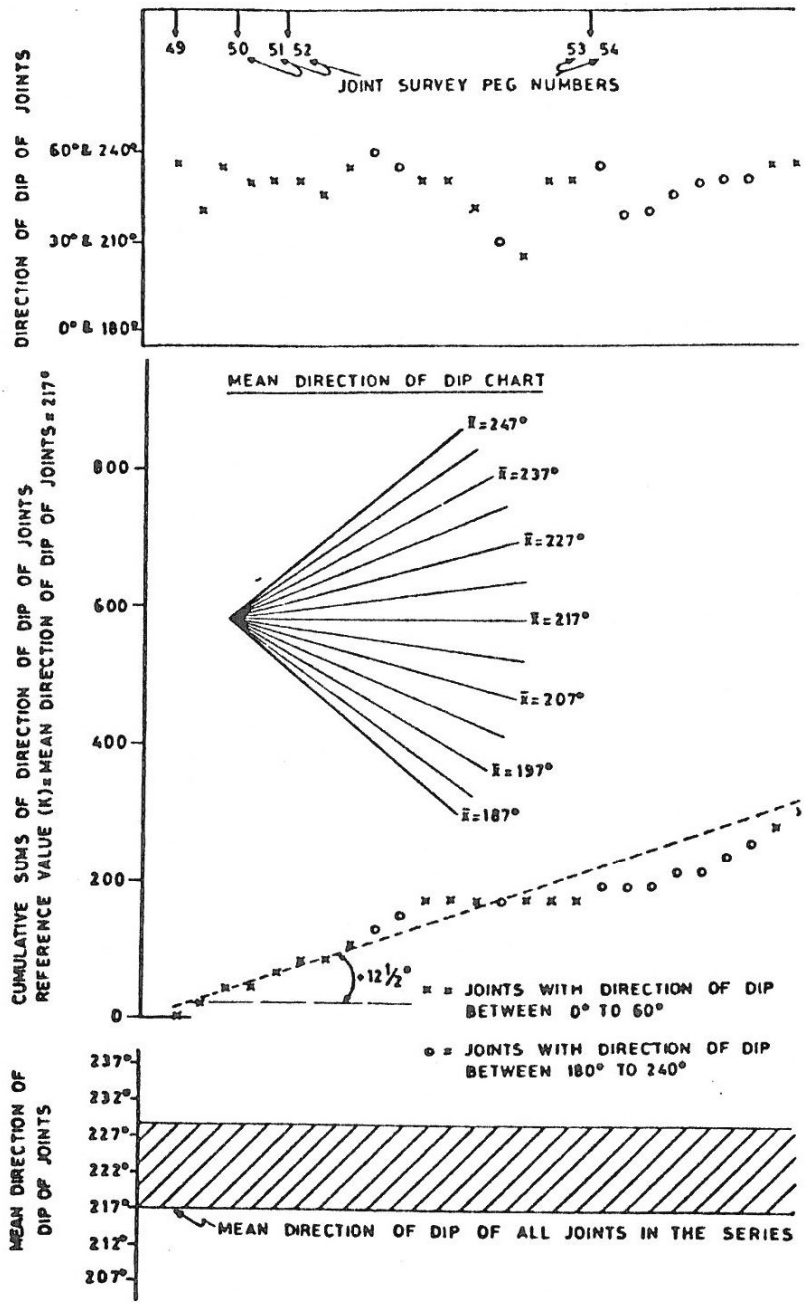


Fig. 4 Enlarged portion of the left side of Fig. 3 showing detail clearer

Joints Considered	Orientation Data	K Value
Direction of Dip 0^{o} - 60^{o}	Strike	310^{o}
" " " 0^{o} - 60^{o}	Angle of Dip	74^{o}
" " " 180^{o} - 240^{o}	Strike	306^{o}
" " " 180^{o} - 240^{o}	Angle of Dip	78^{o}

The general results are similar to those illustrated in Fig. 3, except that four cusum joint orientation plots are produced. Two plots apply to strike and two to angle of dip, although only one strike chart and one angle of dip chart are required. Four Manhattan diagrams must be considered in the same manner. The Manhattan diagrams of this analysis are given in Fig. 6. See Fig. 7 for some details of Fig. 6.

Applying this general form of cumulative sums analysis, boundaries to structural regions (i.e. areas of similar jointing characteristics in a statistical sense) were also determined. Cusum techniques used for this purpose will be published elsewhere.

DISCUSSION OF THE RESULTS

Counter-clockwise Rotation

In Fig. 5 it can be seen that the mean strike of all the joints is 307^{o}. There is, however, a counter-clockwise rotation in the current mean strike, going from west to the east side of the hanging-wall. It rotates from about 317^{o} in areas 1 and 2 to about 297^{o} in areas 9 to 14. Around areas 5 and 6 the current mean strike is about the same as K.

Effects of Major Fault

As shown in Fig. 5, the rate of change of this rotation is greatest in areas 3 to 7. In Fig. 6, where the northeast and southwest dipping joints are analyzed separately, it can be seen that this phenomenon is due largely to the rotation

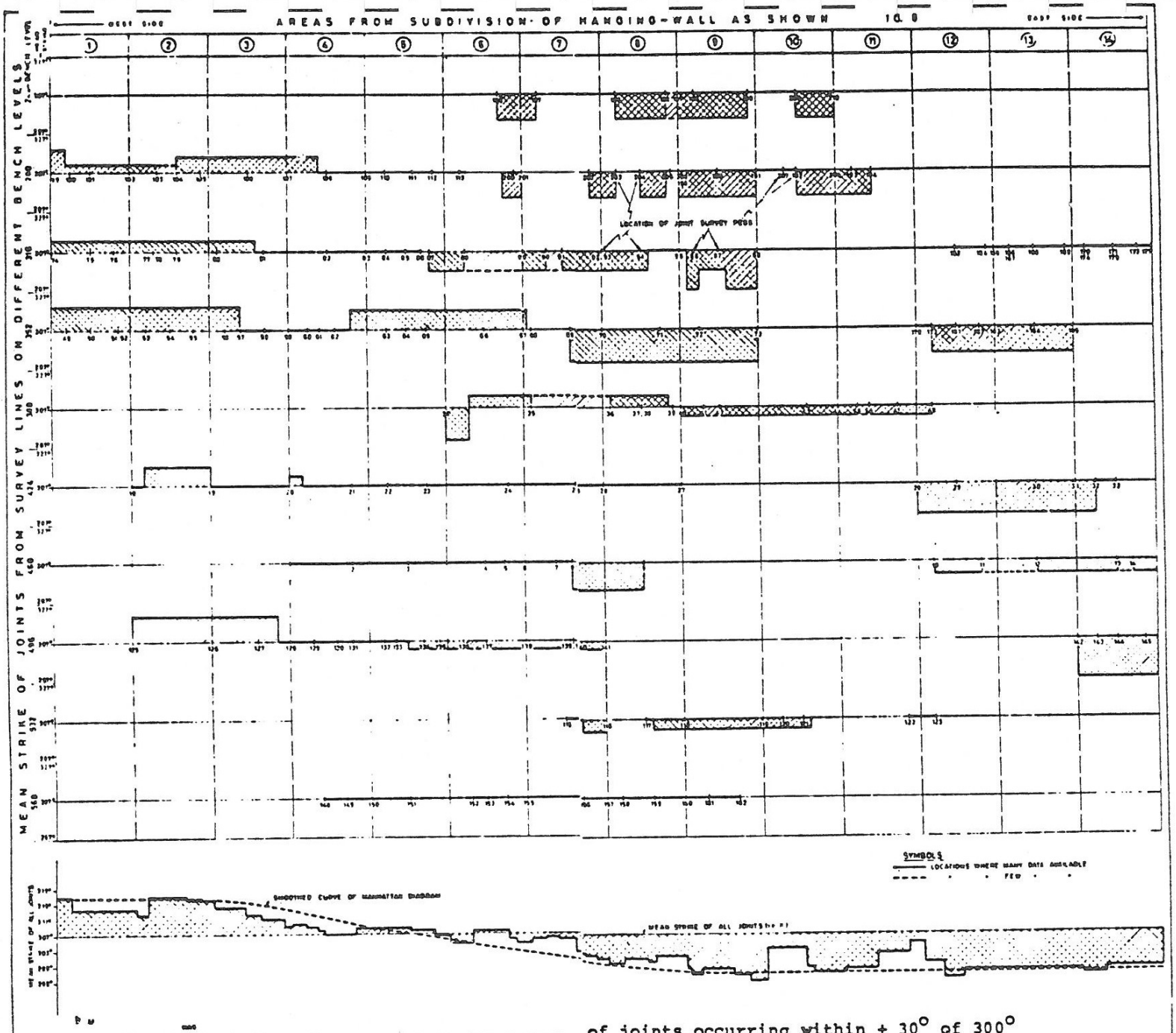


Fig. 5 Manhattan diagrams of strike trends of joints occurring within $\pm 30^{\circ}$ of 300°

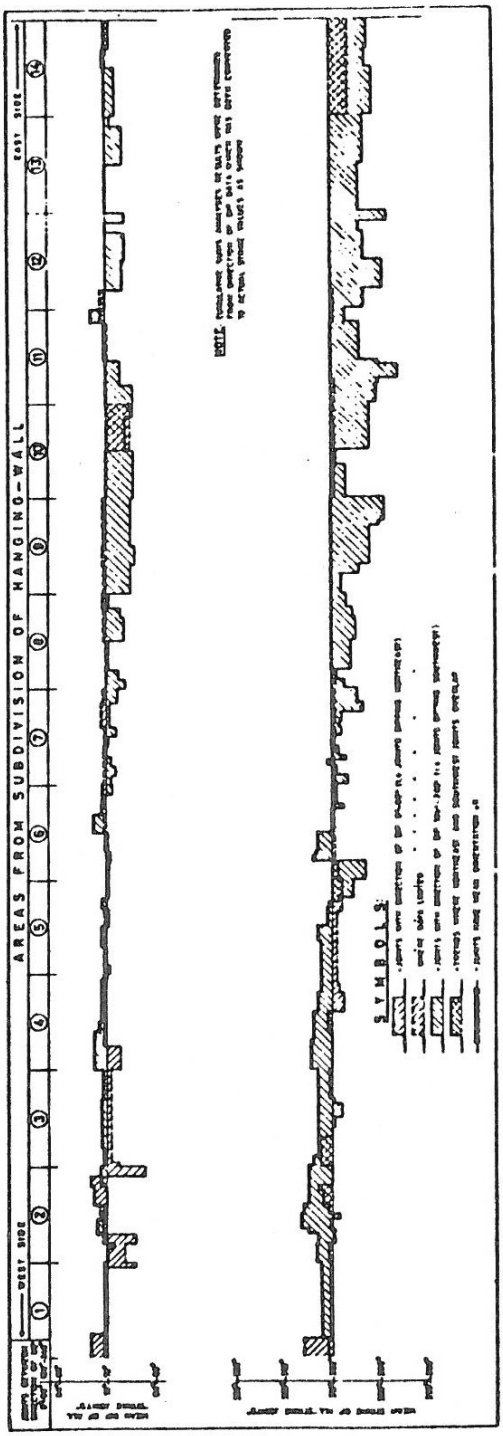


Fig. 6 Manhattan diagrams of the mean values of the cumulative sums analysis of strike and dip trends of "strike joints" dipping northeast and southwest of the estimated regional tectonic structural axis (300^{0}) at Nchanga

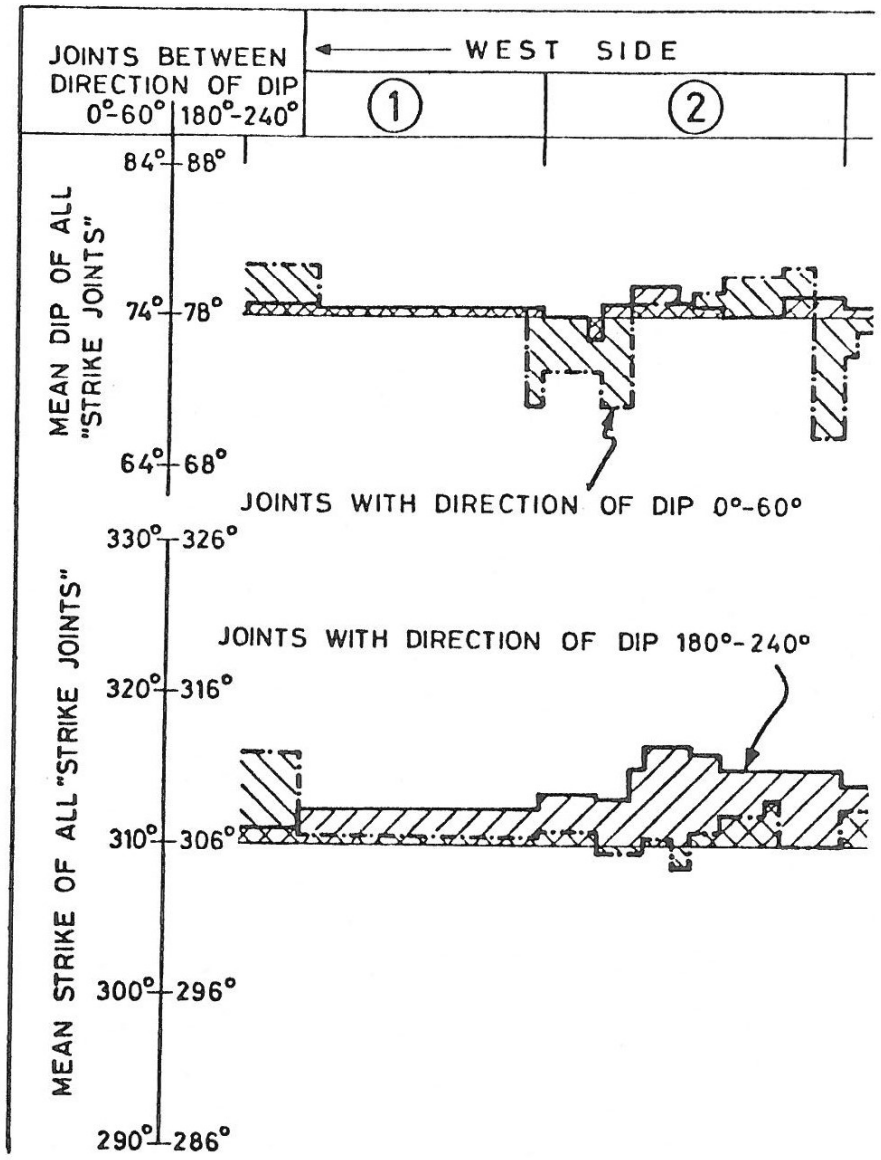


Fig. 7 Enlarged portion of the left side of Fig. 6 showing detail clearer

of the southwest dipping joints. This rotation is due to a major fault, the only major fault occurring in the area considered. This fault strikes 320° and dips 80° to 85° SW. The vertical component of net slip is about 80 ft, the downthrow being to the southwest.

In Fig. 6 the northeast dipping joints, with respect to both strike and dip, vary only slightly about the mean. Also, they decrease in frequency going eastwards, becoming negligible beyond area 7. This indicates, along with their angular relationship to the fault, that these joints are probably feather fractures which have developed sympathetic to the fault.

The southwest dipping joints, on the other hand, are significantly above the mean on the west side of the pit. Here, sympathetic fracturing parallel to the fault has swung the current mean strike slightly towards that of the fault. Further east, however, the southwest dipping joints rotate counter-clockwise past the mean. Beyond area 9, where the influence of the fault is negligible, and where only tectonic forces appear to have been significant in causing the existing joints, they maintain a remarkably consistent current mean strike of about 295°.

Plots in Fig. 8 of both (1) the percentage and (2) the number of joints per foot (i,e, joint intensity) of northeast and southwest dipping joints occurring in each of the areas 1 to 14, provide convincing additional evidence of the conclusions above. Fig. 8(a) indicates that the percentage of northeast dipping joints is considerably greater on the west side of the pit and decreases rapidly, becoming negligible east of area 7. The opposite is true for the southwest dipping joints. Area 4 is the changing point where one or the other dominates. In Fig. 8(b) the influence of the fault can be seen clearly. The intensity of the northeast dipping joints is excessively high in areas 1 to 4,

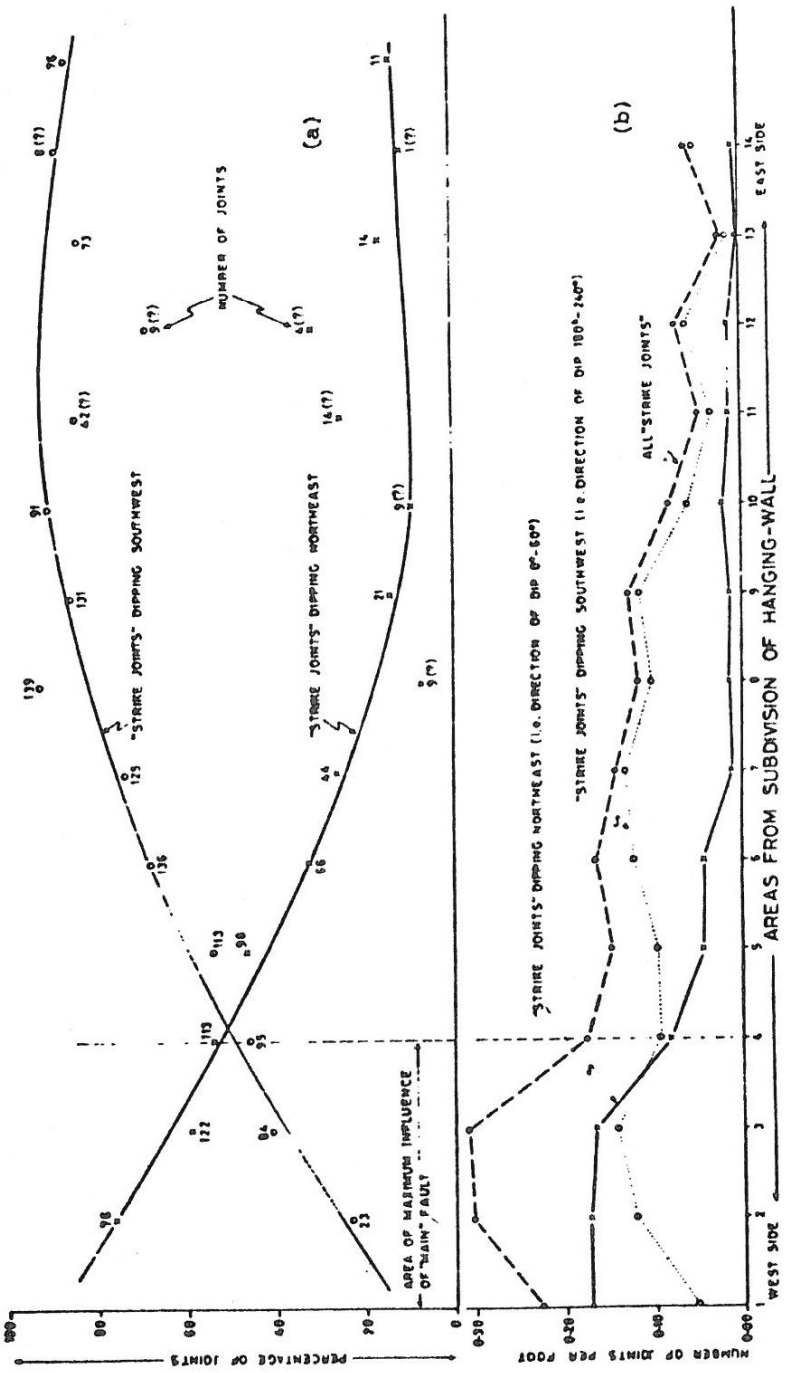


Fig. 8 Plot of the percentage (a) and frequency (b) of "strike joints" dipping southwest and northeast of the synclinal axis for different areas across the hanging-wall

but negligible beyond area 7. The southwest dipping joints, however, increase in frequency only slightly across the fault-affected area and maintain a fairly constant, though slightly decreasing, frequency going from west to east beyond this area.

Regional Joint Pattern

East of area 7 additional joints of an anomalous nature, (i.e. joints other than those originating through regional tectonic processes) are not evident. Thus, it must be assumed that those remaining, namely the joints occurring outside of the limits of the fault influence, are of the regional joint pattern. These are exclusively the southwest dipping joints.

Not only are these joints part of the regional pattern, but they represent greater than 80 per cent of the regional pattern (see Fig. 2 and 8). Greater than 80 per cent of the regional joint pattern, therefore, can be defined, approximately, as having an average strike of 295° and an average dip of 72° SW to 76° SW.

Genesis of Jointing and the Tectonic Process at Nchanga

With the general joint distributions in Fig. 2 and other structural relationships, the genesis of this dominant regional set, and the conditions during which both folding and this jointing took place, can be postulated.

Since definite sets of either one or both conjugate shear joints are not evident, and the intermediate tension joint set is essentially absent, the sedimentary rocks in the area appear to have yielded, at least initially, by plastic deformation or flowage and recrystallization in contrast to brittle fracture. The first and major form of brittle fracture (i.e. southwest dipping joints) appears to

have developed as a result of elastic rebound of the originally highly compressed materials after both the temperature and pressure subsided. The southwest dipping joints, therefore, appear to be tension joints, having developed due to elastic rebound after the principal tectonic force had terminated. The principal form of deformation was that of crustal shortening. The type of folding was related primarily to those of horizontal tectonics, i.e. to processes of deformation wherein the maximum principal stress (tectonic stress) acted horizontally.

EXTRAPOLATION OF JOINT DATA

For purposes of making slope stability evaluations for the pit faces advancing both northwards and eastwards at Nchanga, the question of the reliability of applying information acquired from the existing hanging-wall slope to other parts of the mass where information is not available and where the advancing and final pit faces are to be located, is an important consideration. If any degree of confidence is to be achieved in proposing slope designs based to a large extent on these results, it must be shown whether the joint characteristics can be expected to be the same or to differ, and in what way to differ, in other parts of the mass where information is not available. The question of the extrapolation of joint properties when designing engineering structures in rock, and basic considerations relating to this problem, are discussed by Piteau (7).

Results in Fig. 6 show that both the current mean strike and current mean angle of dip are, statistically speaking, remarkably consistent east of area 8. This is particularly so with respect to the current mean strike. In either case, the deviation about the overall mean strike and mean dip orientation in this area is plus or minus three degrees. The history of folding in the majority of the syncline, and at least within the confines of the pro-

posed final pit limits, is expected to be reasonably similar. Since the joints in question are genetically related to this folding process (in that they are rebound features which developed normal to the principal tectonic stress), based on the results of the cumulative sums analysis described above (see Fig. 6), there is good reason to believe that southwest dipping joints with similar orientations will exist in the proposed eastern extension areas of the pit.

For comparative purposes it is fortunate that at Nchanga an extensive joint survey had been conducted on the hanging-wall of the pit in 1966. The pit face at the time was 250 ft to the south of its present location, but the joint survey was conducted at approximately the same elevation and same relative location as that of the present survey. Hence, an ideal situation exists for determining whether the joint patterns are similar between the two survey lines and, accordingly, whether extrapolation of such structures is reasonable over this same distance in the opposite direction.

The 1966 survey results were available on stereographic projections, hence the peak concentration of the southwest dipping joints was easily measured. This information was compared directly to the cusum results for the respective areas across the pit. Except for minor variations, in general a remarkable similarity was found between the two separate survey results. Since the history of deformation is expected to be similar within the final pit limits, this indicated that the results from the present analysis would probably apply also behind the existing face in areas where the advancing pit faces are to be eventually located. These results also confirmed the conviction that the joint trends will be maintained in areas further east of the pit in which the extension is proposed.

CONCLUSIONS

The cumulative sums technique, illustrated with particular reference to an extensive joint analysis of the Nchanga open pit hanging-wall, provides an efficient and definitive method of examining joint dip and/or joint strike data in the order in which the joints are derived along the survey line. Unlike most joint analysis methods, this technique smooths out "noise" effectively. Also, both step changes in the underlying function and slow cyclic variations are readily displayed.

Basically, it is used to determine:

(a) the current deviation of either the joint dip or strike above or below some level of the orientation data or reference value (K) (i.e. in the Nchanga analysis K was taken to be the mean of the orientation data used);

(b) where these particular changes take place along the pit face; and

(c) the current mean orientation or simple moving average at any point in the consecutive sequence of the joints.

The behavior of a particular group of joints can be ascertained with respect to such characteristics as imperceptible rotation, both in the horizontal (i.e. strike) and vertical (i.e. dip) planes. In that the plots depicting this behavior are statistically significant, they can assist in predicting whether the information from the exposed pit face can be extrapolated with confidence to other parts of the mass where information is limited, but where pit slopes are to be eventually located. In this respect a knowledge of the geological history and the genetic relationship of the joints to the regional structure is important.

ACKNOWLEDGEMENTS

The authors extend their thanks to Nchanga Consolidated Copper Mines Limited - Chingola Division, for the co-operation which was given throughout the course of this work. The authors particularly wish to express their appreciation to C. Kovacevic, cartographer, for drawing not only these figures but numerous others in the Nchanga report; to A. Carbray, for helping to process the data; to F. Chisela, for supervising the survey; and to J. Hellings, for his general co-operation. Finally, the authors acknowledge with grateful thanks J. E. Jennings, O. K. H. Steffen and A. MacG. Robertson, with whom the senior author worked closely in recent years and who, although not directly involved with the development of this new technique, contributed significantly to important earlier development work, of which the results in this paper are an outgrowth.

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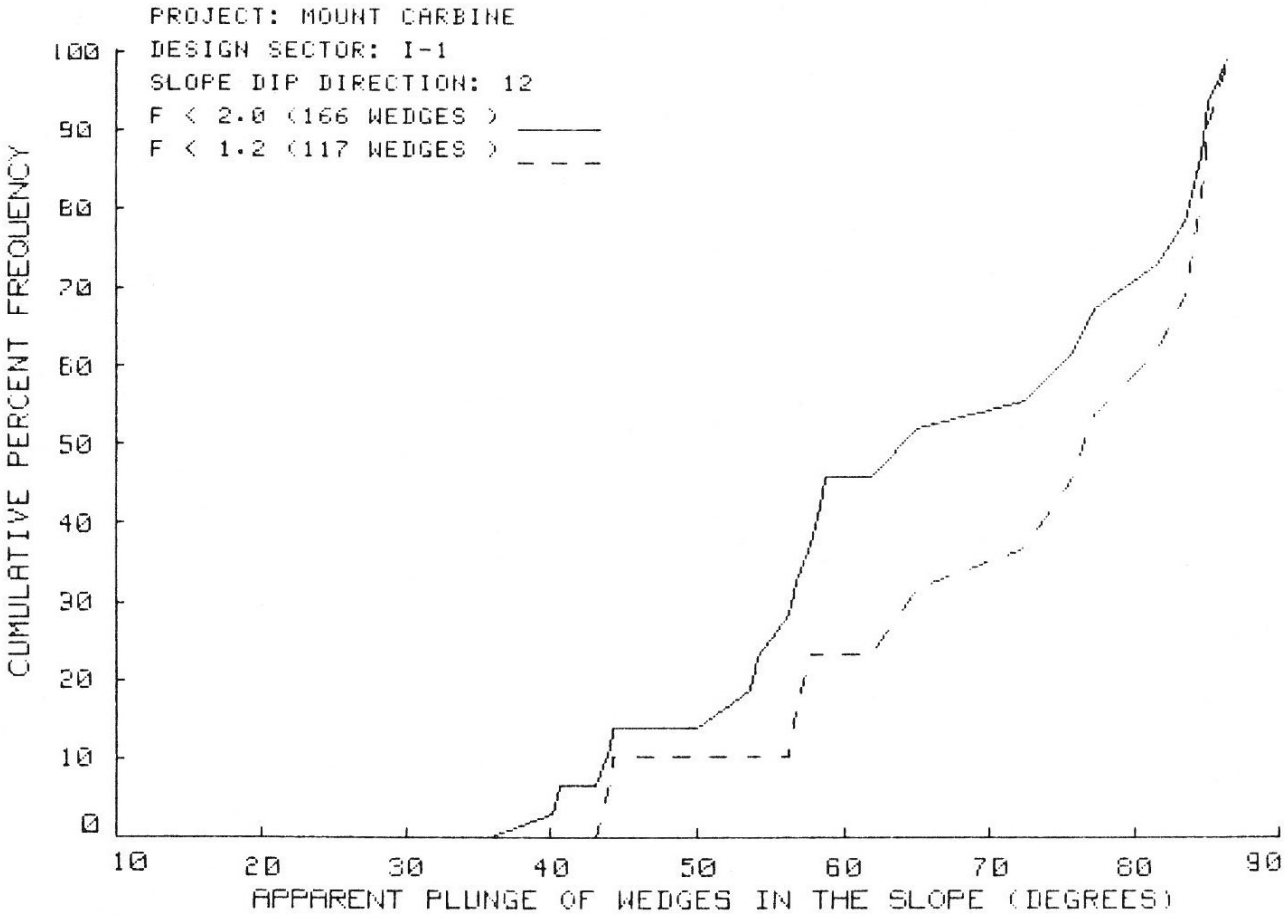
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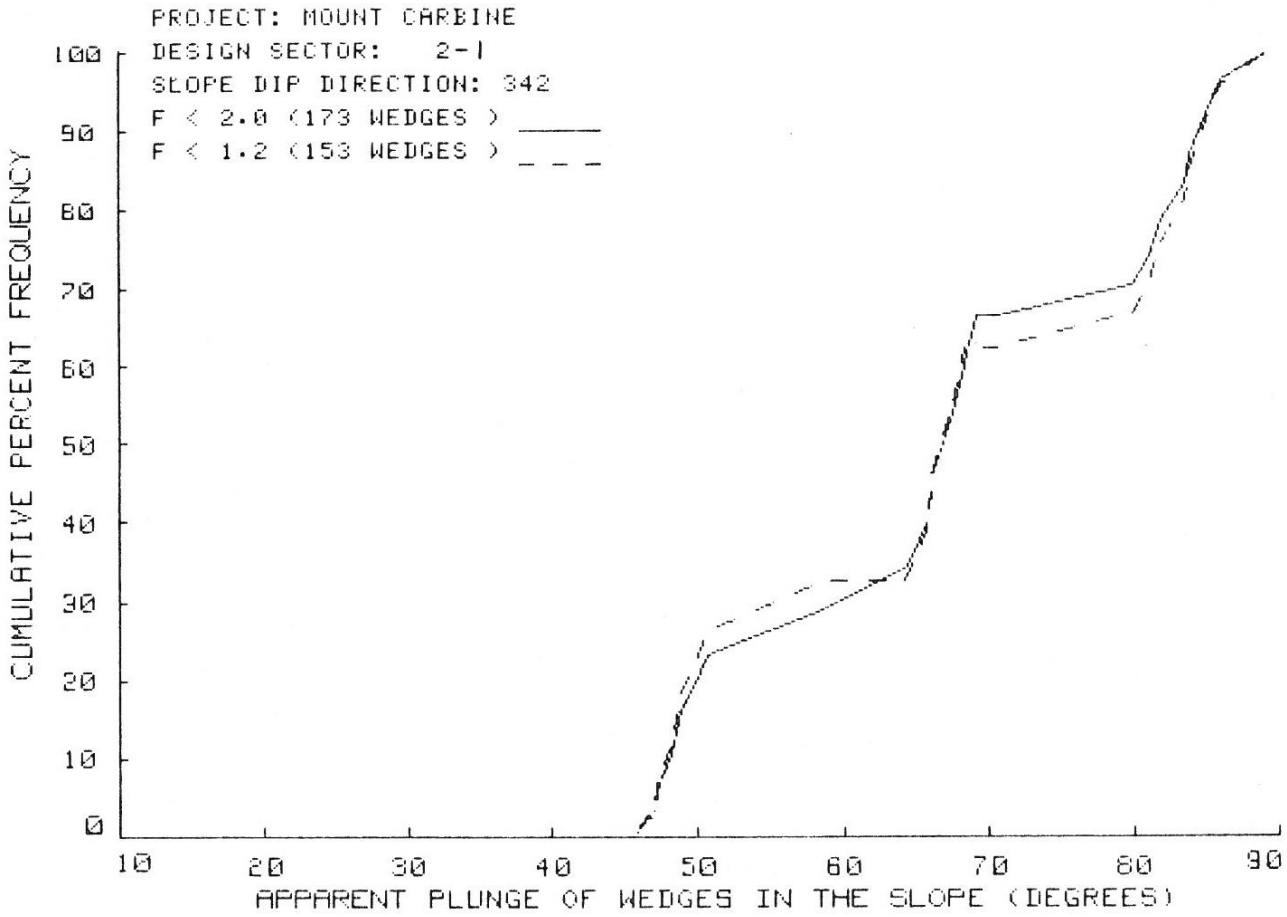
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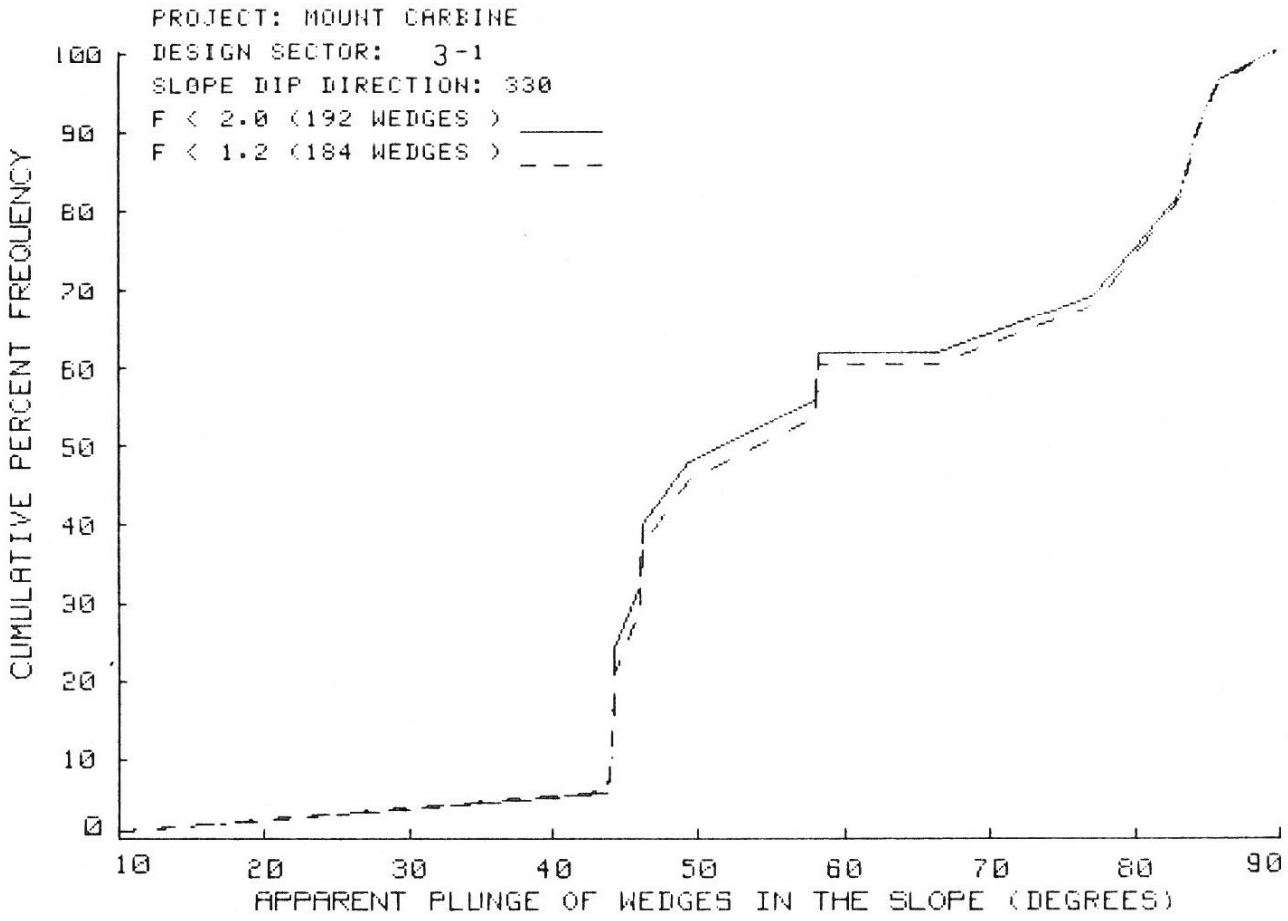
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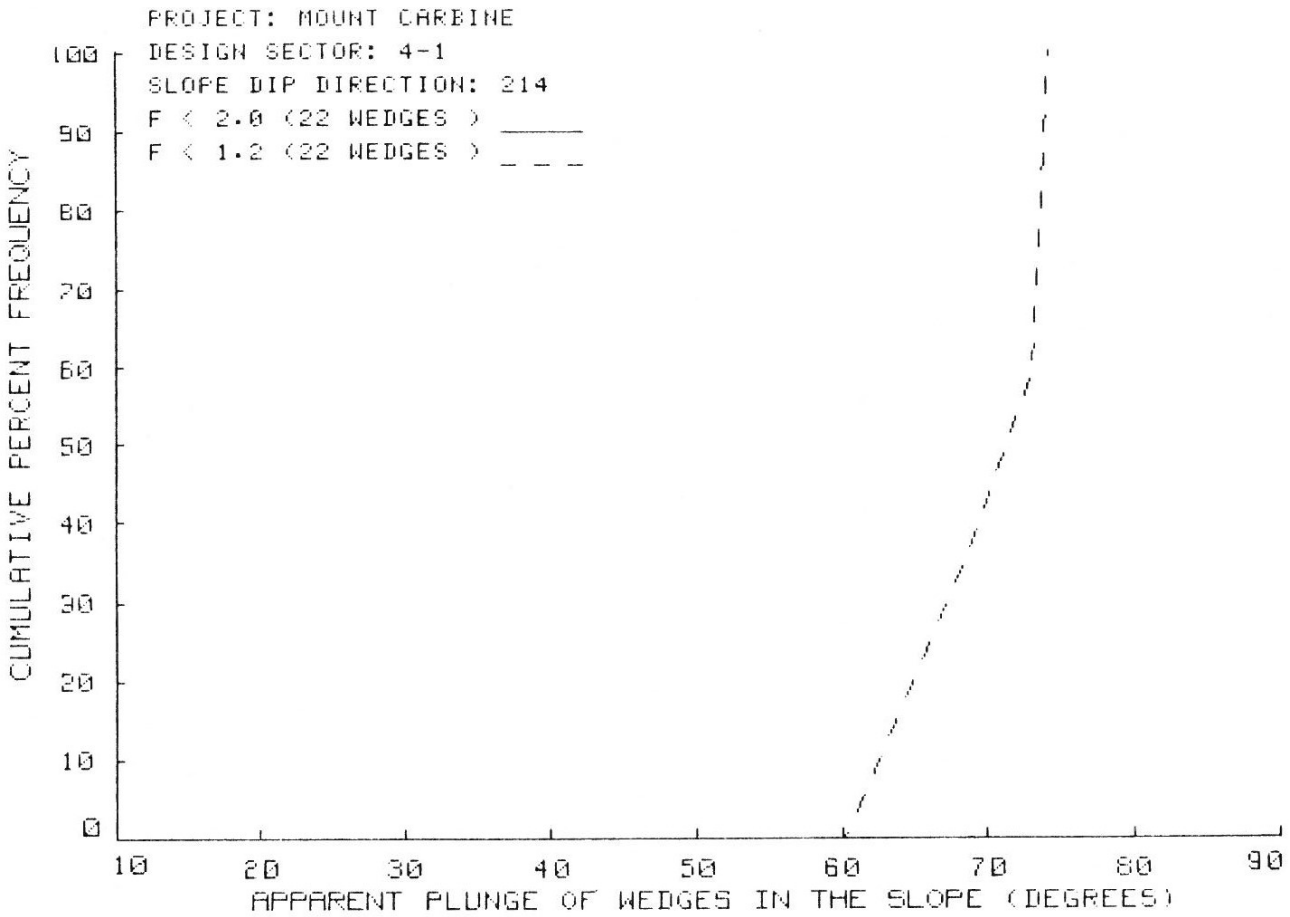
APPENDIX D

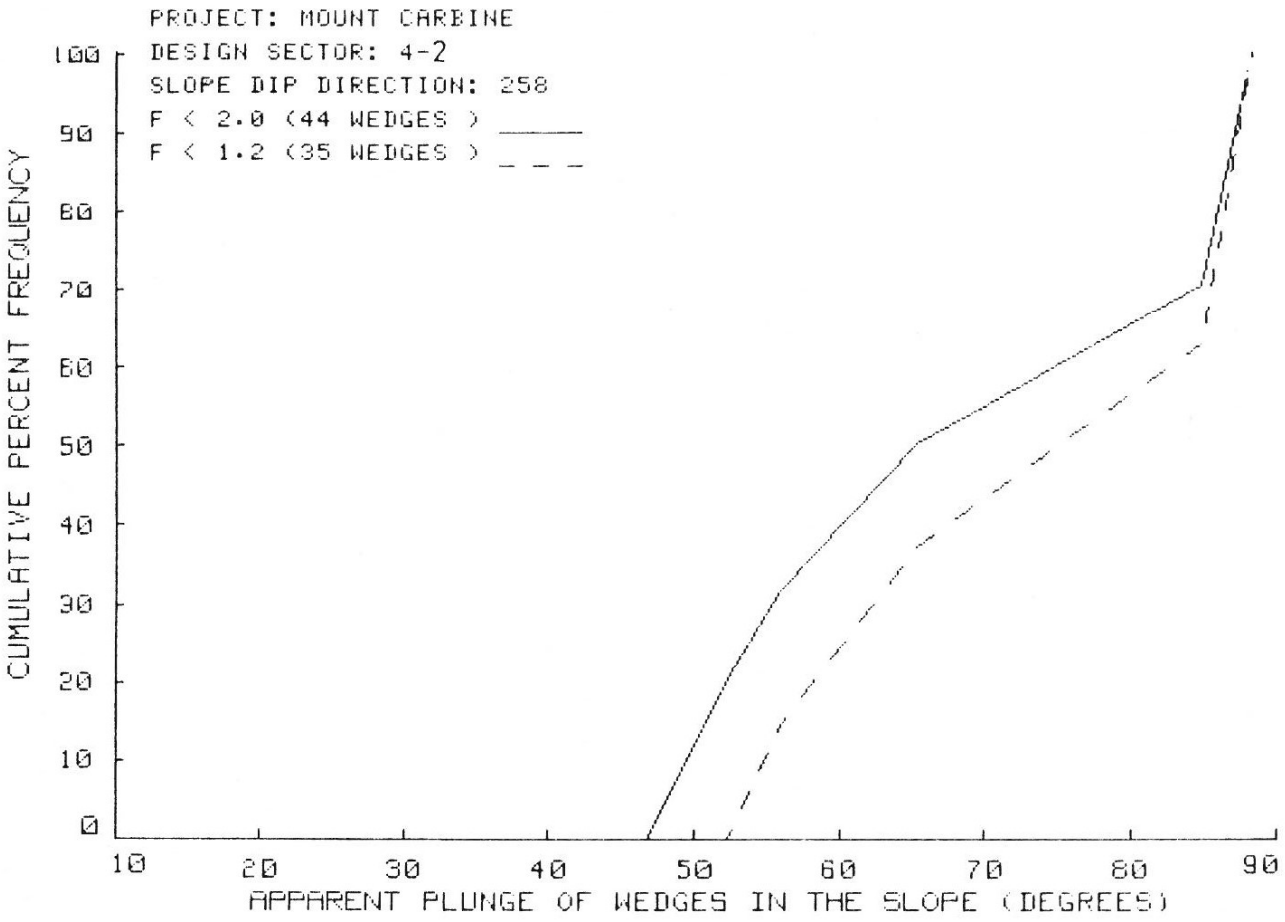
CUMULATIVE FREQUENCY PLOTS OF KINEMATICALLY PROBABLE FAILURES FOR DESIGN SECTORS IN THE OPEN PIT

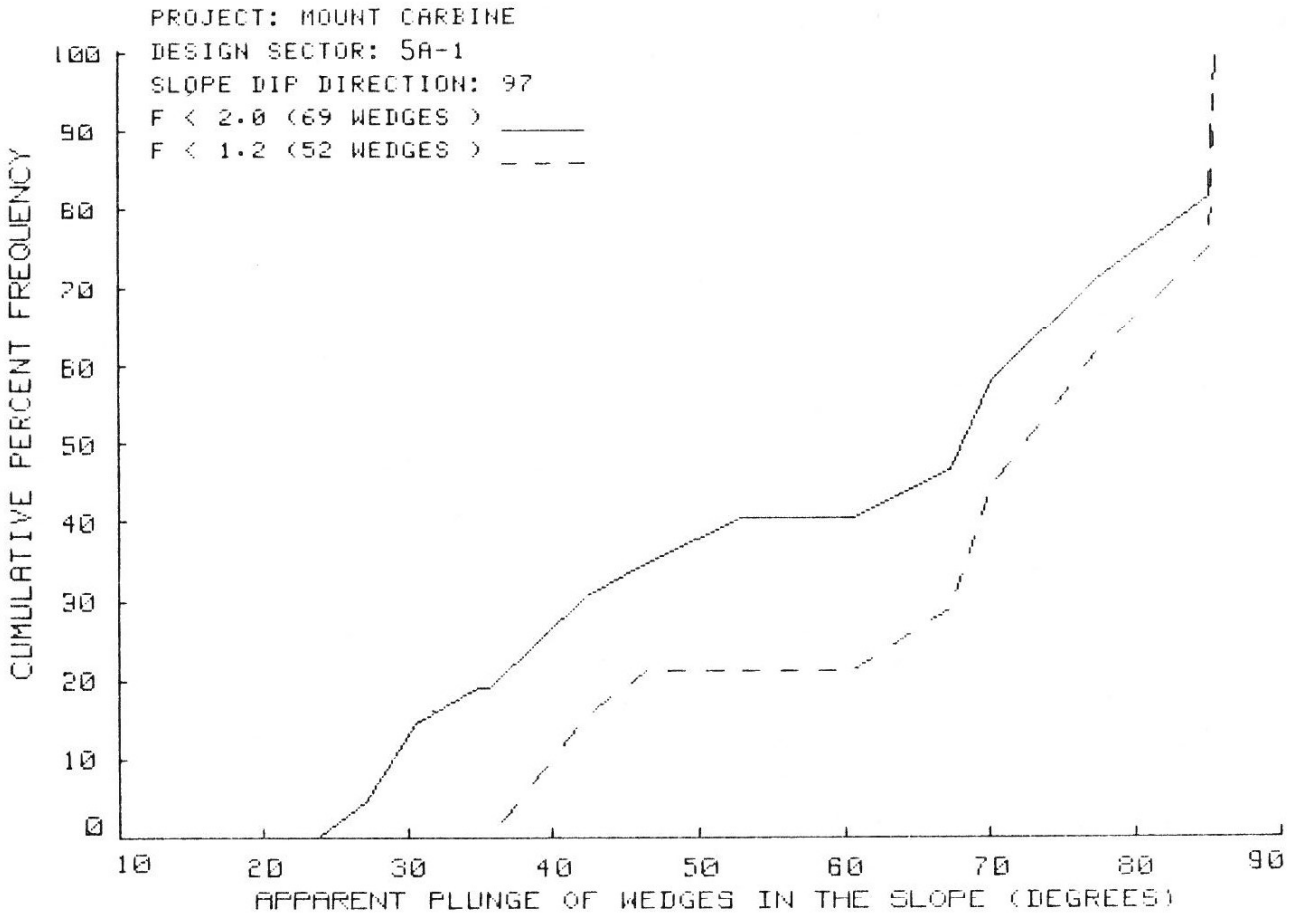

PROJECT: MOUNT CARBINE
DESIGN SECTOR: I-1
SLOPE DIP DIRECTION: 12
F < 2.0 (166 WEDGES)
F < 1.2 (117 WEDGES)
CUMULATIVE PERCENT FREQUENCY
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
APPARENT PLUNGE OF WEDGES IN THE SLOPE (DEGREES)

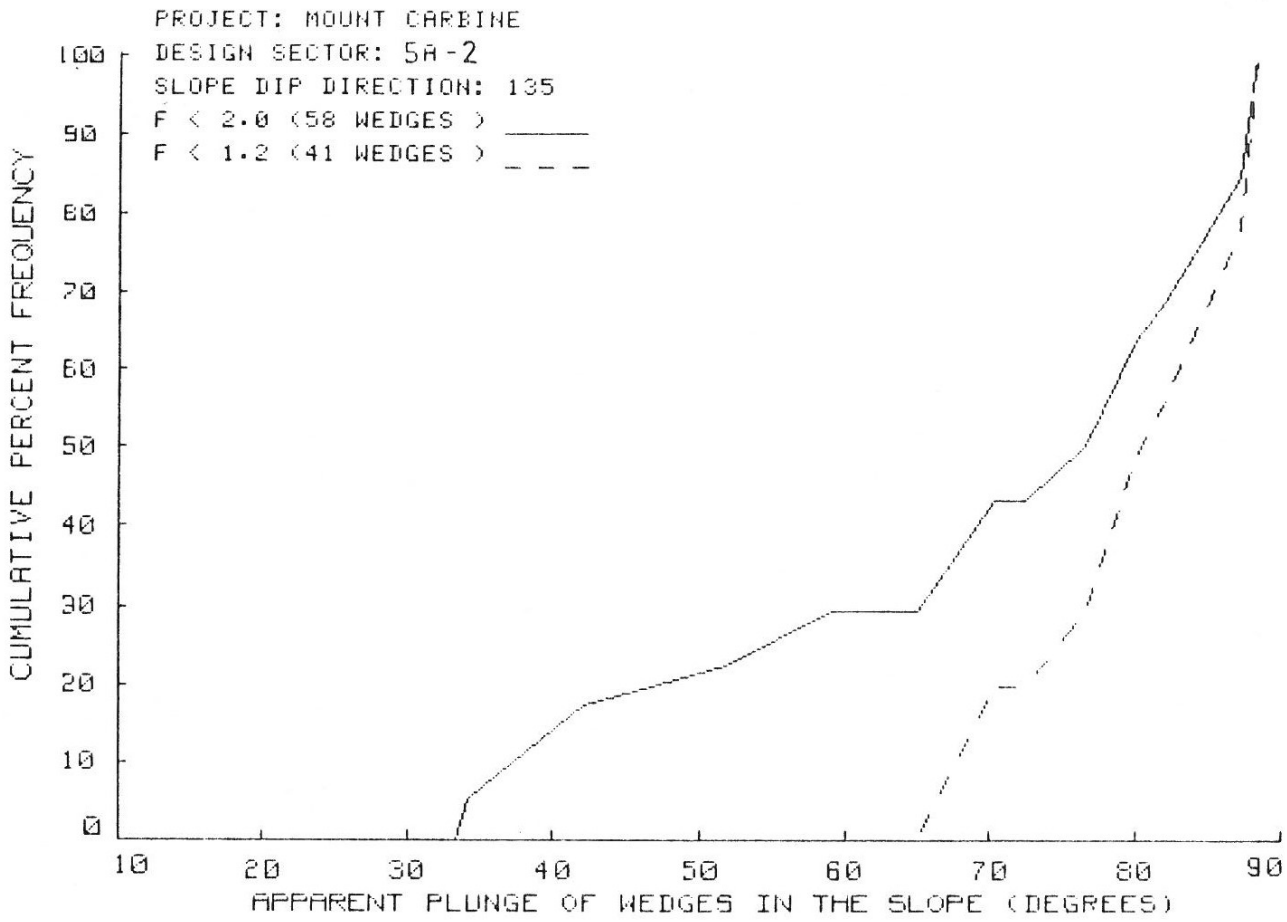

PROJECT: MOUNT CARBINE
DESIGN SECTOR: 2-1
SLOPE DIP DIRECTION: 342
F < 2.0 (173 WEDGES)
F < 1.2 (153 WEDGES)
CUMULATIVE PERCENT FREQUENCY
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
APPARENT PLUNGE OF WEDGES IN THE SLOPE (DEGREES)

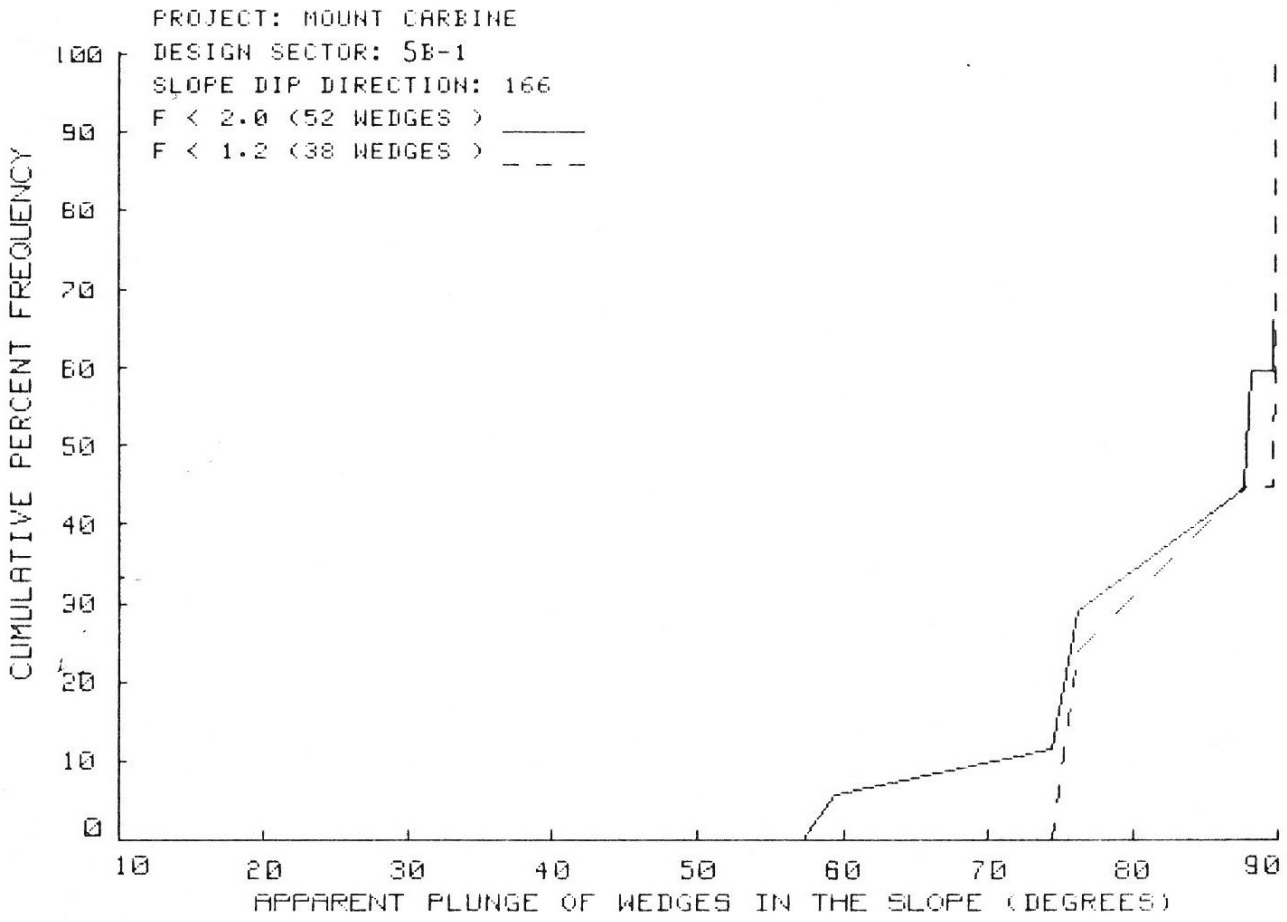

PROJECT: MOUNT CARBINE
DESIGN SECTOR: 3-1
SLOPE DIP DIRECTION: 330
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F < 1.2 (184 WEDGES)
CUMULATIVE PERCENT FREQUENCY
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
APPARENT PLUNGE OF WEDGES IN THE SLOPE (DEGREES)

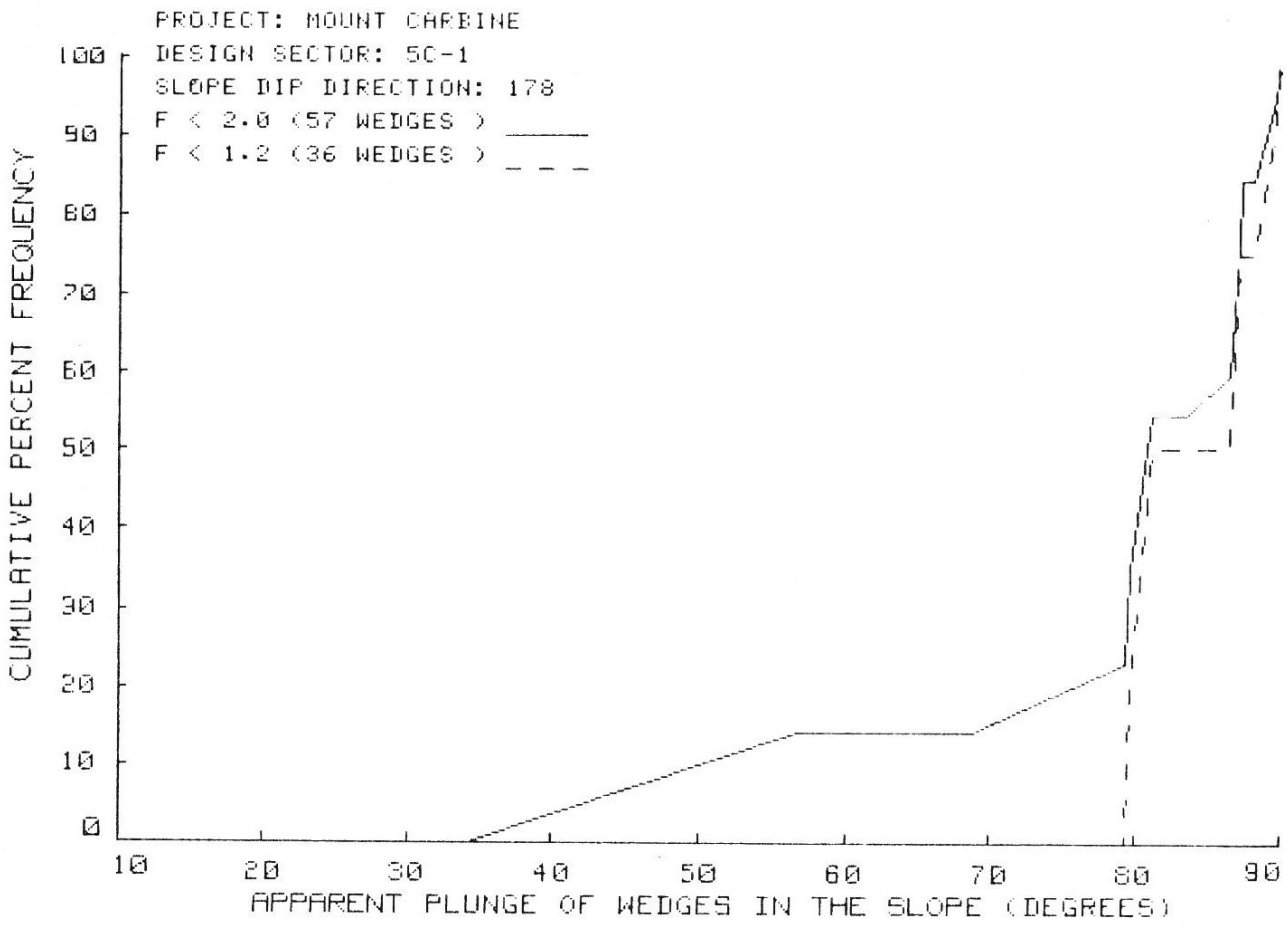

PROJECT: MOUNT CARBINE
DESIGN SECTOR: 4-1
SLOPE DIP DIRECTION: 214
F < 2.0 (22 WEDGES)
F < 1.2 (22 WEDGES)
CUMULATIVE PERCENT FREQUENCY
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
APPARENT PLUNGE OF WEDGES IN THE SLOPE (DEGREES)

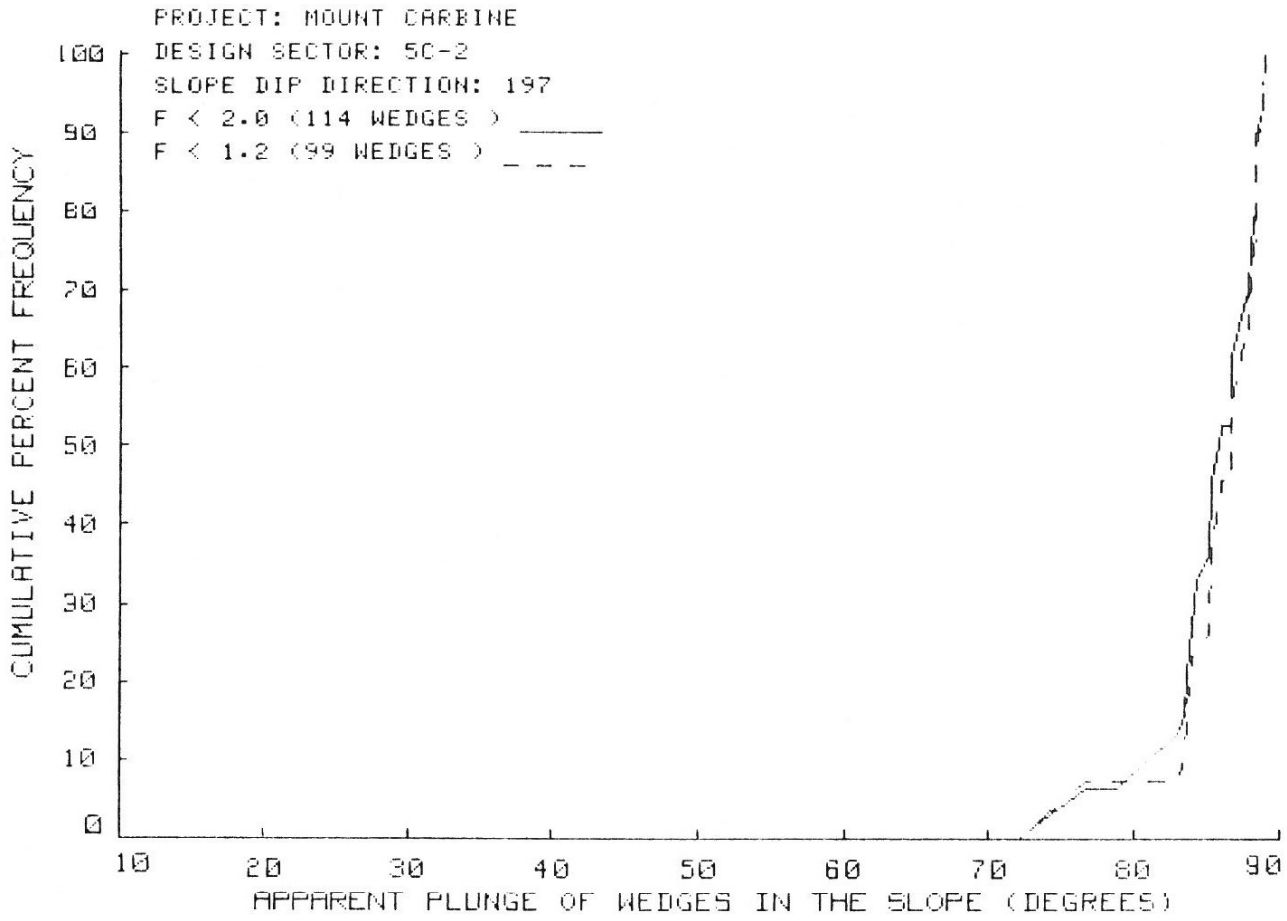

PROJECT: MOUNT CARBINE
DESIGN SECTOR: 4-2
SLOPE DIP DIRECTION: 258
F < 2.0 (44 WEDGES)
F < 1.2 (35 WEDGES)
CUMULATIVE PERCENT FREQUENCY
100
90
80
70
60
50
40
30
20
10
0
10
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60
70
80
90
APPARENT PLUNGE OF WEDGES IN THE SLOPE (DEGREES)

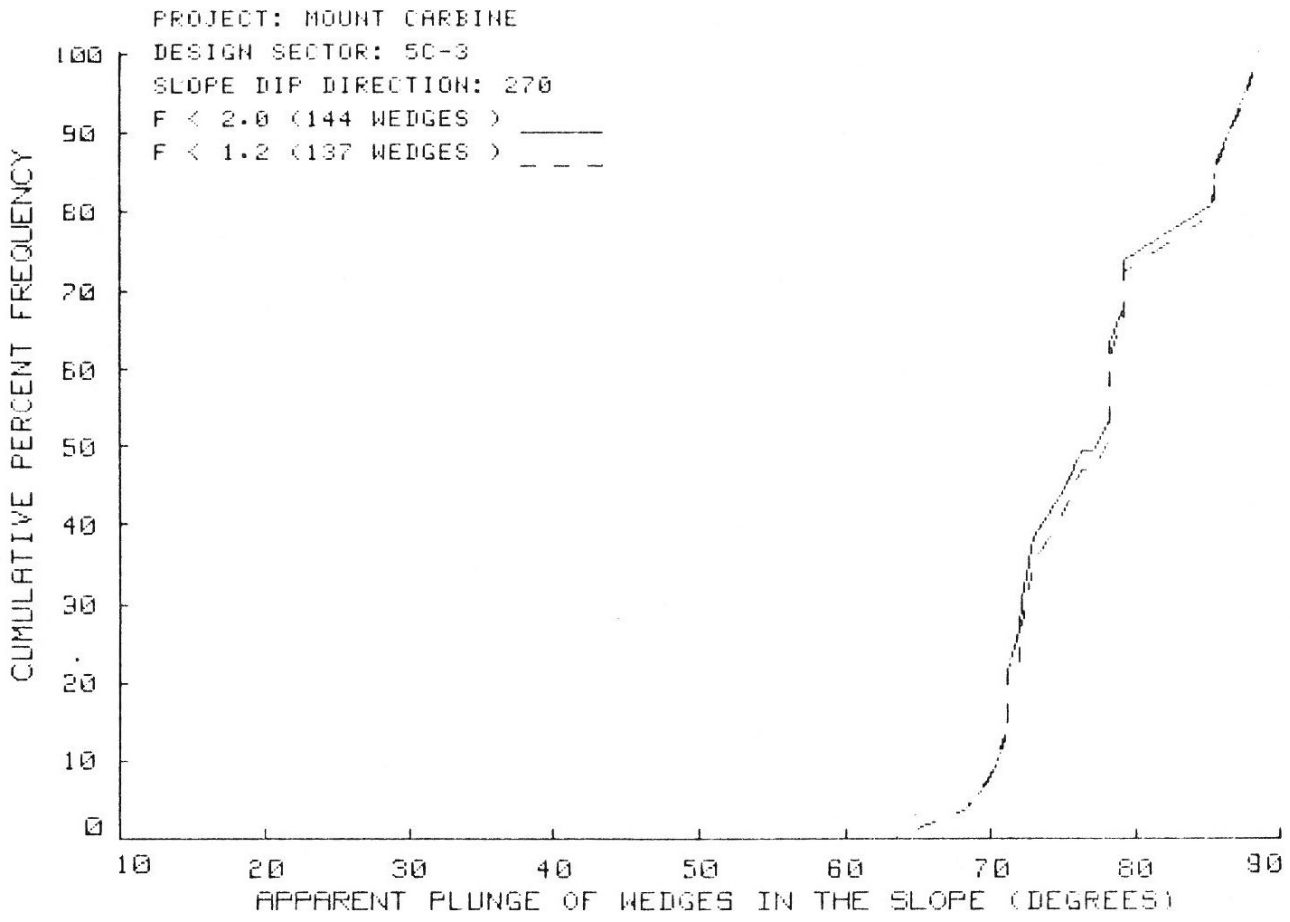

PROJECT: MOUNT CARBINE
DESIGN SECTOR: 5A-1
SLOPE DIP DIRECTION: 97
F < 2.0 (69 WEDGES)
F < 1.2 (52 WEDGES)
CUMULATIVE PERCENT FREQUENCY
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
APPARENT PLUNGE OF WEDGES IN THE SLOPE (DEGREES)

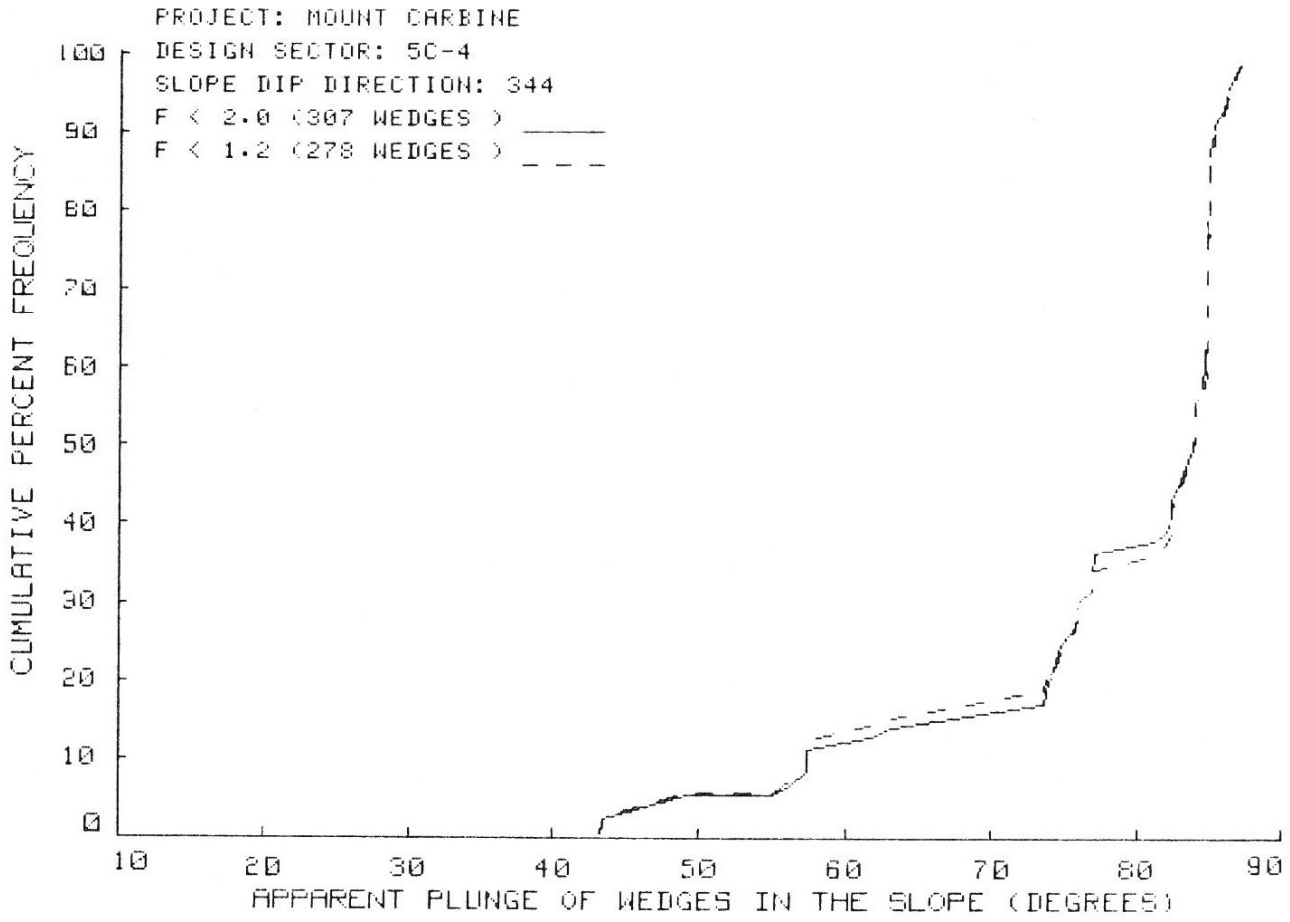

PROJECT: MOUNT CARBINE
DESIGN SECTOR: 5A-2
SLOPE DIP DIRECTION: 135
F < 2.0 (58 WEDGES)
F < 1.2 (41 WEDGES)
CUMULATIVE PERCENT FREQUENCY
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
APPARENT PLUNGE OF WEDGES IN THE SLOPE (DEGREES)

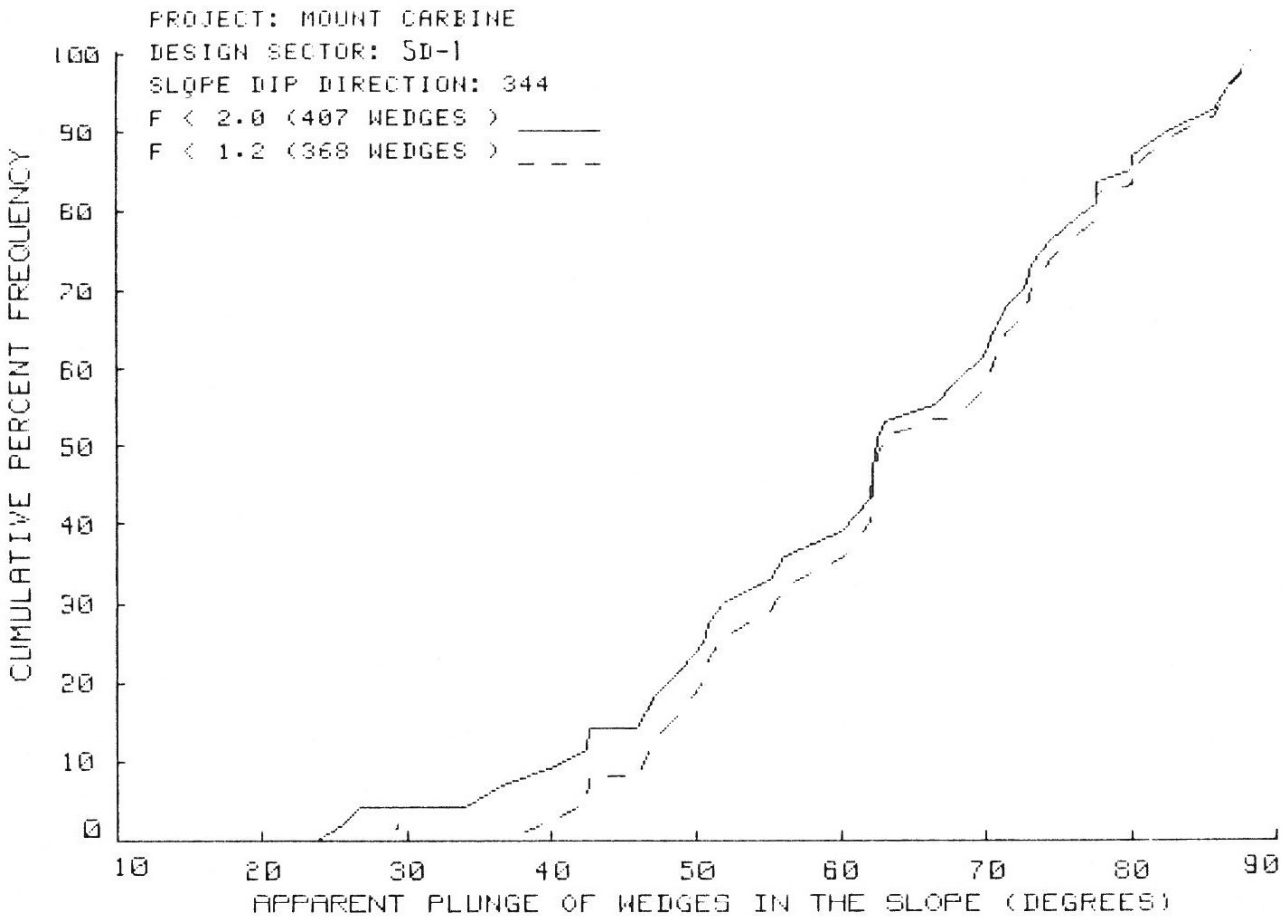

PROJECT: MOUNT CARBINE
DESIGN SECTOR: SB-1
SLOPE DIP DIRECTION: 166
F < 2.0 (52 WEDGES)
F < 1.2 (38 WEDGES)
CUMULATIVE PERCENT FREQUENCY
100
90
80
70
60
50
40
30
20
10
0
10
20
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40
50
60
70
80
90
APPARENT PLUNGE OF WEDGES IN THE SLOPE (DEGREES)

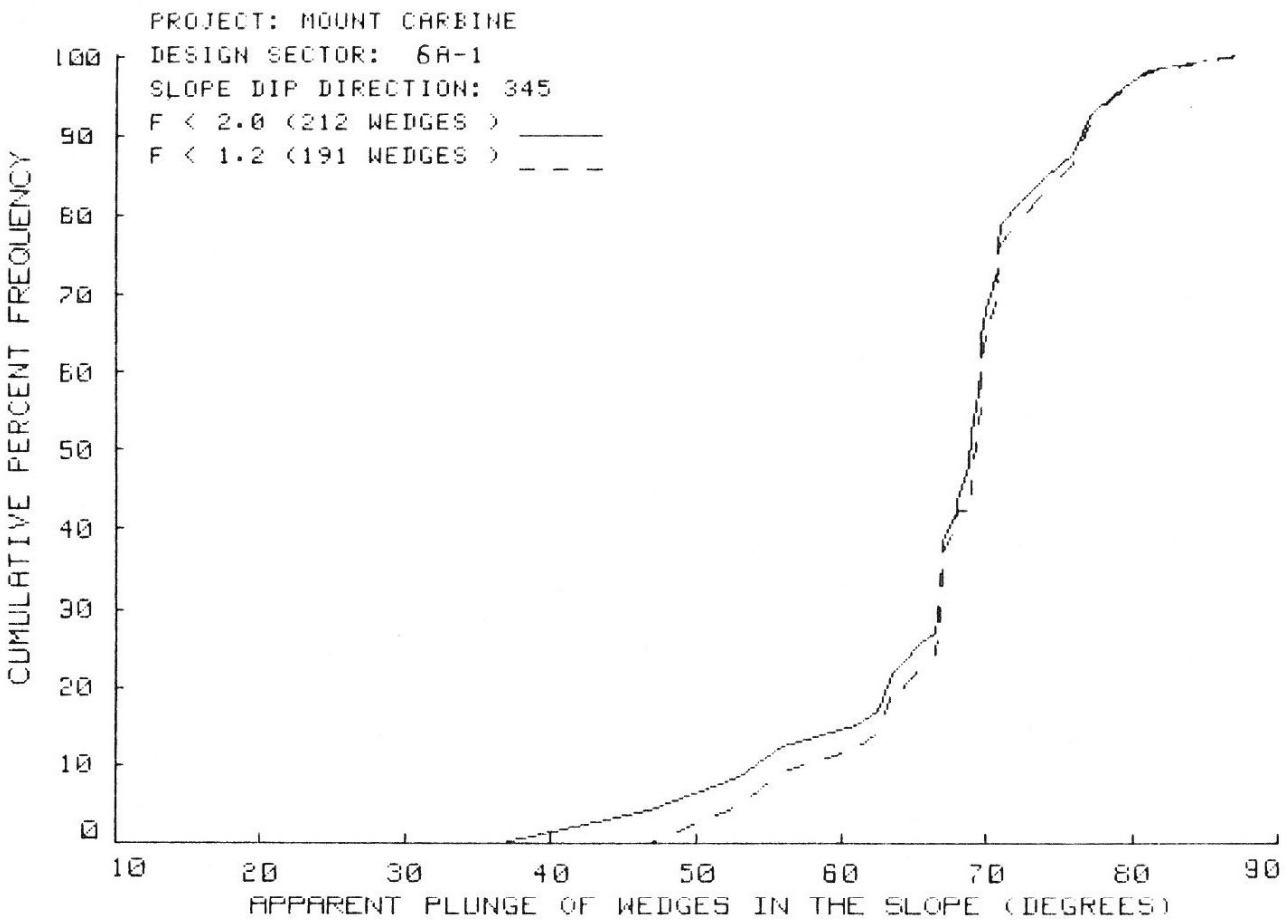

PROJECT: MOUNT CARBINE
DESIGN SECTOR: SC-1
SLOPE DIP DIRECTION: 178
F < 2.0 (57 WEDGES)
F < 1.2 (36 WEDGES)
CUMULATIVE PERCENT FREQUENCY
100
90
80
70
60
50
40
30
20
10
0
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60
70
80
90
APPARENT PLUNGE OF WEDGES IN THE SLOPE (DEGREES)

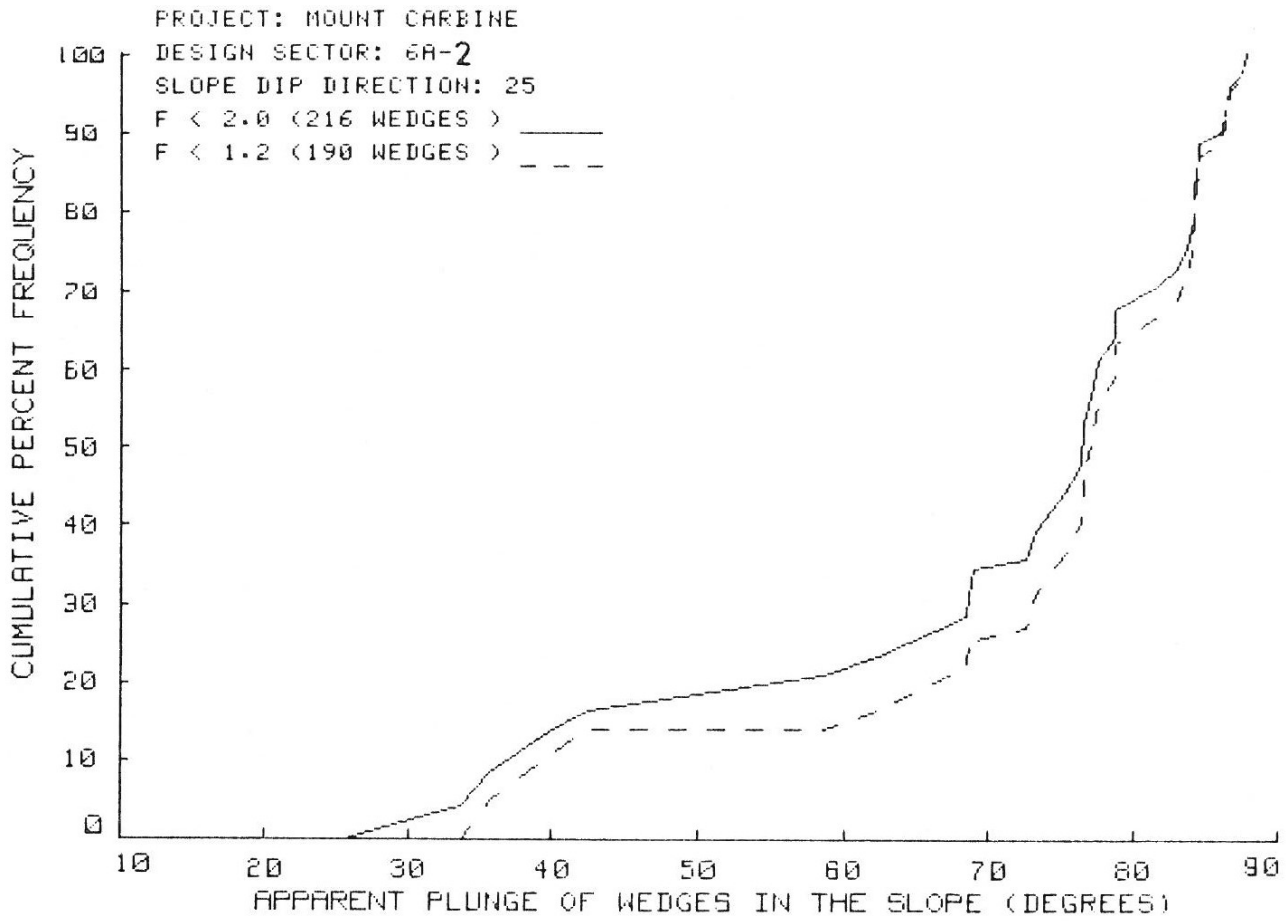

PROJECT: MOUNT CARBINE
DESIGN SECTOR: SC-2
SLOPE DIP DIRECTION: 197
F < 2.0 (114 WEDGES)
F < 1.2 (99 WEDGES)
CUMULATIVE PERCENT FREQUENCY
100
90
80
70
60
50
40
30
20
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0
10
20
30
40
50
60
70
80
90
APPARENT PLUNGE OF WEDGES IN THE SLOPE (DEGREES)

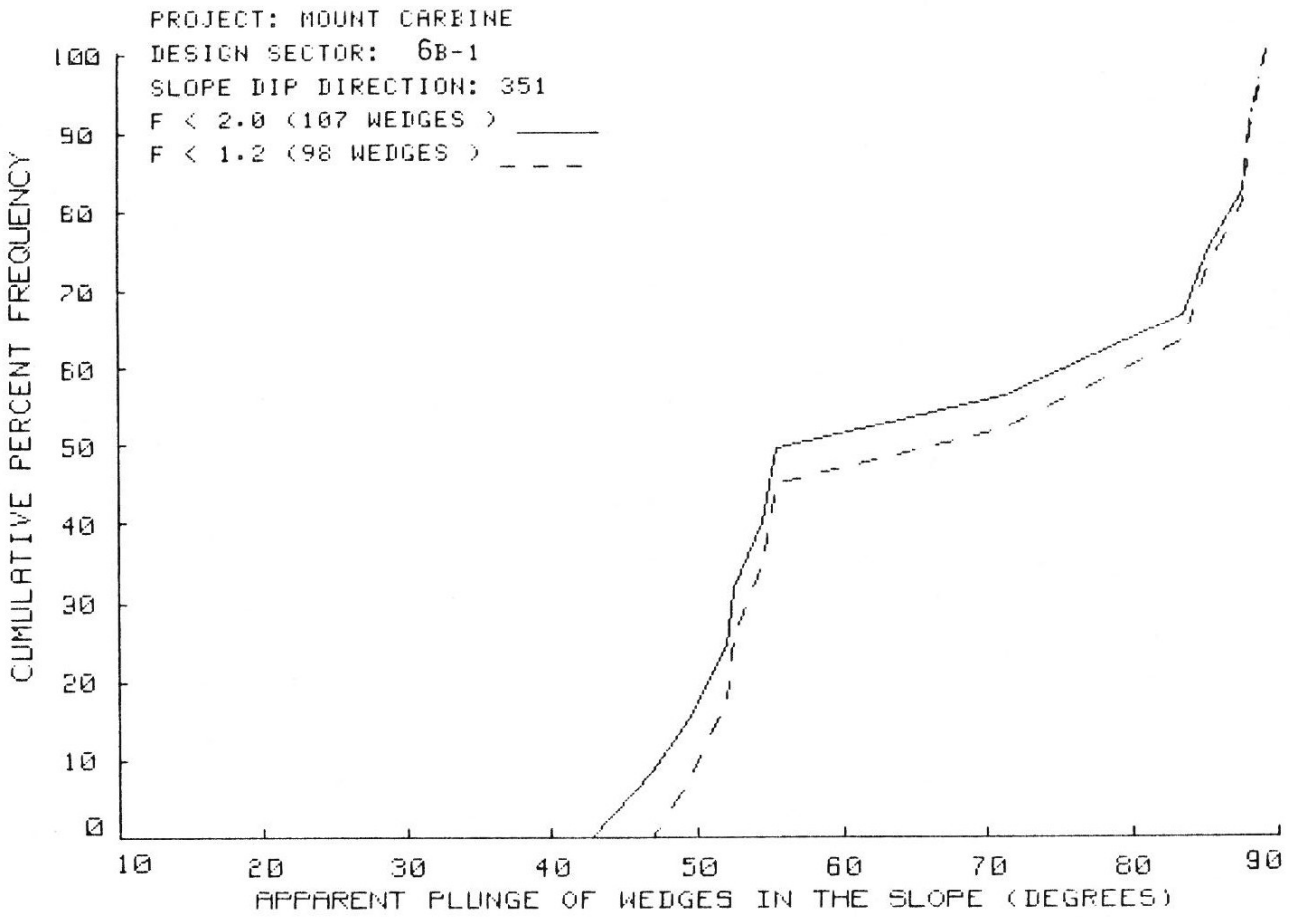

PROJECT: MOUNT CARBINE
DESIGN SECTOR: SC-3
SLOPE DIP DIRECTION: 270
F < 2.0 (144 WEDGES)
F < 1.2 (137 WEDGES)
CUMULATIVE PERCENT FREQUENCY
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
APPARENT PLUNGE OF WEDGES IN THE SLOPE (DEGREES)

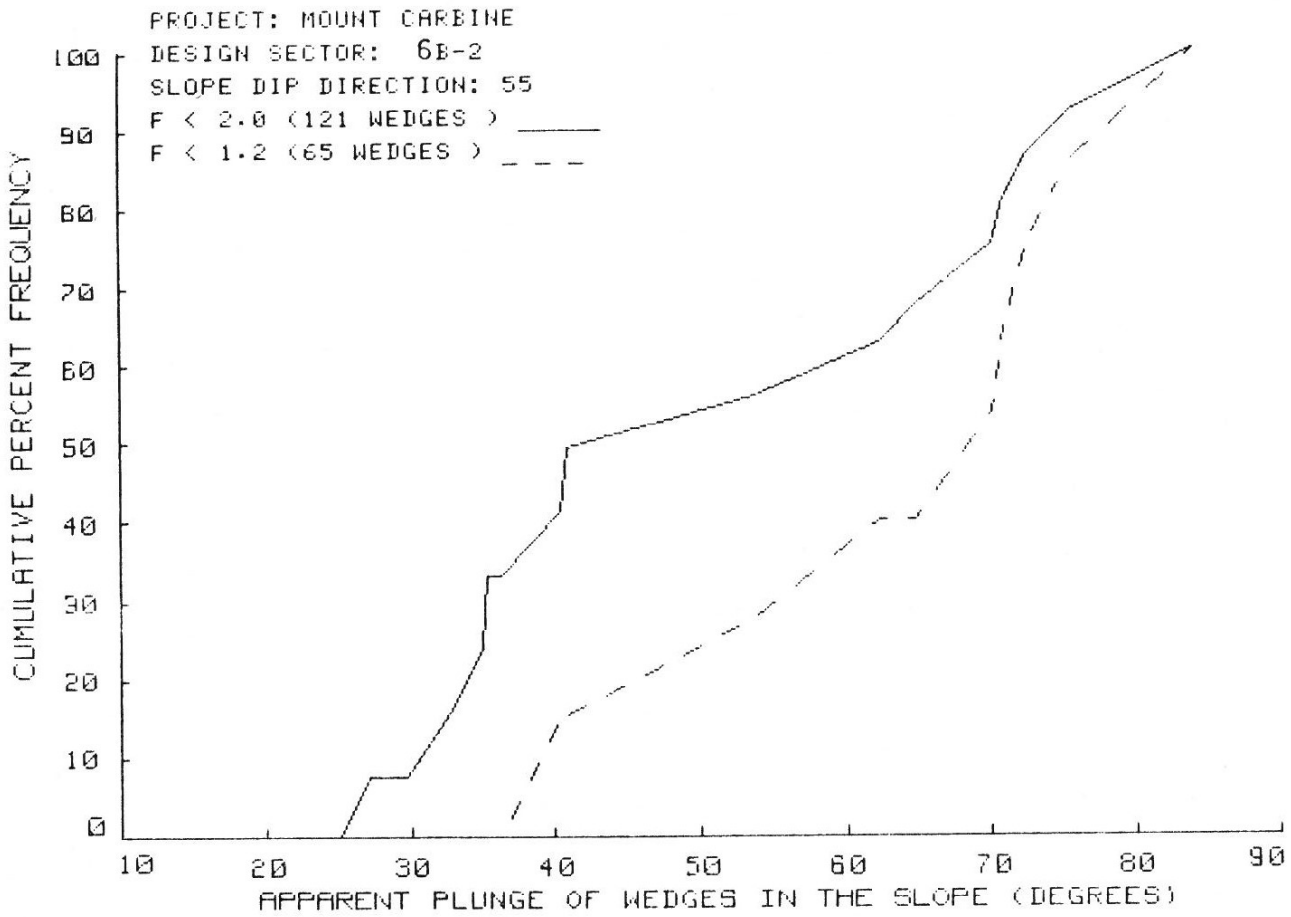

PROJECT: MOUNT CARBINE
DESIGN SECTOR: SC-4
SLOPE DIP DIRECTION: 344
F < 2.0 (307 WEDGES)
F < 1.2 (278 WEDGES)
CUMULATIVE PERCENT FREQUENCY
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
APPARENT PLUNGE OF WEDGES IN THE SLOPE (DEGREES)


PROJECT: MOUNT CARBINE
DESIGN SECTOR: SD-1
SLOPE DIP DIRECTION: 344
F < 2.0 (407 WEDGES)
F < 1.2 (368 WEDGES)
CUMULATIVE PERCENT FREQUENCY
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
APPARENT PLUNGE OF WEDGES IN THE SLOPE (DEGREES)


PROJECT: MOUNT CARBINE
DESIGN SECTOR: 6A-1
SLOPE DIP DIRECTION: 345
F < 2.0 (212 WEDGES)
F < 1.2 (191 WEDGES)
CUMULATIVE PERCENT FREQUENCY
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
APPARENT PLUNGE OF WEDGES IN THE SLOPE (DEGREES)


PROJECT: MOUNT CARBINE
DESIGN SECTOR: 6A-2
SLOPE DIP DIRECTION: 25
F < 2.0 (216 WEDGES)
F < 1.2 (190 WEDGES)
CUMULATIVE PERCENT FREQUENCY
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
APPARENT PLUNGE OF WEDGES IN THE SLOPE (DEGREES)


PROJECT: MOUNT CARBINE
DESIGN SECTOR: 6B-1
SLOPE DIP DIRECTION: 351
F < 2.0 (107 WEDGES)
F < 1.2 (98 WEDGES)
CUMULATIVE PERCENT FREQUENCY
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
APPARENT PLUNGE OF WEDGES IN THE SLOPE (DEGREES)


PROJECT: MOUNT CARBINE
DESIGN SECTOR: 6B-2
SLOPE DIP DIRECTION: 55
F < 2.0 (121 WEDGES)
F < 1.2 (65 WEDGES)
CUMULATIVE PERCENT FREQUENCY
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
APPARENT PLUNGE OF WEDGES IN THE SLOPE (DEGREES)

Appendix I:
Geotechnical Aspects of Environmental Approvals (GTS 2024)

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11 November 2024

Our Ref: gts_mcm_2024_prcp_geotech_v4.1

EQ Resources
Mt Carbine Mine
6888 Mulligan Hwy
Mt Carbine QLD 4871
Attn Mr A Bainbridge

Dear Mr Bainbridge,

GEOTECHNICAL ASPECTS OF ENVIRONMENTAL APPROVALS

This letter addresses the following items for the PRCP as requested by NRA's John Broughton by email dated 20/09/24 and subsequent correspondence.

- Geotechnical assessment of the open pit
- Geotechnical assessment of underground
- Geotechnical assessment of the Noise Bund design updated on 3/10/24, noting that the Noise Bund will become part of the closure Safety Bund.
- Geotechnical assessment of the Safety Bund at closure.
- Landform stability assessment of the Safety Bund post-closure.

1 LONG TERM STABILITY OF FINAL VOID

The proposed final void is shown pictorially in Figure 1-1 and as a snip generated from a 3D mine planning program in Figure 1-2. The geotechnical basis of the design of the open pit was provided by Piteau and Associates (1982). Piteau undertook very detailed mapping and analysis of structures exposed in the open pit and nearby road cuttings as they existed in 1981.

Designs were developed, based on these data, for which a criterion was that the estimated bench spillage, owing primarily to wedge failures and back break, would on average along less than 20% of the length of benches. The designs have been borne out by the minimal extent of spillage that was observed after the pit was drained in 2023 and that has occurred during current mining operations.



Figure 1-1. View of final void set in current landscape (Image from NRA).

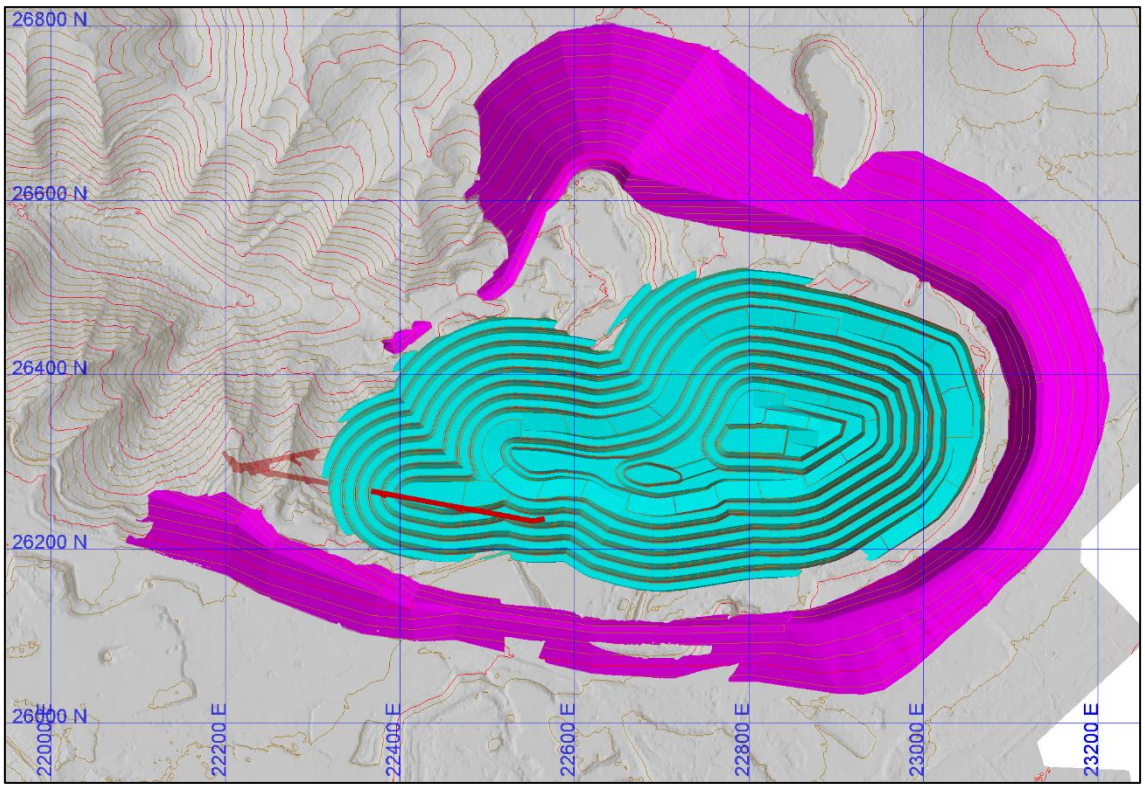


Figure 1-2. Plan view of final void generated from 3D triangulations in mine planning software showing existing decline and the perimetral safety bund (Triangulations from EQ Resources Local Mine Grid).

Having addressed the issue of bench scale failures, Piteau considered that “analyses of geological mapping data, core logs and strength testing results indicate that, within the range of overall slope angles, which are geometrically feasible, the possibility of deep seated failure of the whole slope along a single major discontinuity is small”. Piteau

considered that plane failures could occur along shallow dipping faults and shears but did not consider the likelihood sufficiently high to flatten the slopes with the proviso that the slopes should be progressively mapped, and provisions be made for remedial measures, if required. To date there has been no evidence of such planar failures. This is borne out by comparing photographs (Figures 1-3 and 1-4) of the pit taken in 1984 and after the pit was drained in 2023, having been full of water for approximately 35 years.



Figure 1-3. Panoramic view of the open pit showing exposure of South Wall Fault, 14/06/84. (Golder Associates, Review of Rock Mechanics, 1984)



Figure 1-4. Panoramic view of the open pit showing exposure of South Wall Fault, shortly after the pit had been dewatered.

Piteau did consider the possibility of time dependent strain and failure but considered the likelihood to be small because of the relatively high hardness and strength of most intact rocks in the pit.

To assist with long term stability, Piteau recommended that blast patterns, most particularly those near the final slope, should be designed so that blasting damage to the pit wall would be minimized. Piteau suggested that with regard to benches, for example, this could be done by reducing subgrade drilling and having blastholes span the bench crests. During the last geotechnical inspection in July 2024 it was evident that there would need to be changes in the blasting to achieve smoother and hence more stable walls. Site had begun the process of trialling alternative blast designs

Piteau raised concerns regarding the stability of the wall along the South Wall Fault. Golder & Associates (1984) were less concerned. Piteau recommended wall reinforcement using cable anchors which were installed. Most of those anchors are now dangling in the air have corroded or the rock around them has fretted away but, overall, the South Wall Fault has remained stable. In the current mine plan the excavation will extend behind the South Wall Fault resulting in removal of the fault in most of the pit.

By way of a check for overall stability, I carried out a very simple analysis for a cross section through the south wall using the triangulation model:

- “pit_designs_feb_2024_option_1_max_dual_I.00t”.

Under drained conditions, the minimum overall Factor of Safety (FOS) was calculated as 2.48 based on an assumed UCS of 80 MPa, a GSI of 50 and modelling the pit wall as a having a single rock mass strength calculated by the Generalized Hoek-Brown strength model as implemented in the Rocscience program Slide2. While not conclusive, the analysis does indicate that FOS for the overall stability of the pit is high and exceeds the usual DESI requirement of a FOS of ≥ 1.5 for a final void. The simple analysis is aligned with comments made in the Piteau report.

It is concluded that based on the Piteau 1982 design considerations, the absence of deterioration of the pit walls in fresh rock over the period that the pit has existed and the ground improvement likely to follow improved blasting designs that the walls will remain stable overall in the long term.

2 SUBSIDENCE DUE TO EXISTING DECLINE

The decline for the underground development does not currently interact with the pit. Figure 2-1 shows a plan of the Stage 3 pit shell and the existing decline and Figure 2-2 shows a cross section along the decline's alignment. As can be seen the existing decline will be mined out by the Stage 3 pit.

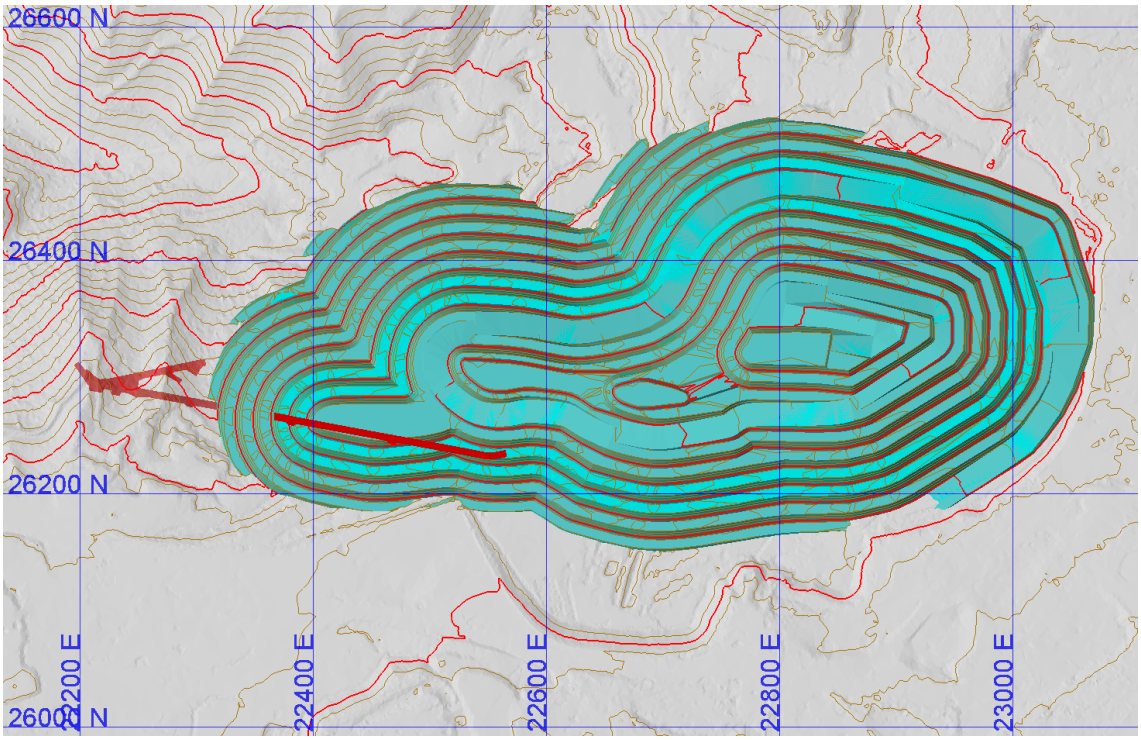


Figure 2-1. Plan showing Stage 3 pit shell and the as-constructed decline. Major contours are shown in red are at 20 m intervals (Mine Grid).

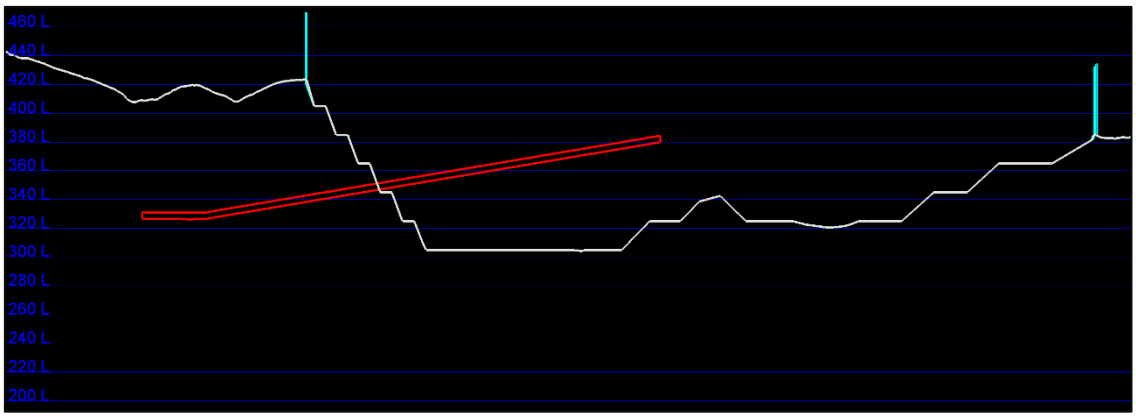


Figure 2-2. Cross section showing along the southern limb of the decline.

The entrance to the decline was uncovered on 8/07/24 and a view is shown in Figure 2-3. The ground surrounding the portal was in sound condition and there was no sign of cracks or other deformation. Steelwork used to construct the portal, and the initial bolting and strapping, had rusted and the decline was full of water up to the invert level but the portal was otherwise in good condition as can be seen in Figure 2-3. Despite the decline being full of water there was no sign of it seeping into the pit suggesting that the rock mass, although jointed is tight and impermeable.

Declines are necessarily designed to be stable structures. The arched roof profile is inherently stable and is enhanced by the high strength rock at Mt Carbine. Once drained, the decline will need to be inspected and routinely reinforced in accordance with current standards. It is expected that, mostly, only minimal pattern bolting will be required apart from locally, where faults are encountered. As described by Golder Associates, these will only be narrow zones. There may need to be some additional bolting around the opening where the Stage 3 pit intersects the decline to secure the benches in the immediate vicinity.

The existing decline has not contributed to any subsidence for over 30 years, and it is not expected to do so in the future.



Figure 2-3. View of the decline entrance, 8/07/24.

3 SUBSIDENCE DUE TO PROPOSED UNDERGROUND WORKINGS

EQ Resources proposes to undertake underground mining at Mt Carbine using the Avoca mining method. The method, named after the Avoca mine in Ireland, is a cut and fill method normally used in thin orebodies. The space created by mining is filled by waste rock. Consequently the risk of post-mining subsidence is minimised as the voids created by ore recovery have been substantially backfilled.

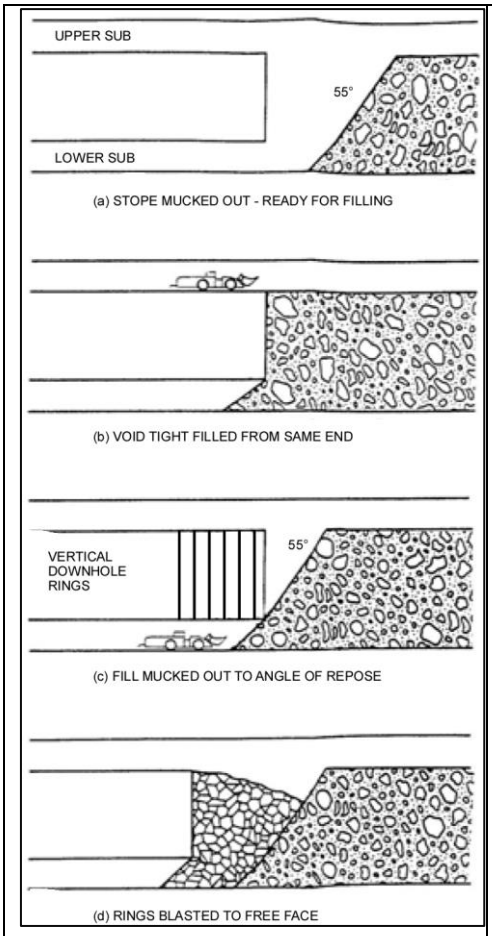


Figure 3-1. Schematic illustrating a version of the Avoca mining method.

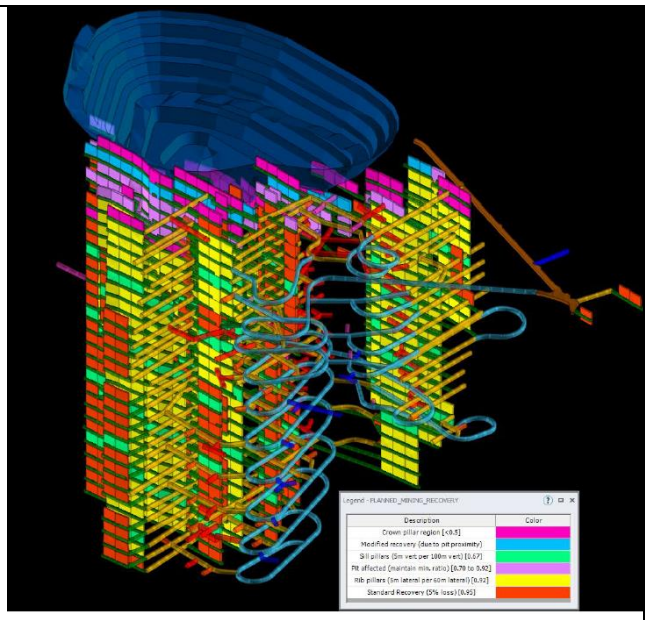


Figure 3-2. Overview of conceptual mine showing planned stope recoveries. View from NW. (Deswick, 2022, Fig 6-3).

A conceptual view of the underground development is shown in Figure 3-2 (Deswick, 2022). In relation to final void subsidence consideration would need to be given the crown pillar and preventing that from failing and thereby connecting completed underground mining with the open pit. Even if this were to occur it would not necessarily result in subsidence extending outside of the pit footprint.

The issue of subsidence, and underground rock mechanics more generally requires additional anlysis and design as recommended by Deswick.

4 GEOTECHNICAL ASSESSMENT OF NOISE AND SAFETY BUNDS

Two bunds are required for the open pit:

- A Noise Bund during production particularly to abate the noise from haul trucks as the pit gets deeper and
- A Safety Bund to provide a physical barrier against unauthorised or accidental entry to the vicinity of the pit.

The Noise Bund will be incorporated into the Safety Bund, and both (as the Safety Bund) will remain at closure.

ATC Williams (2022, Ch 7) has provided design guidelines for the Noise Bund. The Noise Bund was expanded (within design guidelines) during operations and evolved under operational requirement and planning for closure into the Safety Bund.

A plan of the Safety Bund is shown in Figure 4-1. A representative cross section along 26300N is shown in Figure 4-2 and a section through the maximum height of construction along 22600E is shown in Figure 4-3.

The EQ Resources design file “Safety Bund 20241003.00t” triangulation conforms with the design guidelines for the Noise Bund provided by ATC Williams.

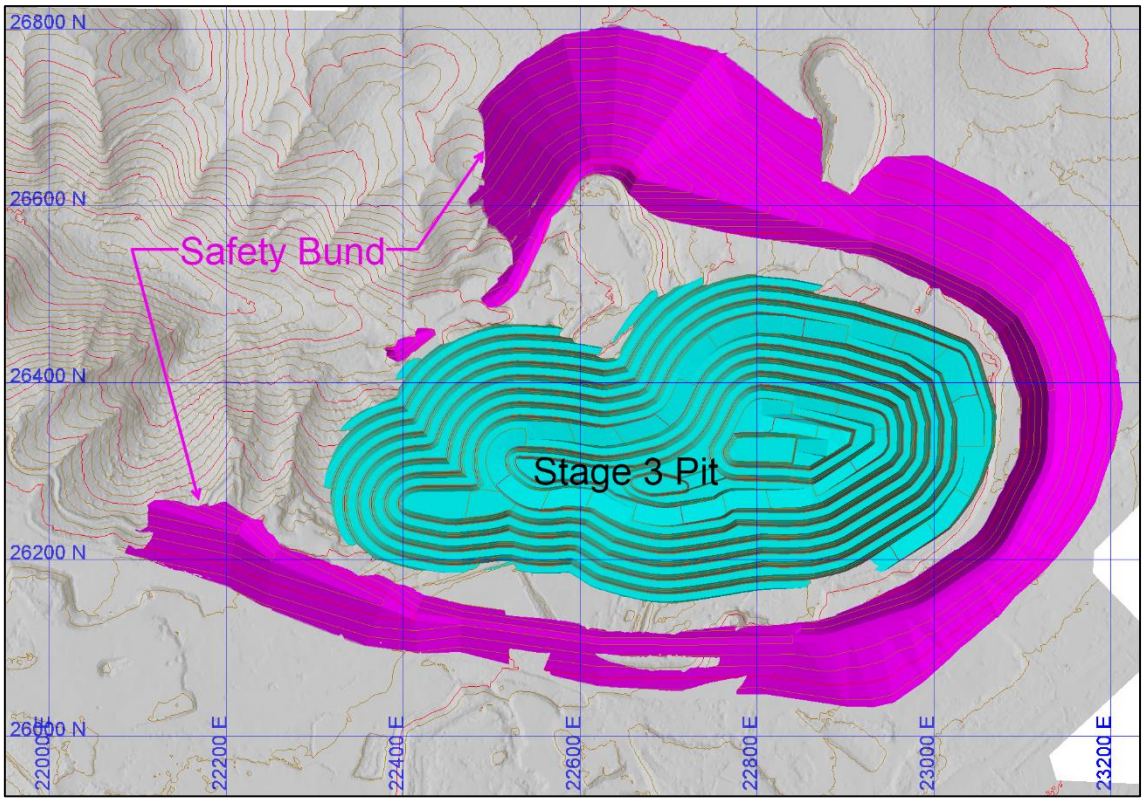


Figure 4-1. Plan view of Safety Bund (Mine Grid).

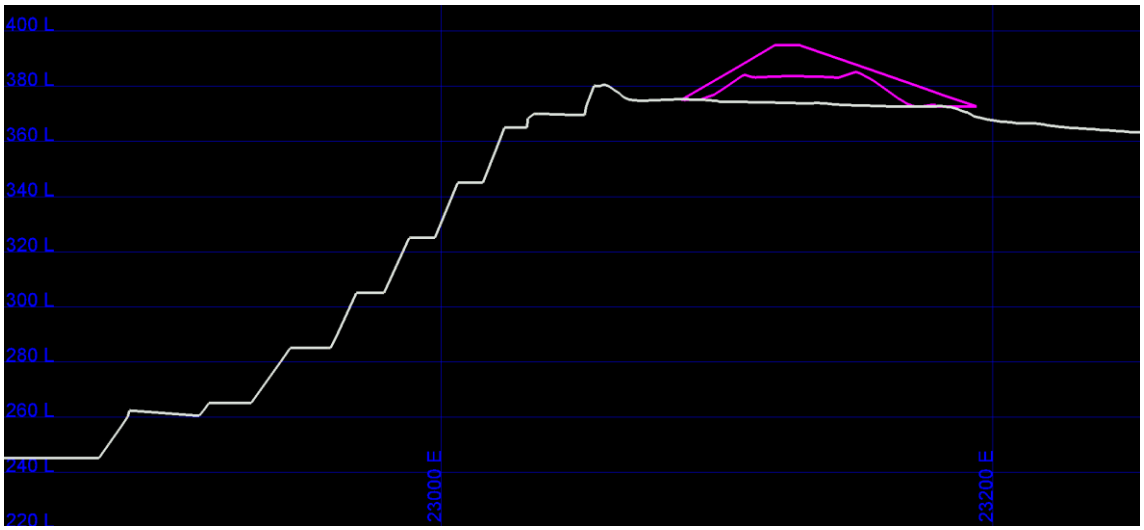


Figure 4-2. E-W cross section at 26300N Mine Grid.

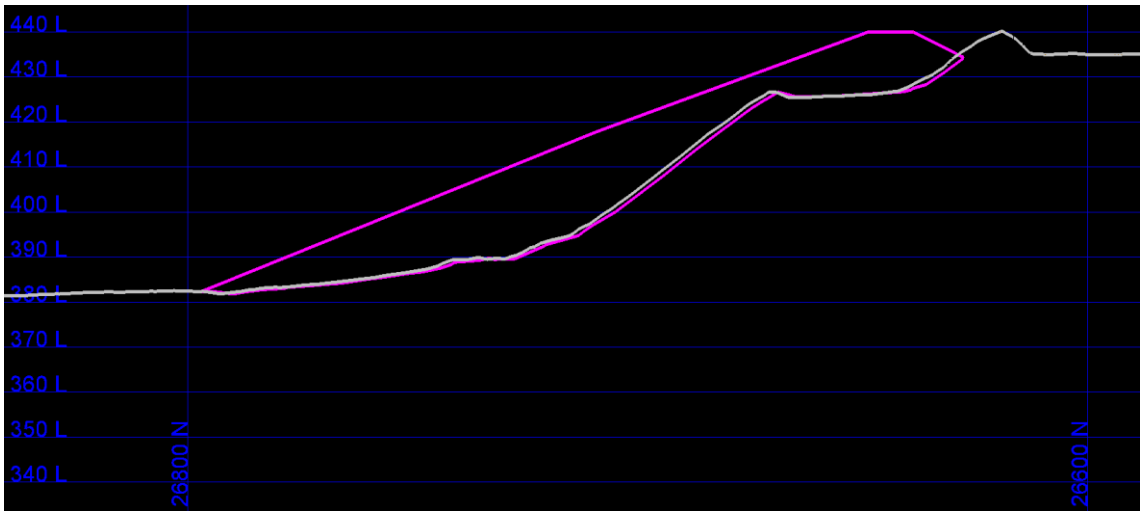


Figure 4-3. N-S cross section at 22600E Mine Grid.

4.1.1 Stability Analysis

Stability analyses were carried out on 2 cross sections to verify that the minimum factor of safety for the Safety Bund exceeds 1.5. DESI generally requires a minimum FOS of 1.5 for any final void slopes.

The first cross section, shown in Figure 4-2 is more typical of the Safety Bund. The second cross section, shown in Figure 4-3, has the greatest construction height and is restricted to the northwestern sector of the bund as can be seen from Figure 4-1.

The cross sections were analysed using the 2D limit equilibrium program Slide2. This is an industry standard program (Rocscience, 2024). A GLE/Morgenstern-Price circular analysis was carried out and the auto-refine search routine was used to identify the critical surfaces. The analysis was carried out left to right and right to left for the E-W cross section because the batter angles are different on each of the faces. Output plots are shown below.

The coarse nature of the rock means that it is reasonable to assume that the Safety Bund will not hold water and for that reason no water table has been included.

Design shear strengths that have been used are shown on the output plots.

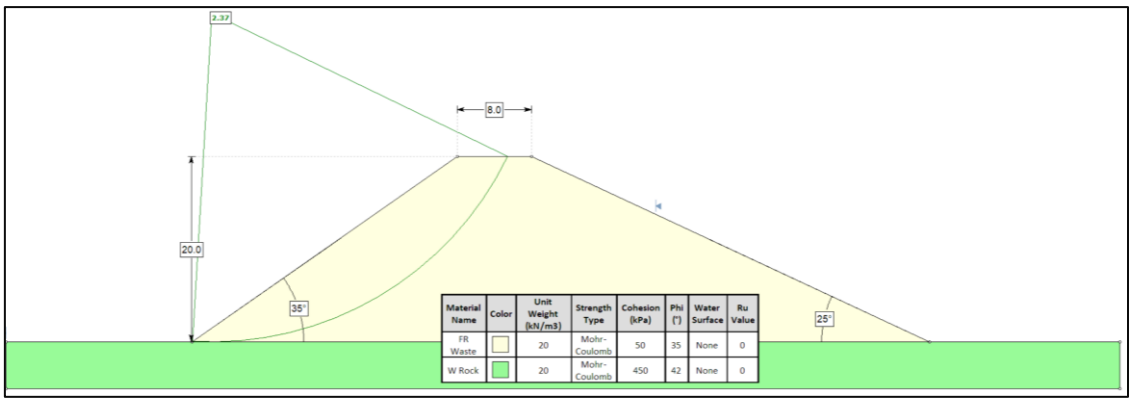


Figure 4-4. E-W section at 26300N - inside batter has minimum FOS = 2.37

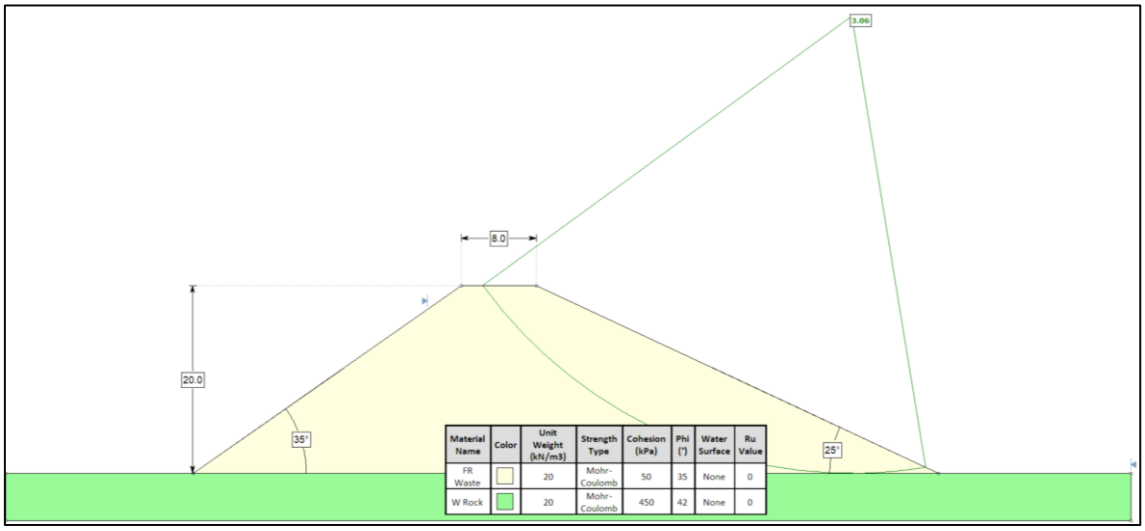


Figure 4-5. E-W section at 26300N - outside batter has minimum FOS = 3.06.

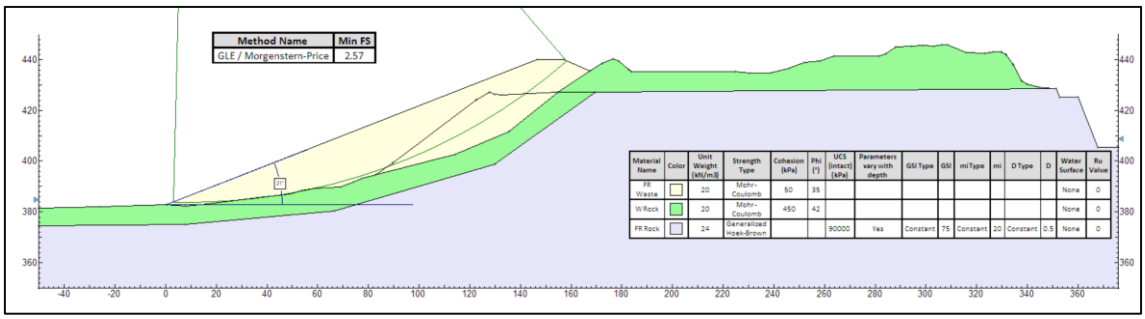


Figure 4-6. N-S cross section at 22600E – batter has minimum FOS = 2.57.

The results indicate that the minimum FOS values lie within the range of 2.4 to 3.1. These values substantially exceed the minimum of 1.5 that is required by Queensland DESI.

The FOS values, combined with the high strength and siliceous nature of the rock that will be used for the Safety Bund indicate that it would be long-lived and could be regarded as a permanent civil engineering structure.

There is a gap in the Safety Bund in the north-west sector where the ground becomes too rugged to construct a bund. The usual practice in these situations is to construct a fence with signage attached to prevent people from entering the vicinity of an abandoned pit.

5 LANDFORM STABILITY ASSESSMENT OF THE SAFTEY BUND POST-CLOSURE

Landform stability is often considered within the scope of a geotechnical stability assessment even though it is different and qualitative. As noted in Simmons et al (2024) “erosional processes may result in physical changes to the geometric arrangement and physical character of ground materials over time, and therefore constitute load action effects that must be included in geotechnical assessments”. For that reason it is considered valid to include this section in an otherwise geotechnically orientated report. It is considered that the Safety Bund will constitute a stable landform. In arriving at this assessment the following have been considered:

- Baseline recommended minimum acceptable factors of safety for new high consequence dams is in the range of 1.3 to 1.5 (Fell et al 2005). The FOS for the Safety Bund has been demonstrated to exceed this range of values. The inference is that for designs with this range of FOS values the structure will be stable both geotechnically and as a landform.
- Simmons et al (2024) note that “a stable slope is characterised by acceptable levels of observed movement together with a judgement that future levels of observable movement will remain acceptable. Mt Carbine has a history of open cut mining and the development of angle-of-repose slopes rock dump from the period of major production in 1973 – 1987. Those dumps, constructed from the same materials from which the Noise Bund has been built and the Safety Bund will be built, exist as stable landforms that have been tested by multiple weather cycles and extreme climatic events (eg cyclones). As an alternative to landscape evolution modelling, the observation of the rock dumps, some of which are potentially up to 50 years old, is a reliable indicator of likely future performance. These rock dumps are much higher than the Safety Bund and therefore more prone to landform instability owing to larger catchment areas yet have remained stable. There are many other high, angle-of-repose hard rock dumps throughout Queensland that are geomorphologically stable after close to a hundred years since mining began e.g. Kidston (Williams, 2006).
- Key characteristics of the rock used to build the Noise Bund is that it is highly siliceous strong (UCS > 80 MPa), blocky and angular. This means that the rock in the Safety

Bund and Noise Bund is highly resistant to weathering and will not break down significantly over the long term. The blockiness and angularity of the rock results in an inherently high particle to particle contact friction. It is and, combined with its angularity, is expected to remain tightly interlocked. As a result, weathering and erosion are unlikely to compromise the stability of the noise bund in the long term. The high strength and resistance to weathering of the rock is further indicated by the sale of oversize rock as coastal armour rock.

- The coarse size of the individual rock fragments makes them resistant to erosion even under conditions of heavy rainfall.

Figure 7 shows an overview of a section of the Noise Bund to show that it has been built from mainly blocky, fresh rock. A closer view of the Noise Bund is shown in Figure 8 to demonstrate the angular nature of the rock and that the blocks are in contact with each other i.e. there are relatively few interstitial fines separating the rock fragments.

Based on the above considerations and the observations captured in Figures 7 and 8 it is considered that the proposed post-mining Safety Bund will constitute a stable long-term landform.



Figure 7. Overview of a section of the Noise Bund showing the blocky nature of the construction material.



Figure 8. Closer view of Noise Bund to show the blocky and angular nature of the construction material.

A. Paul Maconochie RPEQ 5828
Principal Geotechnical Engineer

6 REFERENCES

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4. Forsythe DL, 1983. Geology of Mount Carbine Area, North Queensland. R.B. Mining Pty Ltd report dated August 1983.
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9. Simmons, J.V., Henderson, S. and Kennedy G., 2024. Guidelines for Assessment of Geotechnically Safe and Stabel Post-Mining Landforms. Australian Coal Association Research Program Project C34028 Report.
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Appendix J:
Mount Carbine Mining Stage 3 Water Management Plan – Final Void Water Balance Model (ATCW 2022c)

MEMORANDUM

TO	Tim Anderson	**COMPANY**	NRA Environmental Consultants
FROM	Lee Rigley	**OFFICE**	Brisbane
EMAIL	leer@atcwilliams.com.au	**PHONE**	0400 808 767
PROJECT TITLE	Mount Carbine Mining Stage 3 Water Management Plan		
SUBJECT	Final Void Water Balance Model		
DATE	8 December 2022	**OUR REF**	119190.04-M001Rev0

1 OPEN CUT PIT – FINAL VOID WATER BALANCE MODEL

1.1 Model Description

Final void water balance modelling for the Mount Carbine open cut pit has been undertaken as an extension of the GoldSim water balance modelling of the operational mine described in Mount Carbine Mining Stage 3 Water Management Plan (the WMP), completed by ATC Williams Pty Ltd in November 2022 **[1]**. The objective of the final void water balance model was to assess the long-term water balance of the pit in its closed condition following cessation of mining operations at the site. Consideration of climate change impacts (affecting rainfall and evaporation) were also modelled as alternative scenarios.

Daily rainfall applied within the model is outlined in Section 2.2 of the WMP. For the purposes of the final void model, daily evaporation applied was based on *Morton's lake evaporation*, sourced through SILO Data Drill. Morton's shallow lake evaporation model was developed specifically for calculating evaporation over shallow lakes from climatic measurements at nearby land-based meteorological stations. Based on the observed model outcomes of the final void water levels, use of Morton's lake evaporation was considered appropriate rather than applying pan factor adjusted evaporation data, given that the closest sites with recorded pan factors are Mt Isa Aero and Weipa Aero, which may not accurately represent the climatic conditions experienced at the site post-closure.

Rainfall runoff was simulated using the AWBM described in Section 6.3.2.4 of the WMP. Groundwater inflow rates for the final void are described in Section 6.3.2.5 of the WMP. Final void simulations were commenced following the assumed completion date of mining, ore processing and site rehabilitation. The climatic data sequence applied within the model was repeated to simulate a model period of 650 years, from 2027 to 2677

The geometrical shape of the final void was provided by EQ Resources (EQR) **[2]**.

1.2 Model Forecast Results

1.2.1 Final Void Scenario

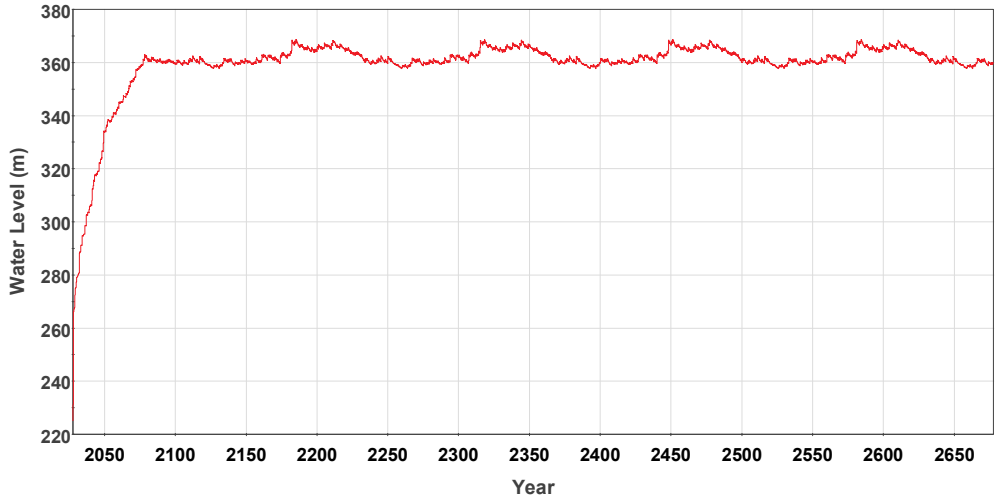
Predicted final void water levels are shown in **DIAGRAM 1**, noting that any overflows from the pit would occur at approximately RL 380 m.

Model results indicate the following:

- The Mount Carbine final void water level is predicted to take approximately 51 years to reach an equilibrium and will then oscillate between approximately RL 357 m and 369 m. The maximum forecast water level is approximately 11 m below the final void spill level.
- There is a very low risk of spill from the final void.

TAILINGS.WATER.WASTE.

DIAGRAM 1: Final Void Water Level



1.2.2 Climate Change Scenarios

Climate change scenarios based on application of average changes to precipitation and evaporation rates from the Queensland Future Climate Change Models **[3]** were modelled. Data for the RCP4.5 and RCP8.5 Scenarios were applied to the final void model described above. The adopted pan evaporation and rainfall climate change data for these two scenarios are presented in **TABLE 1** and **TABLE 2**. The seasonal climate change factors shown represent the percentage change in rainfall and pan evaporation relative to the historical reference period of 1986 to 2005. This period is adopted as an industry standard baseline.

TABLE 1: RCP4.5 Adopted Climate Change Rainfall and Pan Evaporation Factors

Time Period	Seasonal Climate Change Factors (% change relative to 1986 to 2005 historical reference period)			
	Summer	Autumn	Winter	Spring
Rainfall				
2020-2039	-5.2	-4.8	-5.9	-2.3
2040-2059	-1.7	-3.2	0.9	-3.6
2060-2079	-2	-7.1	-14	0.63
2080-2099	-1.1	-6.5	-14	2.6
Pan Evaporation				
2020-2039	9.3	8.4	6.6	5.8
2040-2059	10	11	8.7	8.6
2060-2079	13	13	10	9.6
2080-2099	13	15	12	9.8

TAILINGS.WATER.WASTE.

TABLE 2: RCP8.5 Adopted Climate Change Rainfall and Pan Evaporation Factors

Time Period	Seasonal Climate Change Factors (% change relative to 1986 to 2005 historical reference period)			
	Summer	Autumn	Winter	Spring
Rainfall				
2020-2039	-4.4	0.69	-5.1	2.4
2040-2059	-1.4	-1.8	-8	-7.7
2060-2079	-0.073	-6.4	-2.2	3.1
2080-2099	-1.5	-9.2	4.6	-4.1
Pan Evaporation				
2020-2039	9.2	7.7	5.5	6.1
2040-2059	13	13	9.4	10
2060-2079	16	20	15	16
2080-2099	23	30	23	24

It is noted that GoldSim interprets the climate change factors at the middle of the time period and interpolates the change factors between these central dates. The climate change model scenarios were also run for 650 years, from 2027 to 2677.

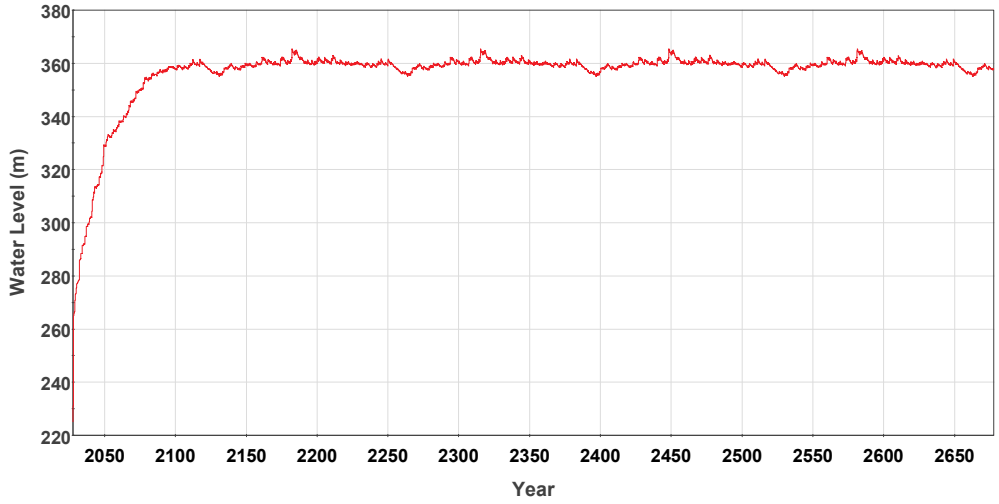
1.2.2.1 RCP4.5 Scenario Results

The RCP4.5 scenario represents the scenario where CO_2 concentrations increase steadily until after the mid-century, with CO_2 concentrations stabilising around 2060. From the climate change factors for this scenario presented in **TABLE 1**, the Mount Carbine area will likely experience generally decreasing rainfall and increasing evaporation.

Predicted final void water levels under the RCP4.5 scenario are shown in **DIAGRAM 2**.

TAILINGS.WATER.WASTE.

DIAGRAM 1: Final Void Water Level – Climate Change Scenario RCP4.5



The RCP4.5 scenario model results indicate the following:

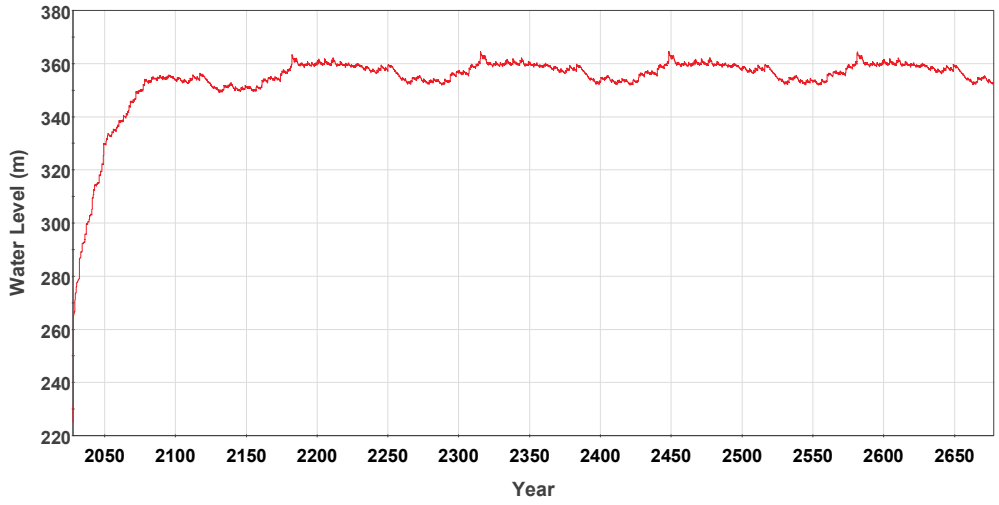
- The final void water level is predicted to take approximately 84 years to reach an equilibrium and will then oscillate between approximately RL 355 m and 365 m. The maximum forecast water level is approximately 15 m below the final void spill level.
- There is a very low risk of spill from the final void.

1.2.2.2 RCP8.5 Scenario Results

The RCP8.5 scenario represents a future with little curbing of emissions, with a CO_2 concentration continuing to rise rapidly.

Predicted final void water levels under the RCP8.5 scenario are shown in **DIAGRAM 3**.

DIAGRAM 3: Final Void Water Level – Climate Change Scenario RCP8.5



TAILINGS.WATER.WASTE.

Model results indicate the following:

- The final void water level is predicted to take approximately 154 years to reach an equilibrium and will then oscillate between approximately RL 352 m and 364 m. The maximum forecast water level is approximately 16 m below the final void spill level.
- There is a very low risk of spill from the final void.

1.3 Conclusions and Recommendations

1.3.1 Conclusions

This memorandum presents the results of final void water balance modelling of the Mount Carbine open cut pit. The modelling is based on information and data provided by EQ Resources and NRA Environmental Consultants. It is concluded that water levels within the final void would reach equilibrium below the final void spill level, and as such is not expected to spill under current climatic conditions nor projected climate change scenarios.

1.3.2 Recommendations

The following are recommendations for future water management plans:

- Ongoing monitoring and modelling of groundwater inflows into (and outflows from) the Open Cut Pit be undertaken. This will provide additional information for any future updates to the water balance model and final void model, which will refine the estimates of the expected long-term water levels within the final void and associated probability of spills.
- Implementation of site climate data monitoring, including rainfall and evaporation, to more accurately model the climatic conditions at the Mount Carbine site, will similarly refine future estimates of long-term water levels and associated probability of spills.

1.4 References

[1] ATCW (2022), Mount Carbine Mining Stage 3 Water Management Plan, Ref 119190.04R01_0, 30 November 2022

[2] EQ Resources (2022), 'Final Void Surface Designs', Stage 3_PIT DESIGNS_V2_STAGE 4_SURFACE_3.dxf, 7 October 2022.

[3] State of Queensland (2022), "Queensland Future Climate Dashboard', The Long Paddock, https://www.longpaddock.qld.gov.au/qld-future-climate/dashboard/#, Queensland Government.

Appendix K:
Mount Carbine Operations – Revised Conceptual Groundwater Model (RLA & Hydrogeologist 2022)

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15 November 2022

EQ RESOURCES

MOUNT CARBINE OPERATIONS

REVISED CONCEPTUAL GROUNDWATER MODEL

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1.0 INTRODUCTION

Rob Lait and Associates Pty Ltd (RLA) was engaged by EQ Resources to revise the conceptual groundwater model for the Mount Carbine project. The original conceptual groundwater model was developed by RLA in 2012, and an additional ten years of groundwater level and quality data is available to refine the conceptual groundwater model. Additional groundwater monitoring bores were installed within the last 12 months to further inform groundwater conditions at the site. The installation of the groundwater monitoring bores was completed in conjunction with Natural Resource Assessments Pty Ltd (NRA).

The revised conceptual groundwater model presented is a collaborative assessment between RLA and hydrogeologist.com.au. The revised conceptual model was developed to support an Environmental Authority (EA) amendment and to assist in the assessment of groundwater exceedances.

2.0 PHYSICAL SETTING

2.1 Site features

The township of Mount Carbine is located approximately 70 km north of Mareeba in northern Queensland. The project abuts the northern outskirts of the town.

Figure 1 shows the site infrastructure associated with the Mount Carbine project, which includes:

- An underground portal and associated workings.
- An existing open pit which was mined in the 1970s and 1980s. The pit has slowly filled with water over time from a combination of direct rainfall, rainfall runoff, groundwater seepage and inputs from other water management structures at the site. Measurements provided by EQ Resources indicate that the pit lake currently has an elevation of 350 mAHD (EQ Resources, 2022a).
- Tailings storage facilities (TSF) and associated water impoundments.
- Low-grade ore stockpiles.
- A rejects stockpile.



Figure 1: EQ Resources site infrastructure features and layout (figure courtesy of Natural Resource Assessments Pty Ltd)

2.2 Topography and drainage

The regional topography is dominated by the floodplain of the Mitchell River and a range that separates the Mitchell River and Daintree River catchments. The foothills of the range rise approximately 150 m above the elevation of the floodplain. The elevation of the site varies from 350 mAHD to 500 mAHD.

The catchment to the immediate north of the open pit (Carbine Hill) and within the pit crest is locally diverted to the open pit (pers comm.; T Bainbridge, EQ Resources). Otherwise, surface waters around the open pit flow towards Manganese Creek, while surface waters around the low-grade stockpile flow towards Holmes Creek. Holmes Creek and Manganese Creek both discharge downstream to the Mitchell River (Figure 2).

Typically, drainage features are controlled by the development of faults and fracture zones. A dendritic drainage pattern is evident in the range to the north of the project, however the pattern rapidly loses definition at the base of the slope. This drainage pattern suggests that the path of Manganese Creek is structurally controlled by a system of conjugate joints in the underlying Hodgkinson Formation.

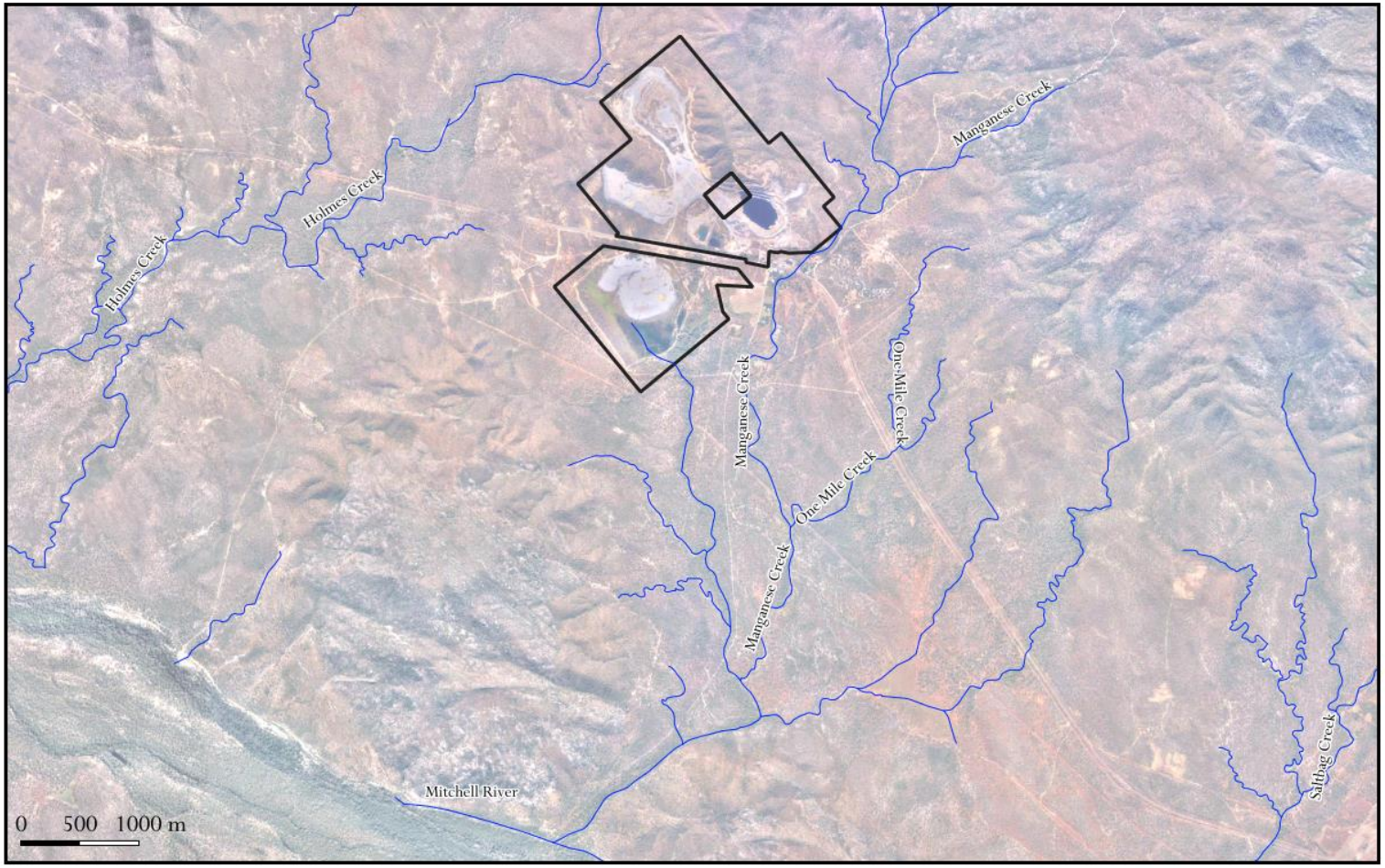


Figure 2: Watercourses

2.3 Geology

The mapped geology is shown in Figure 3 and includes reference to the following geological units:

- Cainozoic sediments, including colluvium, weathered sediments, and poorly consolidated sediments;
- early Permian Mount Carbine granitoid intrusives; and
- Silurian to Devonian aged Hodgkinson Formation.

No developed alluvium is present within the vicinity of the Mount Carbine project.

The Mount Carbine project is covered with a laterally extensive regolith of in-situ weathered Hodgkinson Formation. The regolith is typically up to 10 m thick on-site, however in the elevated terrain the regolith is thin and rocky. The depth of regolith cover (CSIRO, 2015) indicates a general thickness of between 0 m to 10 m over the project site, consistent with site observations. The depth of regolith is shown in Figure 4.

The project lies within the Hodgkinson Formation. This is an extensive sequence of marine silici-clastic rocks, dominated by deep water turbidite sequences (Bultitude *et al.*, 1990). The formation is commonly described as 'shale' by drilling contractors. Subordinate chert layers and metabasalt lenses occur locally, and muddy sandstone (or 'greywacke') is common. Where granitoid intrusives occur, the Hodgkinson Formation is locally metamorphosed to hornfels. RLA (2012) describes a well-developed slaty cleavage within the Hodgkinson Formation, which generally strikes in a northwest-southeast direction and dips towards the southwest at angles of 70° to 90° (Bultitude *et al.*, 1990).

Permian granitoid intrusives are mapped approximately 300 m southeast of the Mount Carbine open pit, adjacent to and beneath Manganese Creek. At Mount Carbine, the ore deposit sits within the hornfels occurring adjacent to the margin of the Mount Carbine Granite. Several felsic dykes cut through the project site (EQ Resources, 2022). Figure 3 shows a mapped felsic dyke adjacent to the western margin of the open pit. The felsic dykes generally strike in a north-northeast orientation, consistent with the orientation of the mapped granitoid.

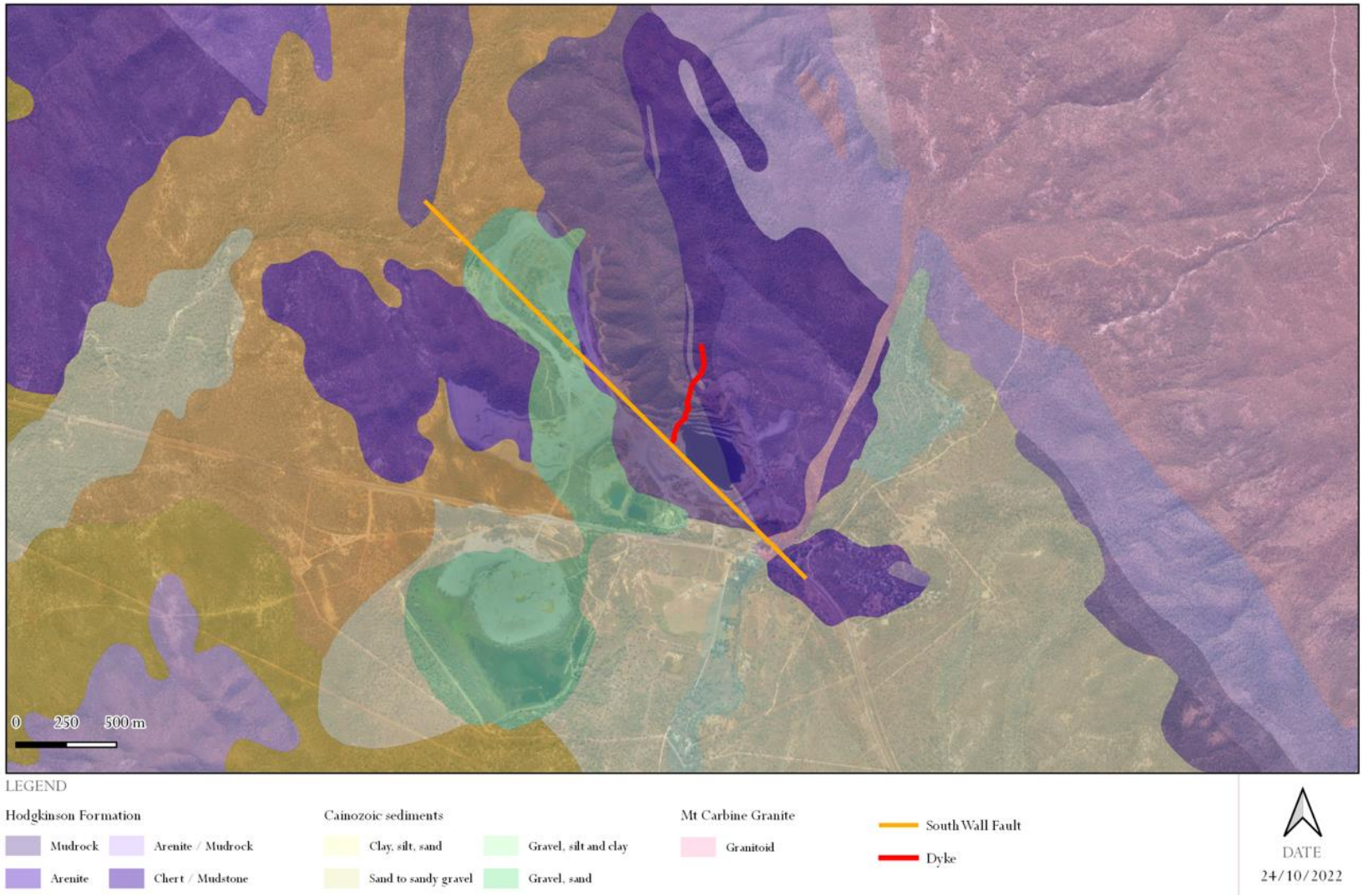


Figure 3: Geology map

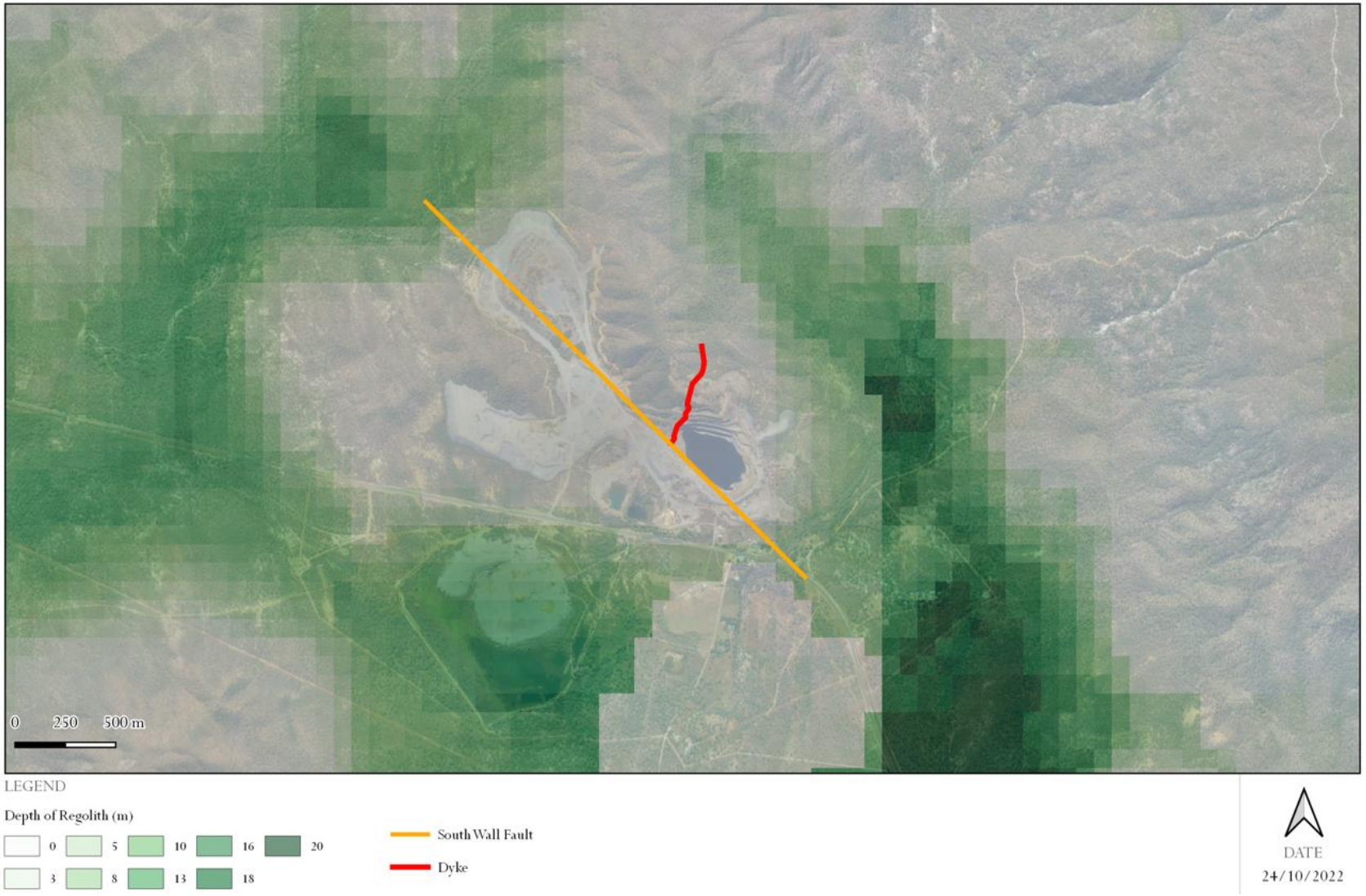


Figure 4: Depth of regolith

A review of the geology and structure at the site was undertaken by EQ Resources in October 2021 (EQ Resources, 2021) and describes the primary lithologies observed in the open pit as:

- ***Metasediments*** *– the major rock unit within the pit, this unit consists of hornfelsed mudstones and interbedded rudites, with a prominent cleavage. Alteration within the unit varies from pervasive silicification to hornfelsed cordierite chlorite. Breaks along cleavage and schistosity planes.*
- ***Metavolcanics*** *– located on the eastern end of the pit and on the south side of the South Wall Fault (SWF) this unit is pale green with greenschist facies alteration and contains locally hard siliceous chert bands.*
- ***Quartz Veins*** *– this unit consists of white, bucky quartz, typically less than 20 cm in width. Quartz veins can be barren or contain tungsten.*
- ***Dyke Material*** *– two types of dykes are observed - a pale, uniform fine-grained felsic dyke that is present as a 10 to15 m wide dyke at the western end of the pit; and a dark green/grey basic dyke that is present as a 0.5 to 1 m wide dyke cross-cutting the pit.*

Geological structure

Structural features have a major influence on the geology of the project site. EQ Resources (2021) discusses the dominant structural feature of the site as follows:

"Mount Carbine sits at a spur on a major arc parallel fault called the South Wall Fault (SWF). The SWF is a thrust that appears to be a long-lasting fault forming at the time of compression and the district scale isoclinal folding of the basement rock… The SWF truncates the tungsten orebody at an angle of 70 degrees to the grid north. It forms a boundary fault on the south-west side of the mineralisation (deposit). Evidence suggests it is a reverse thrust fault… Other minor faults occur, orientated in a northerly direction and show less severe movement."

The general alignment of the SWF is shown in Figure 3. EQ Resources (2022b) provides further discussion on the SWF:

"The SWF truncates the ore body and forms the southern boundary of the pit. This is a steep (75 degrees) reverse fault… The fault typically occurs as one central 0.5 to 1.0 m zone of intense clay crushed rock or, less frequently, in two parts separated by 1 to 2 m of fractured rock. The clay is greasy dense montmorillonite clay with 20-30% ground-up, but visible, rock particles of mostly metavolcanic rock. It is a clastic fault of high elasticity due to the clay content. The orientation and extent of the fault is well known … and it is seen to be very consistent in its 75° dip to the grid north direction… The fault has a fractured footwall for 1 to 5 m in width with only minor extra fracturing observed in the hanging wall."

There is generally little evidence of faulting at the surface as the regolith obscures any geological structure.

Further information on the SWF is included in Appendix A.

3.0 UPDATED GROUNDWATER INFORMATION SINCE 2012

3.1 Groundwater monitoring bores

Table 1 summarises the groundwater monitoring bores that were installed by Carbine Tungsten in November 2011. The Rural Fire Brigade (RFB) bore is also used by EQ Resources for groundwater quality monitoring. The bore locations are shown in Figure 5.

Table 1: 2011 GROUNDWATER MONITORING BORES

Bore ID	*Easting*	*Northing*	*Depth drilled (mBGL)*	*Screened zone (mBGL)*	*Airlift yield (L/s)*	*Surface elevation * (mAHD)*
MB1A	299177	8171929	36.5	Not reported	Not reported	364.54
MB1B	299177	8171929	74	44-74	5.5	364.91
MB3A	301004	8172643	60	30-60	0.5	376.50
MB3B	301004	8172643	90	72-90	0.4	376.89
MB4A	299994	8170776	30	18-30	5.8	353.49
MB4B	299994	8170776	61	37-61	25.0	353.30
MB5A	298226	8172597	30	18-30	3.0	357.30
MB5B	298226	8172597	60	42-60	Not reported	357.41
MB6A	300597	8171181	31	19-31	1.7	357.19
MB6B	300597	8171181	62.5	44.5-62.5	2.0	357.28
RFB	301144	8171764	Not reported	Not reported	Not reported	360.87

Note: mBGL – metres below ground level
Coordinates in GDA94, Zone 55
* It is not clear whether this elevation represents ground level or the top of the bore monument. For the purposes of this assessment, it is assumed that this elevation represents ground level.

The groundwater monitoring bore network installed in 2011 comprises the current EA monitoring network. Groundwater level and quality data is regularly measured to monitor groundwater conditions at the site.

Table 1 shows that two aquifer intervals were targeted by the 2011 groundwater monitoring bores - one at a depth of 30 m or less, and a deeper interval at a depth of 60 m to 90 m. Geology logs for the monitoring bores indicate that the bores all intersected shale, which has been interpreted as the Hodgkinson Formation as described in RLA (2012).

3.2 Surficial bores

Table 2 summarises the surficial bores (SB bores) that were installed by EQ Resources in December 2021. The bores were installed to assess the extent and behaviour of groundwater within the regolith (i.e. at depths generally less than 10 m), and to identify any recharge that may occur within the regolith over the wet season. The SB bores are further discussed in NRA (2022b). The locations of the SB bores are shown in Figure 5. Bore logs for the SB bores are also presented in NRA (2022b).

Table 2: 2021 SURFICIAL BORES						
Bore ID	***Easting***	***Northing***	***Depth drilled (mBGL)***	***Screened zone (mBGL)***	***Static water level (mBTOC)***	***Top of monument elevation (mAHD)***
SB02	299217	8171190	9.5	5.7 – 8.7	Dry	358.78
SB03	299579	8170806	9.5	5.9 – 8.9	8.58	356.71
SB04	299849	8170898	10.0	6.0 – 9.7	5.86	353.98
SB05	300056	8171184	16.5	5.5 – 9.0	4.34	355.35
SB07	299346	8172108	10.0	6.1 – 9.1	Dry	365.07
SB08	299964	8171852	9.0	5.9 – 8.9	Dry	363.63
SB09	300331	8171786	10.0	6.1 – 9.1	Dry	363.47
SB10	299633	8171923	9.7	6.2 – 9.2	Dry	362.01
SB11	299458	8173194	10.0	6.0 – 9.0	3.53	370.94

Note: mBGL – metres below ground level
mBTOC – metres below top of casing
Coordinates in GDA94, Zone 55

SB02, SB07, SB08, SB09 and SB10 did not intersect groundwater during drilling, and these bores have remained dry since installation. SB03, SB04, SB05 and SB11 all record a groundwater level and are monitored for groundwater levels only.

3.3 Investigation bores

Table 3 summarises the investigation bores (IB bores) that were installed by EQ Resources in January 2022. The bores were installed to expand the groundwater monitoring network, assessing groundwater levels and quality across the site. IB01, IB02 and IB08 were located to assess the groundwater characteristics of the SWF, while IB03, IB05 and IB06 assess the metasediments, IB04 assesses the metavolcanics and IB07 assesses the granite. The locations of the IB bores are shown in Figure 5. Bore logs for the IB bores are shown in Appendix B.

Table 3: 2022 INVESTIGATION BORES								
Bore ID	***Easting***	***Northing***	***Depth drilled (mBGL)***	***Top of monument elevation (mAHD)***	***Airlift yield (L/s)***	***Static water level (mBTOC)***	***EC (µS/cm)***	***Perf. zone (mBGL)***
IB01	299429	8173222	23	369.00	0.2; 0.8	0.5	4400	17-23
IB02	300180	8172487	72	391.63	0.1; 0.4; 0.2	11	350	44-50
IB03	300569	8171746	30	364.06	1.5	17.5	9200	24-30
IB04	301030	8172127	30	368.26	0.6	19	1800	24-30
IB05	299916	8171748	30	361.02	0.6	12.2	3100	24-30
IB06	298743	8171345	24	363.13	0.4	15.8	5300	20-24
IB07	299574	8170830	53	Unknown	4.5	13.5	4000	18-53
IB08	300894	8171793	54	364.10	0.3	15	1700	20-26

Note: mBGL – metres below ground level
mBTOC – metres below top of casing
Coordinates in GDA94, Zone 55

The IB bores generally exhibited similar airlift yields of less than 1 L/s, with the exception of IB03 (at 1.5 L/s) and IB07 (at 4.5 L/s). Groundwater electrical conductivity (EC) is relatively high for the majority of the bores (with the exception of IB02). This is due to the low hydraulic conductivity of the aquifer resulting in a high groundwater residence time. This consequently creates greater opportunity for groundwater chemistry to equilibrate with the aquifer matrix, resulting in an elevated EC.

IB07 was assessed for potential use as a groundwater supply bore for the project. With IB07 returning an airlift yield of 4.5 L/s with an EC of 4,000 µS/cm, the bore was deemed inadequate for groundwater supply purposes.

An unnamed test hole was drilled near MB4 to assess the airlift yield at that site. The test hole was drilled to a depth of 75 m and yielded 15 L/s with an EC of 2,000 µS/cm. The unnamed test hole was abandoned and was not constructed as a water supply bore.

3.4 Hydraulic conductivity

Hydraulic testing was carried out in all monitoring bores where reasonably practical to do so. The bores were tested by either falling or rising head methods and analysed using the Bouwer and Rice method (for falling head tests) or the Theis method (for rising head tests). Table 4 summarises the hydraulic conductivity values determined from the hydraulic testing.

The hydraulic conductivity of the regolith, where saturated, is low with estimated values between 0.001 m/d to 0.056 m/d.

The hydraulic conductivity of the Hodgkinson Formation is low to moderate with hydraulic conductivity values ranging from 0.038 m/d to 0.58 m/d.

The unnamed test hole drilled near MB4 yielded 15 L/s, which is indicative of a high hydraulic conductivity zone within the Hodgkinson Formation.

The hydraulic conductivity of the SWF is nominally low with estimated values between 0.015 m/d to 0.088 m/d. Hydraulic testing was not able to be practically carried out at IB01 as the water level in the bore casing was only 0.15 m below the top of the casing and was too high to effectively introduce a ‘slug’ of water.

IB07 has a nominal airlift yield of 4.5 L/s. The bore intersected fractured granite, and, on this basis, it can be concluded that the granite has localised zones of high hydraulic conductivity.

In addition to the above data, data has been made available from a number of historic geotechnical piezometers installed within the Hodgkinson Formation in the vicinity of the SWF in the open pit (Piteau & Associates, 1982). This hydraulic conductivity data is in the range of 0.033 m/d to 2.3×10^{-5} m/d. The historic hydraulic conductivity data is generally lower than the data collected from the MB, IB and SB bores. This lower hydraulic conductivity reflects the rationale of the geotechnical holes to target a specific rock mass within a spatial zone of the open pit, whereas monitoring bores are typically drilled and constructed within water bearing zones.

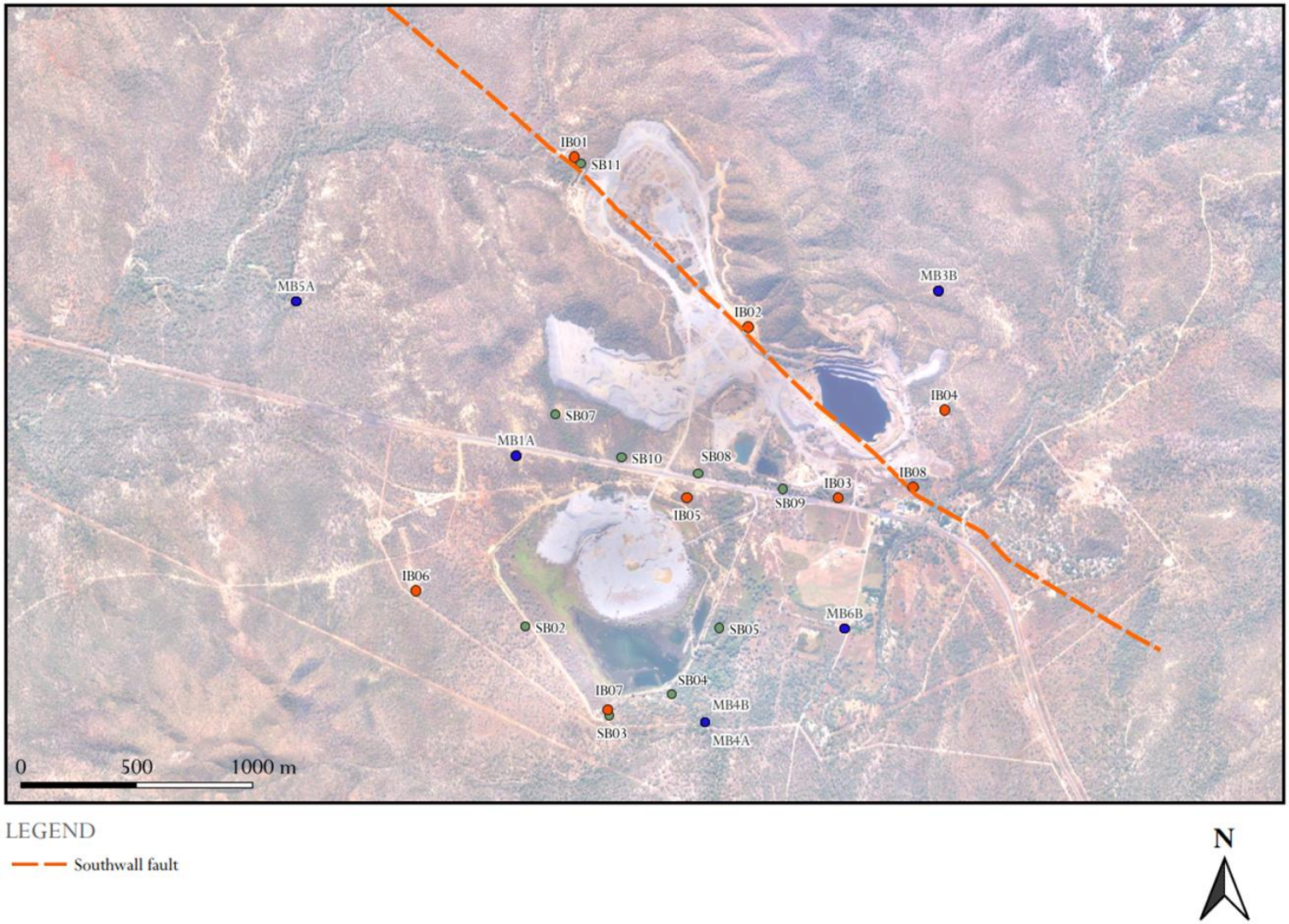


Figure 5: Bore locations

Table 4: NOMINAL HYDRAULIC CONDUCTIVITY VALUES			
Bore ID	***k (m/d)***	***k (m/s)***	***Tested lithology***
MB1A	4.0×10^{-1}	4.6×10^{-6}	Metasediments
MB1B	2.2×10^{-1}	2.5×10^{-6}	Metasediments
MB3A	3.6×10^{-1}	4.2×10^{-6}	Metasediments
MB3B	3.8×10^{-2}	4.4×10^{-7}	Metasediments
MB4A	5.8×10^{-1}	6.8×10^{-6}	Metasediments
MB5A	3.7×10^{-1}	4.3×10^{-6}	Metasediments
MB5B	3.7×10^{-1}	4.3×10^{-6}	Metasediments
MB6B	1.8×10^{-1}	2.0×10^{-6}	Metasediments
IB02	1.5×10^{-2}	1.7×10^{-7}	SWF
IB03	1.1×10^{-1}	1.2×10^{-6}	Metasediments
IB04	1.6×10^{-1}	1.8×10^{-6}	Metavolcanics
IB05	4.9×10^{-2}	5.7×10^{-7}	Metasediments
IB06	4.6×10^{-2}	5.3×10^{-7}	Metasediments
IB08	8.8×10^{-2}	1.0×10^{-6}	SWF
SB03	3.6×10^{-2}	4.2×10^{-7}	Regolith
SB04	1.0×10^{-3}	1.2×10^{-8}	Regolith
SB05	2.6×10^{-2}	3.0×10^{-7}	Regolith
SB11	5.6×10^{-2}	6.5×10^{-7}	Regolith

Notes: SWF – South Wall Fault

3.5 Groundwater level and quality data

EQ Resources has carried out groundwater level and quality monitoring in accordance with their EA conditions. The site has been actively monitored for over 10 years. Additional monitoring outside of the EA conditions is carried out where required.

In addition to the recent data from the monitoring bore network, data has been made available from a number of historic piezometers installed within the Hodgkinson Formation in the vicinity of the SWF in the open pit (Piteau & Associates, 1982). This groundwater level data is from 1982, prior to expansion of the open pit, and indicates groundwater elevations in the range of 359 mAHD to 365 mAHD.

4.0 REVISED HYDROGEOLOGY

4.1 Hydro-stratigraphic units

There is little or no development of alluvial sediments within the Mount Carbine project site. As such the alluvium is not regarded as a hydro-stratigraphic unit within the project site.

Regolith

Groundwater is present as an unconfined aquifer where it occurs within the regolith.

SB series bores SB03, SB04 and SB05 show that there is groundwater development in the regolith where water from the TSF has caused localised mounding. Within the vicinity of the TSF the regolith is only saturated where surface infiltration has been sufficient to develop a groundwater table.

The other SB series bore that has developed a groundwater table is SB11, which is co-located with IB01 (screened into the SWF). The groundwater table in the regolith at SB11 is likely influenced by elevated groundwater levels within Carbine Hill to the southeast (Figure 1 and Figure 5). Further discussion on the groundwater levels at SB11 is provided in Section 4.2.

Based on the evidence from the remaining SB series bores it is concluded that the regolith is typically unsaturated across the site.

Hodgkinson Formation

The primary hydro-stratigraphic unit at Mount Carbine occurs within the Hodgkinson Formation. The fractured rocks of the Hodgkinson Formation comprise a secondary porosity aquifer. Drilling within the Hodgkinson Formation indicates discrete zones of moderate to high hydraulic conductivity within a generally low hydraulic conductivity rock mass. Groundwater within the Hodgkinson Formation is interpreted to be semi-confined at shallow depths and confined at deeper depths.

The Hodgkinson Formation has a slaty cleavage which is regionally pervasive. This cleavage would provide a heterogenous environment which is assessed to influence the preferential direction of groundwater flow within the hydro-stratigraphic unit. That is, the horizontal hydraulic conductivity within the Hodgkinson Formation will be higher in a northwest-southeast alignment compared with the horizontal hydraulic conductivity in a southwest-northeast alignment. A representation of the magnitude of horizontal hydraulic conductivity is shown in Figure 6.

In the vicinity of the open pit the Hodgkinson Formation has been locally metamorphosed and altered to hornfels (EQ Resources, 2021). This would result in a localised reduction of the hydraulic conductivity of the Hodgkinson Formation. However, there are no direct hydrogeological observations from the hornfels to confirm this.

South Wall Fault

Investigation bores IB01, IB02 and IB08 were located to assess groundwater occurrence in the SWF. Each of these bores intercepted small volumes of groundwater in a sticky grey clay. The sticky grey clay was identified by Mr. Tony Bainbridge (EQ Resources geologist) as characteristic of the SWF. As discussed in Section 2.3, the SWF typically occurs as one central 0.5 m to 1.0 m zone of intense clay crushed rock or, less frequently, in two parts separated by 1 m to 2 m of fractured rock. Further, the fault has a fractured footwall for 1 m to 5 m in width, with only minor extra fracturing observed in the hanging wall.

The airlift yields from IB01, IB02 and IB08 were 0.8, 0.2 and 0.3 L/s respectively. Given the bores construction, these airlift yields are representative of the SWF, and the Hodgkinson Formation immediately above and below the SWF.

The clay layer associated with the SWF lines the hanging wall of the SWF and acts as a local confining layer.

The SWF is exposed in the southwestern wall of the open pit where the clay layer has been removed by mining.

If the SWF was a significant conduit for groundwater flow, the groundwater levels at IB02 would be similar to those observed in the open pit void (as the fault is exposed in the open pit). However, the groundwater levels at IB02 are elevated and are the highest observed in the project site.

It is therefore assessed that the SWF is an aquitard or a leaky barrier to groundwater flow. This implies that there is limited opportunity for groundwater flow across the SWF owing to the retarding effect of the clay layer that lines the fault plane. It does not however imply total exclusion of groundwater flow across and along the SWF.

Similarly, it is assessed that the felsic dykes that are within the vicinity of the open pit also behave as aquitards or a leaky barriers to groundwater flow. This assessment is based upon the steep groundwater flow contours interpreted to occur to the west and northwest of the open pit. However, there are no direct hydrogeological observations from the dykes to confirm this assessment.

4.2 Groundwater levels and flow

Groundwater levels have been measured within the dedicated groundwater monitoring bores since they were installed in November 2011 and in the IB and SB series bores (that were not dry) since they were installed. While no pre-mine groundwater levels available, groundwater levels pre-expansion of the open pit in 1982 are available as discussed in Section 3.5.

The groundwater levels in MB4A and MB4B are relatively higher that the groundwater levels in the rest of the groundwater monitoring bore suite. The groundwater levels in MB4A and MB4B are highly likely to be influenced by the standing water in the TSF4 water storage, which has been a more or less permanent water storage for a number of years. The SB series bores (SB3, SB4 and SB5) installed around the footprint of the TSF confirm this assessment of localised mounding.

The groundwater level in IB02 is some 12 m higher than the groundwater levels in other bores to the north of SWF. The mechanism for this elevated groundwater level is interpreted to be the ridge immediately to the north of IB02. It is probable that the ridge has a low hydraulic conductivity core and a veneer of permeable, shallow, and thin regolith (akin to a clayey gravel). Infiltrating rainfall on the ridge is likely to be held up in this elevated terrain. The lower salinity observed at IB02 confirms this concept.

Water levels within the open pit void have recently been measured by EQ Resources at 357 mAHD (July 2021) to 350 mAHD (January 2022). The reduction (7 m) in the elevation of the pit lake is in response to pumping by EQ Resources. Groundwater level data for IB08 (installed in January 2022) indicates a groundwater elevation of 350 mAHD. This suggests very similar elevations (and a flat hydraulic gradient) between the open pit void and IB08. However, it is not known whether there has been a corresponding change in groundwater level at IB08 in response to the lowering of the pit lake level. Available data shows little to no response, this may be due to the time of installation of IB08 and available monitoring record, or the low to moderate hydraulic conductivity measured at IB08 (0.088 m/d).

Local artesian conditions are observed at IB01 i.e., the groundwater level is slightly above ground surface. The hydraulic gradient for this artesian condition is most likely driven by the elevated outcrop of Hodgkinson Formation to the east and southeast along the SWF. This local groundwater flow would preferentially follow the SWF and cleavage partings within the Hodgkinson Formation. At IB01, the co-located surficial bore, SB11 is sub-artesian yet exhibits a similar groundwater elevation (368.98 mAHD at IB01 and 368.66 mAHD at SB11) due to topographic effect. This suggests a slight upward gradient from the SWF / Hodgkinson Formation groundwater to the regolith groundwater at this location. This upward gradient is more reflective of groundwater movement along the SWF and within the cleavage partings of the Hodgkinson Formation, rather than shallow groundwater flow from the low-grade stockpile.

The SWF and felsic dykes are regarded as leaky barriers to groundwater flow and "hold groundwater up" locally. Hydraulic gradients are much steeper to the northeast of the SWF than those to the southwest of SWF, reinforcing the concept that the SWF inhibits groundwater flow to the south. As discussed, the steep hydraulic gradient to the west and northwest of the open pit is likely a result of the felsic dyke that is mapped immediately adjacent (to the west) to the open pit.

A potentiometric surface contour map of groundwater elevations (representative of February 2022) is shown in Figure 6. Figure 6 also shows the location of the SWF and its influence on groundwater elevations. The contours have been prepared based on the groundwater elevations of all bores summarised in Table 1, Table 2 and Table 3. The pit lake elevation has also been used to define the potentiometric contours.

The potentiometric contours are considered to be valid based on the following assumptions:

1. There is generally sufficient hydraulic connectivity within the bedding planes and cleavage fractures of the Hodgkinson Formation to permit regional groundwater flow.
2. Groundwater will flow from more elevated areas to less elevated areas.
3. The SWF is an aquitard or a leaky barrier to groundwater flow. This implies that there is limited groundwater flow across the SWF. It does not imply total exclusion of groundwater flow across the SWF.
4. The felsic dykes are aquitards or leaky barriers to groundwater flow. As above this implies limited groundwater flow but does not imply total exclusion of groundwater flow across the dykes.

The potentiometric contours potentially indicate the presence of separate hydro-stratigraphic units on either side of the SWF. To the southwest of the SWF, the contours are flatter, and the hydraulic gradient is lower. To the northeast of the SWF the contours are steeper, and the hydraulic gradient is higher.

These separate hydro-stratigraphic units relate primarily to the bulk rock mass hydraulic conductivity of the Hodgkinson Formation, that is likely to be influenced by the presence of the SWF and also by the presence of the felsic dykes to the north of the SWF and adjacent to the open pit. There is also expected to be a topographic influence, with the region to the northeast of the SWF having higher elevation than the area to the southwest.

Two hydrogeological cross-sections are presented to illustrate the shape of the potentiometric surface contour profile at the site. These hydrogeological cross-sections are shown in Figure 7 and Figure 8. Figure 7 extends from the northwest to the southeast, whereas Figure 8 extends in a general northeast to southwest alignment. Figure 8 shows the retarding effect of the SWF on the potentiometric levels to the south of the SWF.

It is also apparent from the potentiometric surface contours (Figure 6) that the TSF is leaking, and a localised groundwater mound has formed.

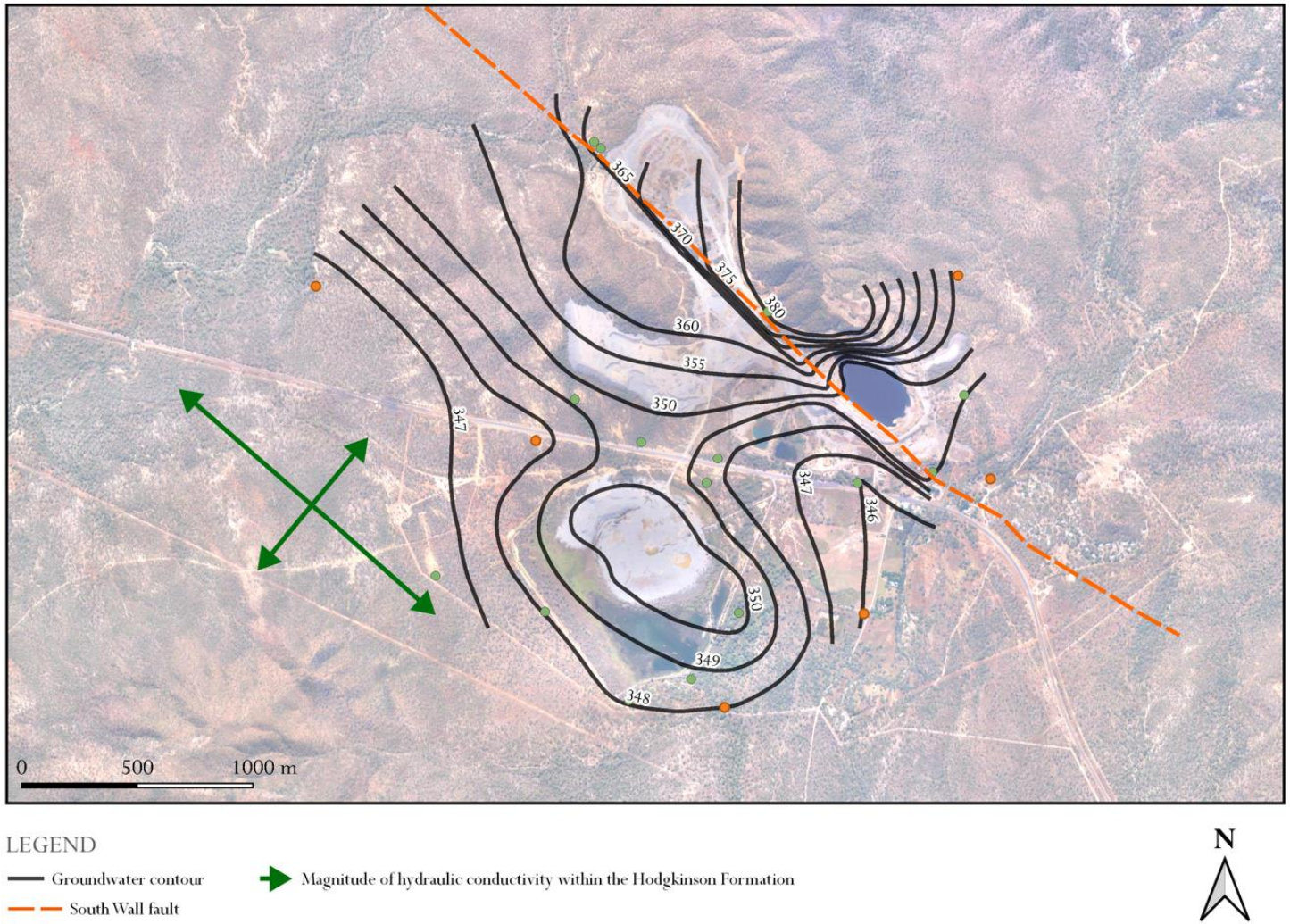


Figure 6: Potentiometric contour map

Note: Contours are at a 5 m interval above 350 mAHD and at a 1 m interval below 350 mAHD.

4.3 Groundwater recharge

The primary mechanism for recharge to the aquifers in the area is the direct infiltration of rainfall. Recharge to the Hodgkinson Formation will be rapid in areas where open cleavage partings are both exposed at the surface and persist to depth. There are significant areas to the north of the Mulligan Highway where such conditions exist.

There is little or no evidence of exposed Hodgkinson Formation to the south of the Mulligan Highway.

A secondary mechanism for recharge to the aquifers at Mount Carbine is episodic or runoff recharge. During a major rainfall event, a significant percentage of water will occur as surface runoff. The maximum opportunity for recharge to these aquifers will occur where cleavage partings are exposed in ephemeral gullies that traverse the site and flow during the wet season.

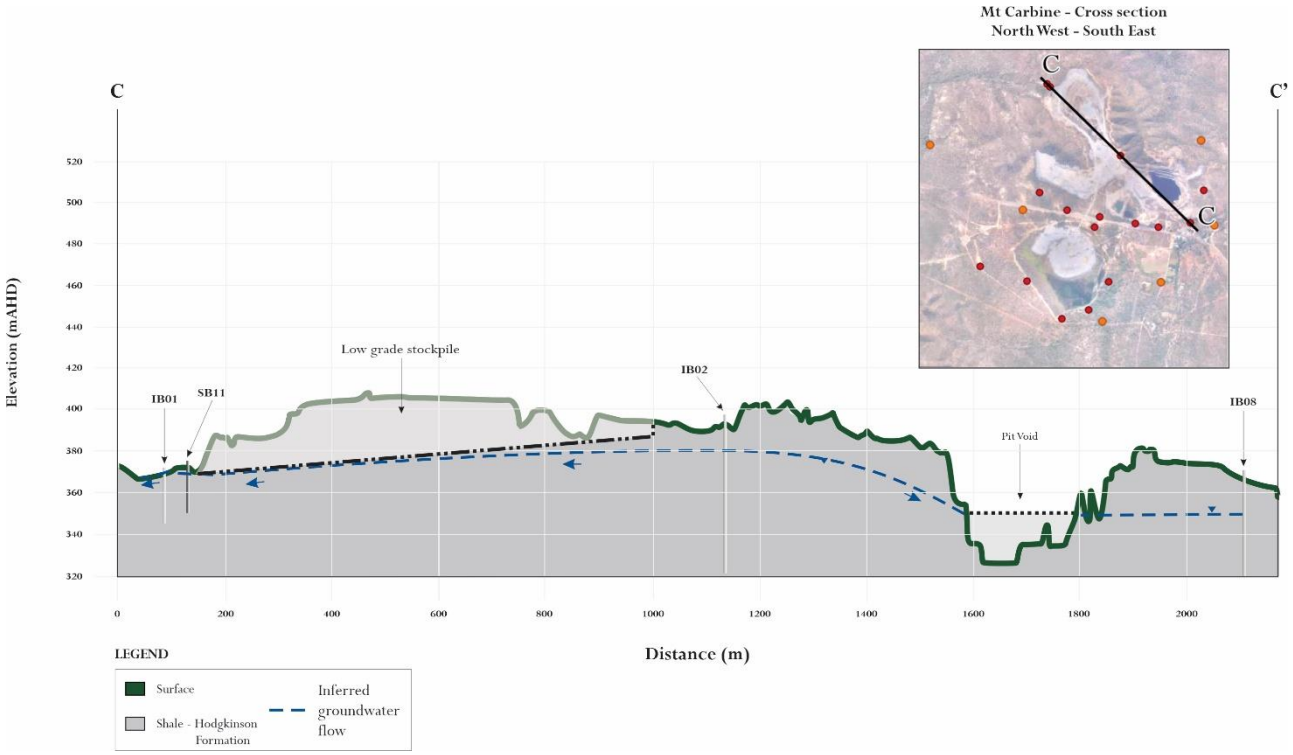


Figure 7: Northwest – southeast cross section

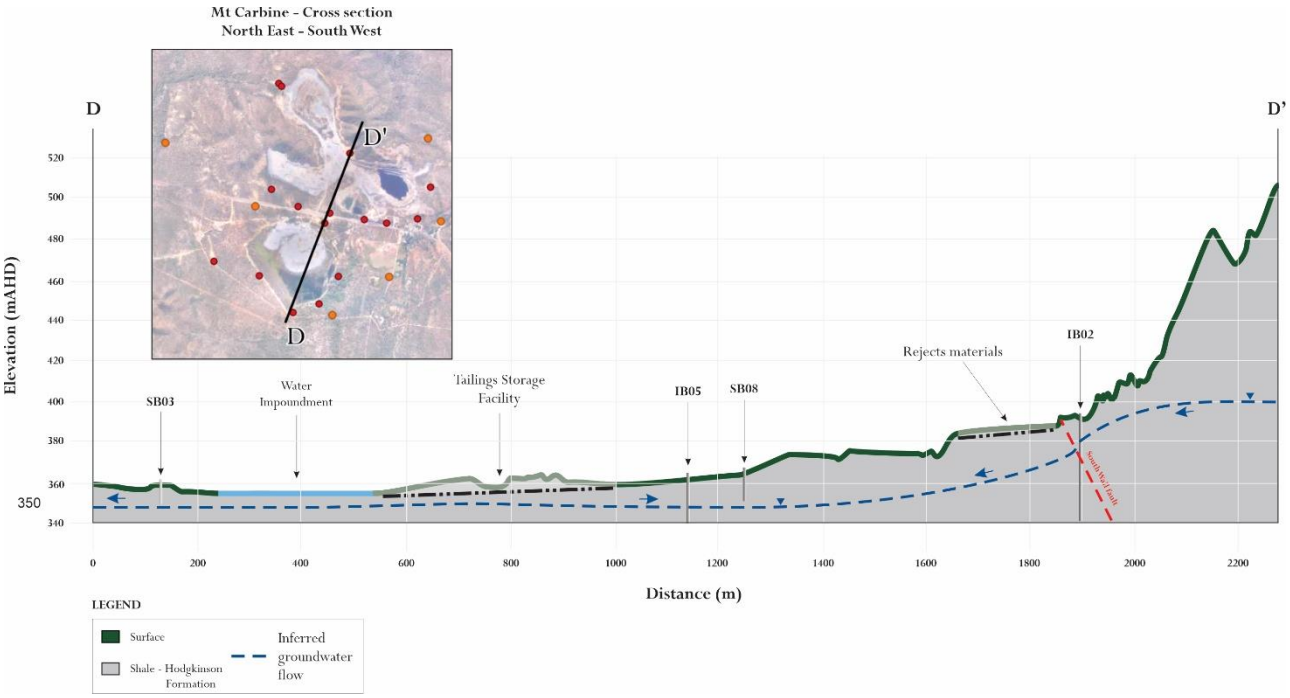


Figure 8: Northeast – southwest cross section

4.4 Groundwater discharge

Groundwater discharge is potentially occurring between the low-grade stockpile and Holmes Creek. It is understood that the Receiving Environment Monitoring Program (REMP) assessment at SW20 is reported to show Pandanus vegetation which is indicative of wet soil conditions. There is not necessarily any physical discharge of groundwater seepage occurring at this site rather the potential for sub-surface seepage. There is also evidence of potential salt scalding in this area.

There are minor surface water expressions at the toe of the rejects stockpile (Figure 1), however this is not assessed to be a natural expression of groundwater.

5.0 GROUNDWATER CHEMISTRY

Water chemistry is monitored at the EQ Resources site at a number of surface water sites as well as in the dedicated groundwater monitoring bores.

In a spatial context, the groundwater salinity (EC) does not present any obvious pattern or distribution of increasing or decreasing salinity over the project area. There is however a general pattern of increased salinity with depth which is confirmed by the majority of the paired monitoring bore sites.

Major ion groundwater chemistry data has been assessed to determine the overall geochemical signatures of groundwaters as part of the conceptual model development. These geochemical signatures allow the origin, evolution, and mixing processes to be interpreted.

The interpretation is made from the MB series bores which have a long-term (ten year) dataset. The IB series bores have had ten monitoring rounds within the last 12 months which is considered an adequate dataset for the purposes of assessment. The SB series bores have had only field water quality parameters (EC and pH) measured. No quality assurance process has been carried out on the client provided laboratory data.

Figure 9 and Figure 10 show Piper diagrams for the MB and IB groundwaters respectively. Figure 11 and Figure 12 show Durov diagrams for the MB and IB groundwaters respectively.

The data shows a notable shift in groundwater chemistry at both MB1B and MB3B. The shift at MB1B (located to the northwest of the TSF4) appears to be sudden, however the shift at MB3B (located to the northeast and upgradient of the open pit) appears gradual. MB1B exhibited a sudden increase in the proportion of Ca, Mg, and bicarbonate alkalinity and Cl, whereas MB3B is gradually increasing in salinity yet reducing in sulfate concentration.

These trends potentially relate to the sampling methodology. MB3B is a deep bore and is upgradient of the open pit and is unlikely to be related to direct mining impact. MB3B may not have been purged adequately during historical sampling. The change at MB1B is assessed as too sudden and is unlikely to be related to groundwater processes.

The Durov diagram shows that bores MB6A and MB6B have significantly higher salinity than the other MB bores.

The IB dataset shows a further spread of water quality types with IB02 (located to the northwest of the SWF, and with an elevated groundwater level) showing a distinctive high percentage of bicarbonate, generally associated with recharge when combined with low salinity. IB02 also shows low chloride and low sulfate, consistent with the site being elevated, well above any potential influence from mining activities.

The pH of the MB groundwaters is generally recorded between 6 and 9 with the occasional outlier. The pH of the IB groundwaters is generally between 6.5 and 8.0.

Figure 13 and Figure 14 show scattergrams of bicarbonate alkalinity vs sulfate for the MB and IB groundwaters respectively. Increased sulfate concentrations are typically used as an indicator of interaction with mineralised rock.

Data from MB4A and MB4B show elevated concentrations of sulfate and potential influence of seepage from TSF4 and its associated water storage. This is consistent with the groundwater level data which shows evidence of a localised groundwater mound beneath this site infrastructure. However, the influence of TSF4 on MB4A groundwater quality is confounded by sulfate concentrations in the bore that are greater than contemporary values from TSF4. Figure 13 also shows a large range (up to 150 mg/L) in sulfate concentrations at both MB4A and MB4B when compared to other bores. The change in water quality at MB1B resulting from varying bicarbonate alkalinity concentrations is also evident.

Sites MB1, MB5 and MB6 are generally higher in bicarbonate alkalinity, whereas site MB3 and the RFB bore are lower in bicarbonate alkalinity. This suggests a potential clustering of lower bicarbonate water to the northeast of the SWF, and higher bicarbonate water to the southwest of the SWF.

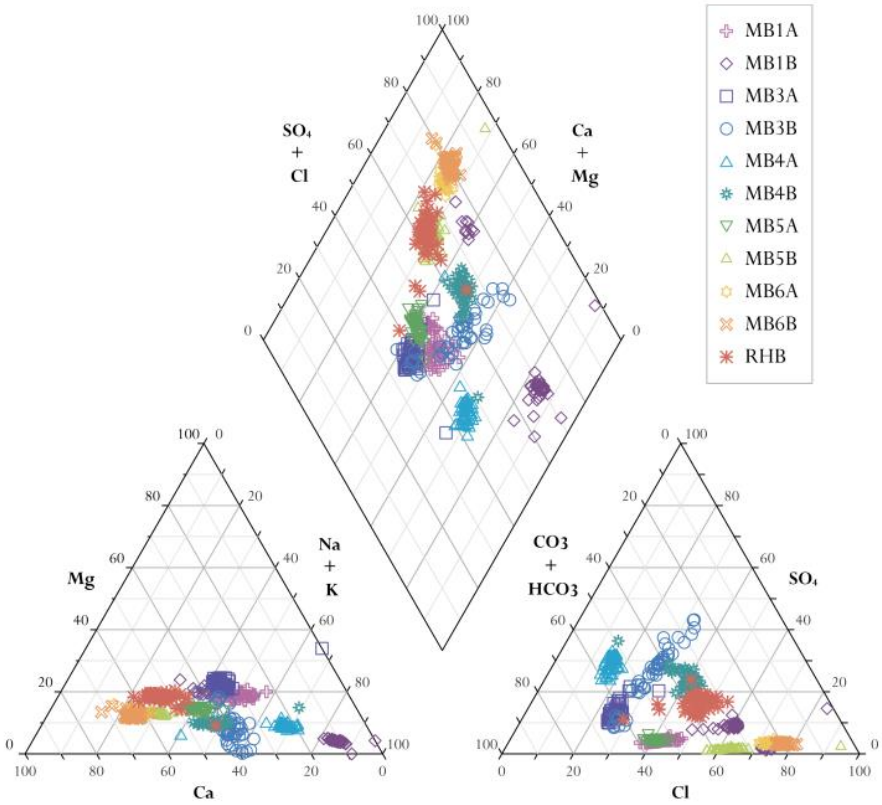


Figure 9: Piper diagram – MB series bores

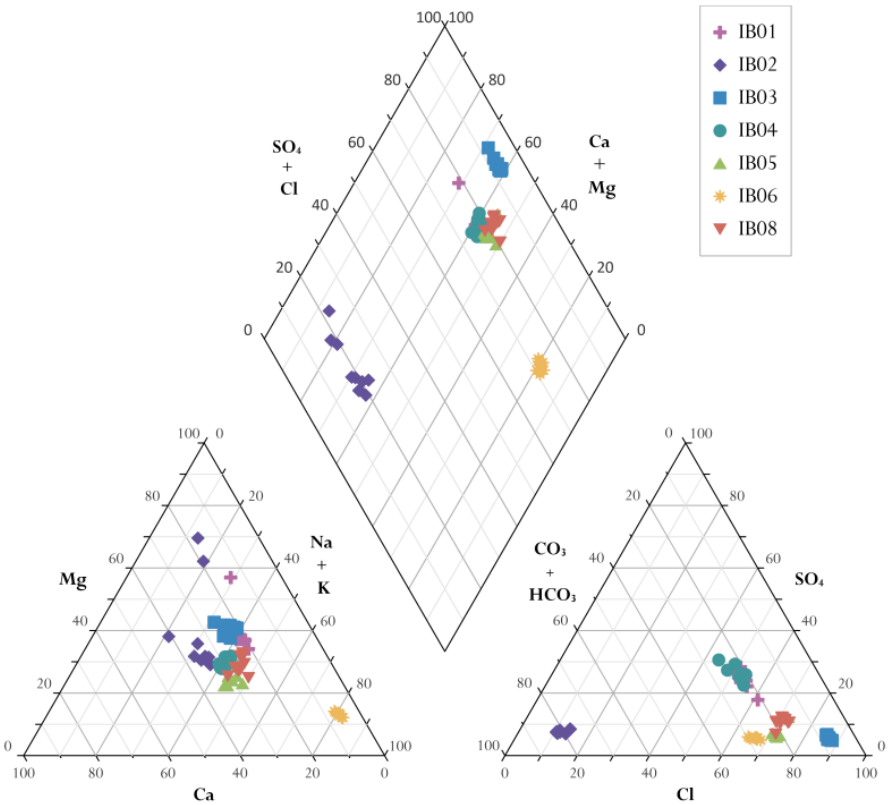


Figure 10: Piper diagram – IB series bores

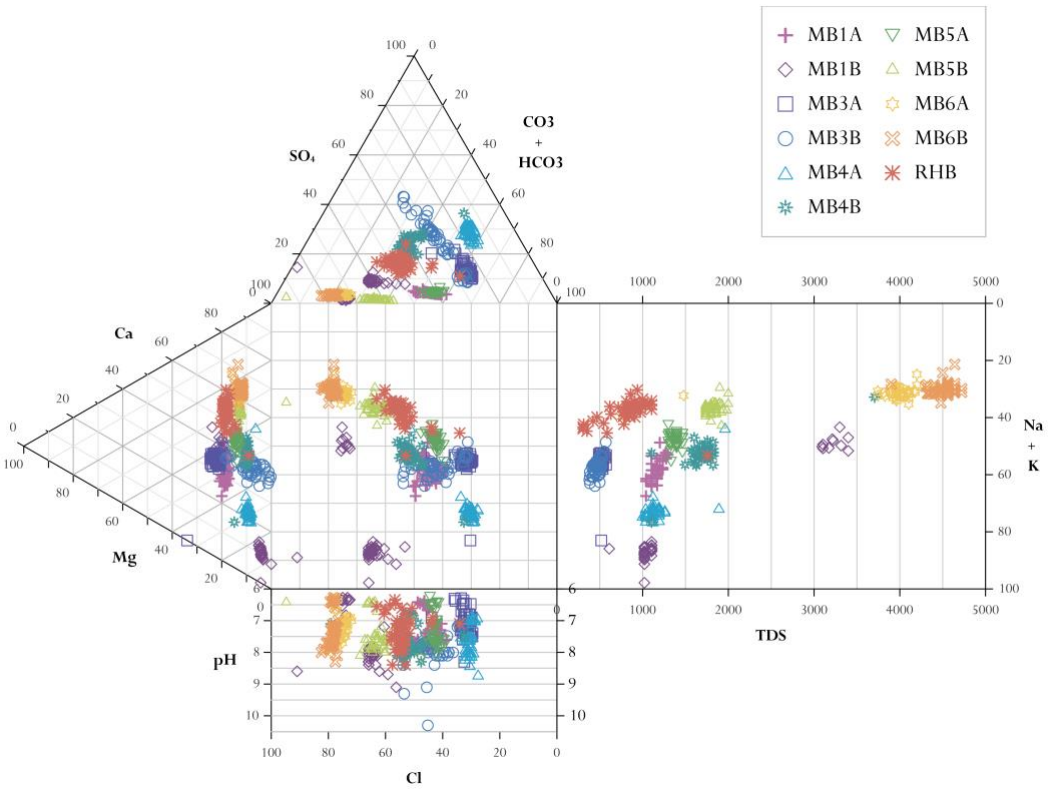


Figure 11: Durov diagram – MB series bores

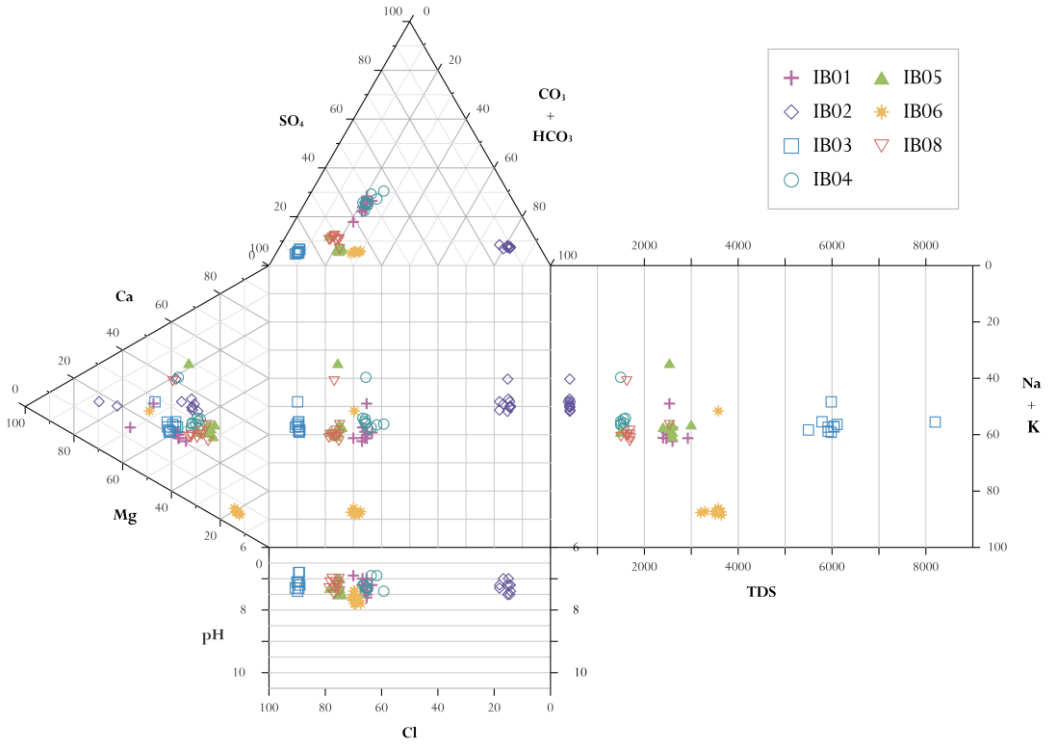


Figure 12: Durov diagram – IB series bores

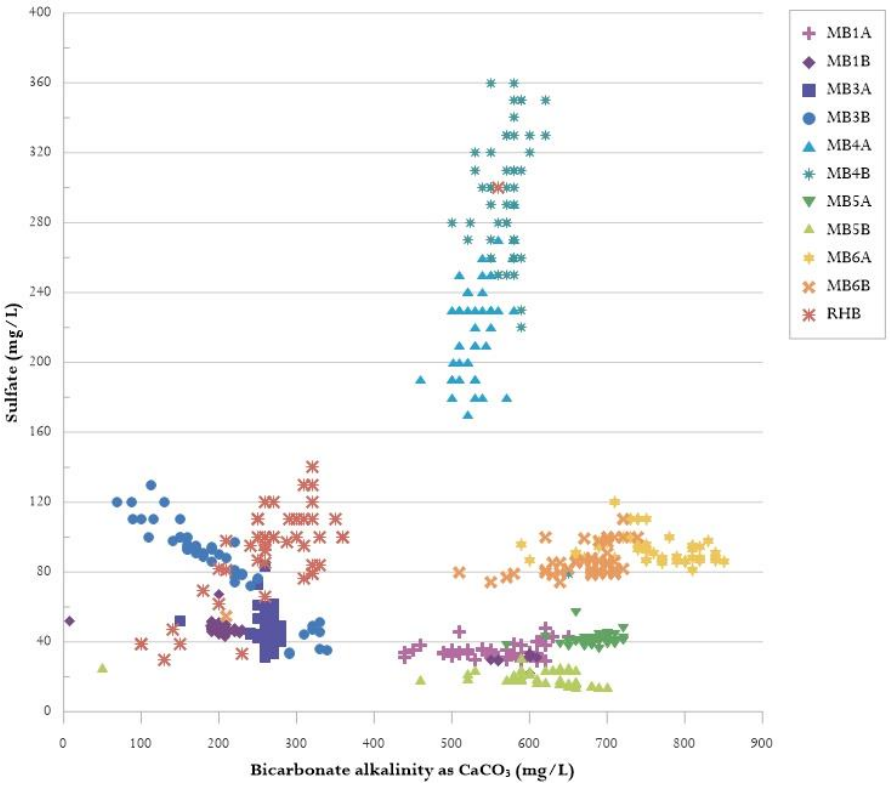


Figure 13: Scattergram - MB bores – bicarbonate alkalinity vs sulfate

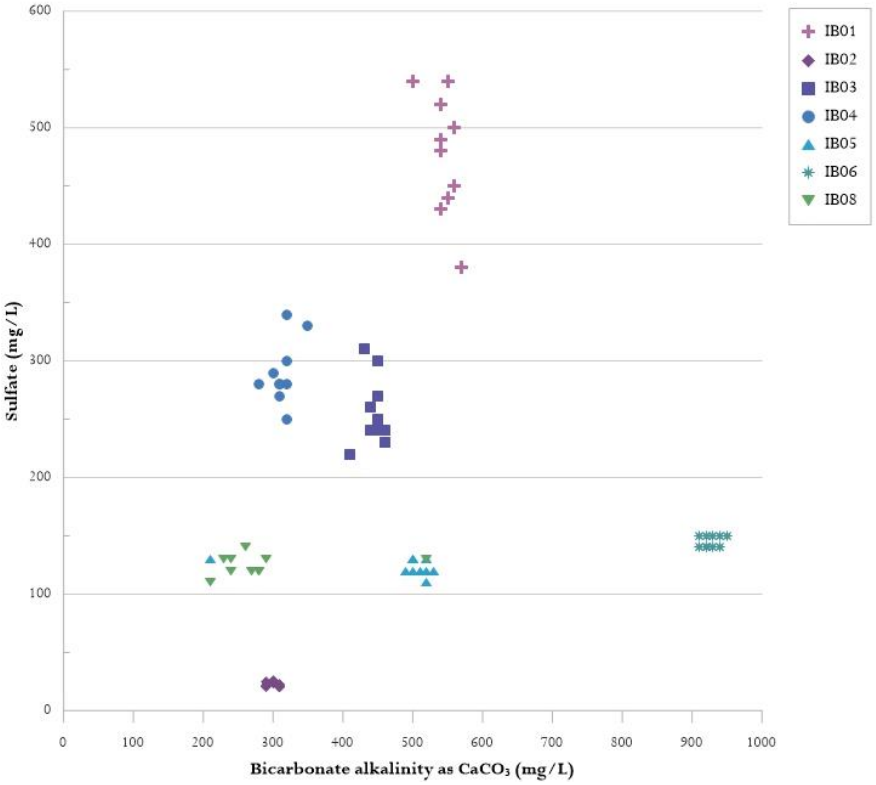


Figure 14: Scattergram - IB bores – bicarbonate alkalinity vs sulfate

Data from IB01 shows elevated concentrations of sulfate and potential influence of seepage from the mineralised rock. This mechanism is consistent with the groundwater level contours, which show the spatial potential for low-grade stockpile seepage to enter the SWF and Hodgkinson Formation in this area, also the area to the east and southeast of IB01 is consistent with the ore body and mineralisation.

Groundwaters at IB04 and IB03 also show more elevated sulfate concentrations when compared with the MB series groundwaters. The elevated sulfate levels at IB03 and IB04 may be due to the interaction with mineralised rock in the regional flow paths.

Sites IB01, IB03, IB05 and IB06 are generally higher in bicarbonate alkalinity , whereas sites IB04 and IB08 are lower in bicarbonate alkalinity . As per the MB groundwaters, this suggests a potential clustering of lower bicarbonate water to the northeast of the SWF, and higher bicarbonate water to the southwest of the SWF.

Figure 15 and Figure 16 shows a scattergram of chloride vs sulfate for the MB and IB groundwaters respectively. As per Figure 13, MB4A and MB4B show elevated concentrations of sulfate. The presentation of chloride vs sulfate shows more distinct grouping for each monitoring bore. Once again there is a potential clustering of lower chloride groundwater to the northeast of the SWF (MB3 and RHB), and higher chloride groundwater to the southwest of the SWF (MB1, MB5 and MB6).

Bores MB6A and MB6B have higher chloride than the other MB bores, consistent with the salinity data. There are subtle differences in the water types between MB5A and MB5B. MB5B exhibits slightly higher chloride and slightly lower sulfate. Further, MB4B has slightly higher chloride and higher sulfate than MB4A. The majority of sites show slightly higher chloride concentrations in the deeper monitoring bore.

The significant and sudden change in groundwater quality at MB1B is evident in the chloride concentrations.

MB5B exhibits slightly higher chloride and slightly lower sulfate. Further, MB4B has slightly higher chloride and higher sulfate than MB4A. The majority of sites show slightly higher chloride concentrations in the deeper monitoring bore.

Bores IB01, IB03 and IB04 show elevated concentrations of sulfate. IB03 has comparatively higher chloride concentrations than the other IB groundwaters.

There are subtle differences in the water types between the IB groundwaters.

Figure 17 and Figure 18 shows a scattergram of fluoride vs sulfate for the MB and IB groundwaters respectively. As per the scattergrams for chloride vs sulfate for the MB and IB groundwaters presented in Figure 15 and Figure 16, MB4A and MB4B show elevated concentrations of sulfate. The presentation of fluoride vs sulfate show grouping for both the MB and IB series groundwaters.

NRA are currently undertaking related work associated with the groundwater quality at the project site. The results of this work will be reported in conjunction with this assessment.

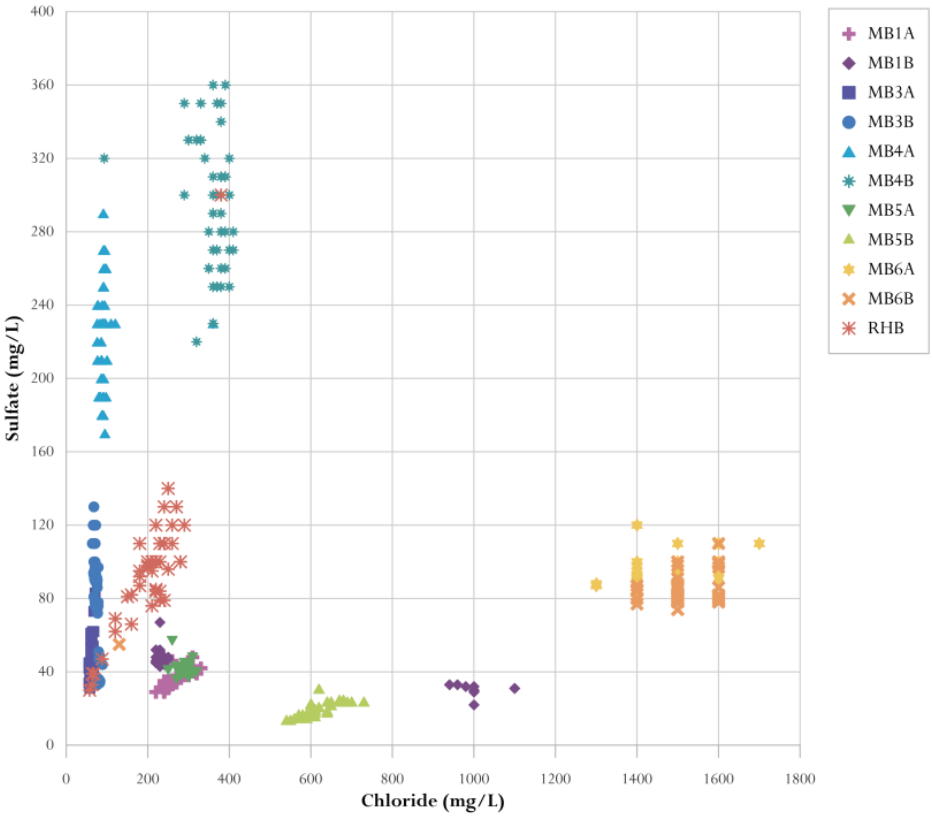


Figure 15: Scattergram – MB bores – chloride vs sulfate

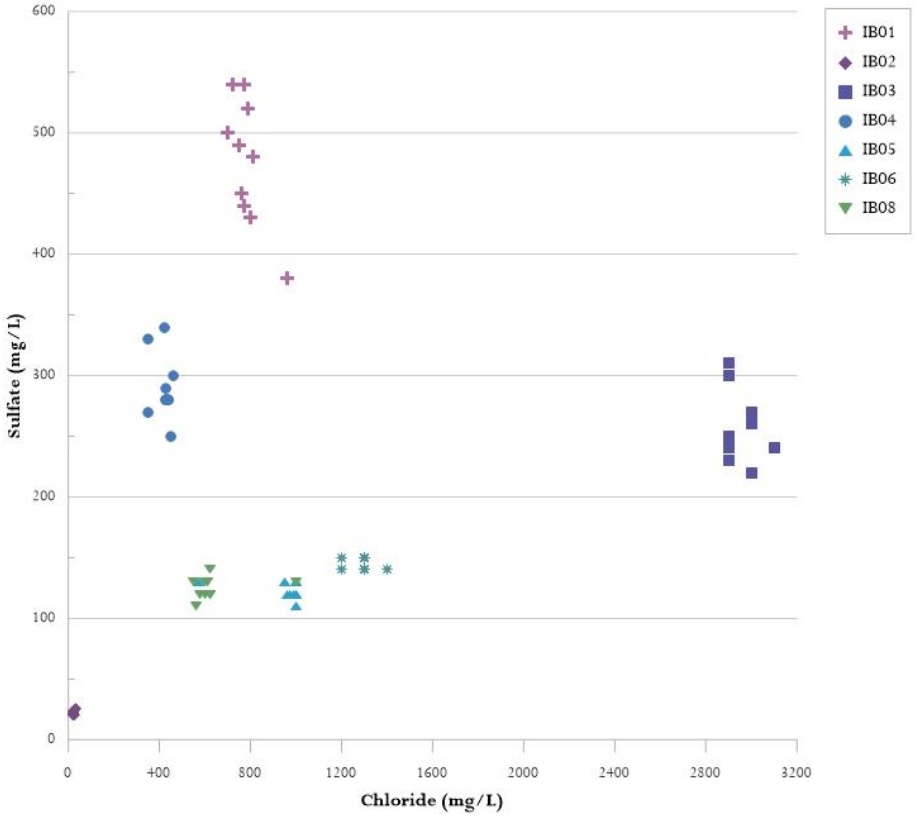


Figure 16: Scattergram IB bores – chloride vs sulfate

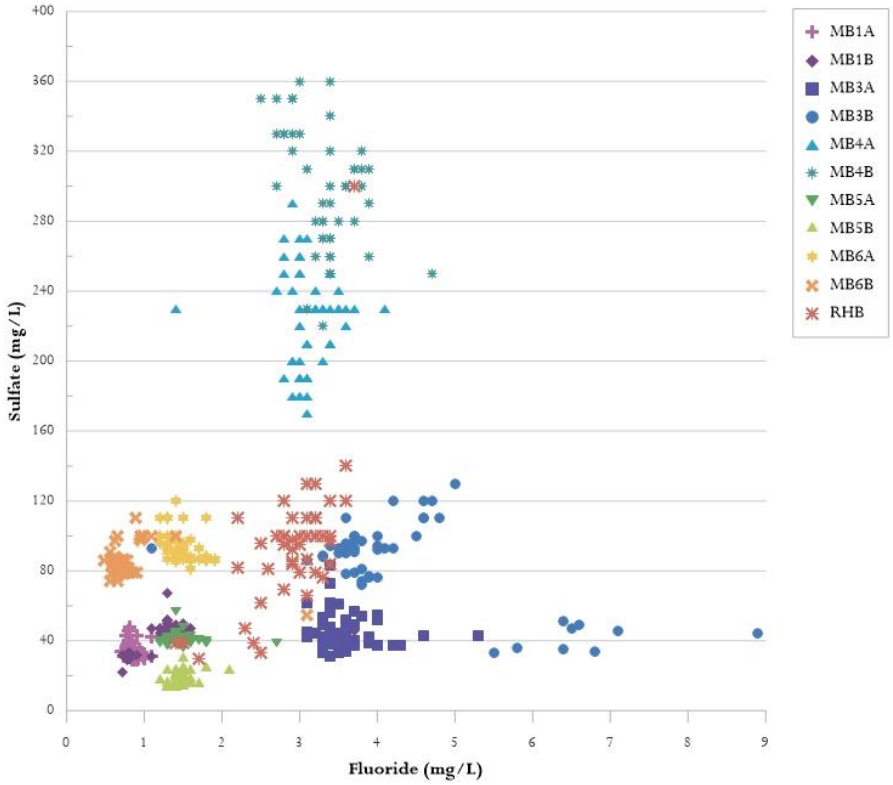


Figure 17: Scattergram MB bores – fluoride vs sulfate

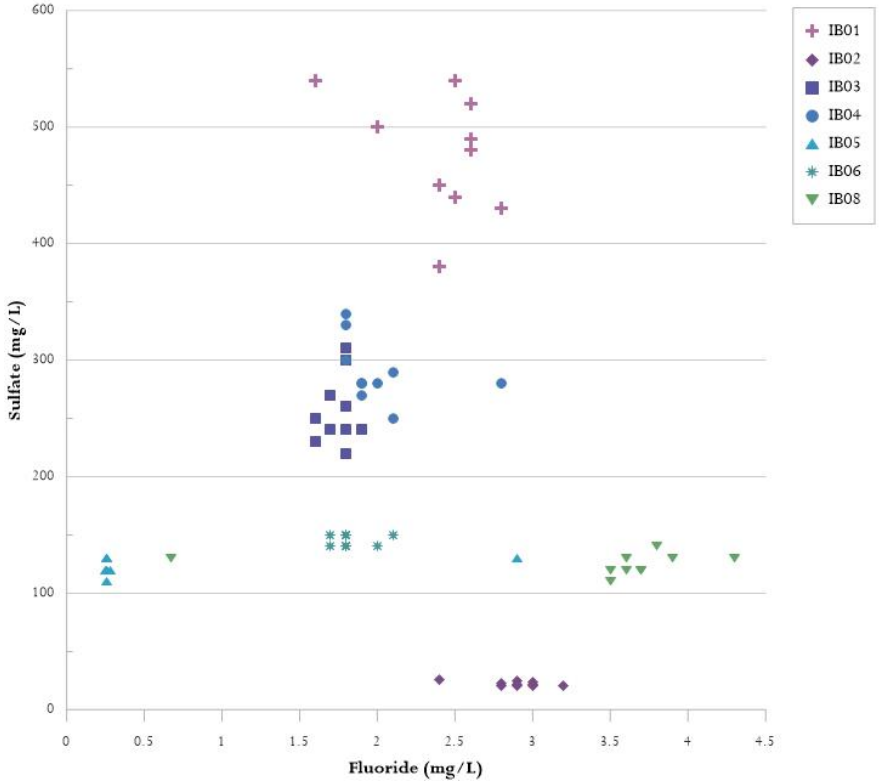


Figure 18: Scattergram IB bores – fluoride vs sulfate

6.0 GROUNDWATER - SURFACE WATER INTERACTION

Mining development is assessed as impacting groundwater levels beneath the TSF4 and associated water storages (localised mounding). The downgradient TSF4 monitoring bores MB4A and MB4B have observed groundwater levels approximately 4 mbGL to 7 mbGL. The downgradient TSF4 monitoring bores are located within a drainage feature, and the observed data suggests minimal interaction between groundwaters and surface waters downgradient of the TSF4.

Groundwater is likely discharging to the sub-surface between the low-grade stockpile and Holmes Creek, with vegetation suggesting wet soil conditions. Based on the available data there is potential for groundwater surface water interaction to be occurring in the upper catchment of Holmes Creek. The groundwater level data, presence of established vegetation (Pandanus at SW20) and the monitoring carried out under the REMP suggests this potential shallow groundwater interaction is a natural, established occurrence rather than an impact of mining.

Elsewhere, there is minimal interaction between watercourses and groundwater at the Mount Carbine project site RLA (2012). The 2022 REMP (NRA, 2022a) report concluded that there is no discernible impact on the aquatic ecosystem and human use environmental values (EVs) associated with the contemporary mining activities.

7.0 REVISED CONCEPTUAL GROUNDWATER MODEL

Following a review of all the groundwater information available for the EQ Resources site, the following statements regarding the conceptual groundwater model have been derived:

1. There is little or no development of alluvial sediments within the Mount Carbine project site. As such the alluvium is not regarded as a hydro-stratigraphic unit within the project site.
2. There is no significant groundwater in the regolith (i.e., at depths <10 m) within the project site. Where groundwater in the regolith does occur, this is primarily associated with leakage from the TSF4 and associated water storage. The other known occurrence of groundwater in the regolith is at SB11. This occurrence at SB11 is driven by the upward gradient from the SWF / Hodgkinson Formation groundwater to the shallow regolith groundwater and supported by the regional groundwater flow conditions to the northeast of the SWF.
3. The Mount Carbine granitoid intrusives occur proximal to the open pit void and the project site. Several felsic dykes cut through the project site. These felsic dykes are likely to have a low hydraulic conductivity bulk rock mass, however drilling indicates discrete zones of moderate to high hydraulic conductivity are likely.
4. The primary hydro-stratigraphic unit at Mount Carbine occurs within the Hodgkinson Formation. The fractured rocks of the Hodgkinson Formation comprise a secondary porosity aquifer.
5. Groundwater within the Hodgkinson Formation is typically semi-confined to confined and drilling indicates discrete zones of moderate to high hydraulic conductivity within a generally low hydraulic conductivity bulk rock mass.
6. The potentiometric surface southwest of the SWF is relatively flat with a low hydraulic gradient. The potentiometric surface northeast of the SWF is relatively steep with a high hydraulic gradient. This suggests separate hydro-stratigraphic domains either side of the SWF, the groundwater chemistry data supports this concept.
7. The SWF is an aquitard or a leaky barrier to groundwater flow. This implies that there is limited opportunity for groundwater flow across the SWF owing to the retarding effect of the clay layer that lines the fault plane. It does not however imply total exclusion of groundwater flow across and along the SWF.
8. The felsic dykes are also leaky barriers for groundwater flow and locally “hold groundwater up”.
9. The potentiometric surface contours southwest of the SWF show that the TSF4 (and associated water storage) is leaking, and a localised groundwater mound has formed around this site infrastructure.
10. The salinity and groundwater chemistry across the site is variable and does not readily present any spatial trends or obvious water types. There is a potential clustering of lower chloride / lower bicarbonate groundwater to the northeast of the SWF, and higher chloride / higher bicarbonate groundwater to the southwest of the SWF, which supports the separate hydro-stratigraphic domain concept.

8.0 REVISED EA MONITORING NETWORK

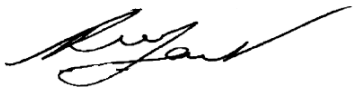
Table 5 below summarises the recommended EA monitoring network. The recommended EA monitoring network is supported by the current understanding of the groundwater system and is suggested for the short-term inclusion in the EA.

Due to the compartmentalised nature of the hydrogeology, the complex geology and anisotropic properties of the groundwater system, no bores within the monitoring network are suitable for use as reference bores. As such, it is recommended that all bores within the recommended EA monitoring network as classified as compliance bores.

Table 5: RECOMMENDED EA MONITORING NETWORK

Bore ID	***Classification***	***Parameters***	***Rationale***
MB1A	Compliance	Level and quality	Site is located to the northwest (downgradient) of TSF4. Monitoring to assess potential water quality change from TSF4 seepage.
MB4A	Compliance	Level and quality	Site is located to the southeast (downgradient) of TSF4. Monitoring to assess potential water quality change from TSF4 seepage.
MB7	Compliance	Level and quality	New monitoring bore proposed to the east (downgradient) of TSF4. Monitoring to assess potential water quality change from TSF seepage. Proposed coordinates 300350 mE, 8171260 mE. Nominal depth of 30 mBGL.
IB03	Compliance	Level and quality	Site is located to the south (downgradient) of the open pit. Monitoring to assess potential water quality change from pit seepage, and interaction with pit lake level.
IB04	Compliance	Level and quality	Site is located to the east (potentially downgradient) of the open pit. Monitoring to assess potential water quality change from pit seepage, and interaction with pit lake level.
IB06	Compliance	Level and quality	Site is located to the west (downgradient) of TSF4. Monitoring to assess potential water quality change from TSF4 seepage.
IB08	Compliance	Level and quality	Site is located to the southeast (potentially downgradient) of the open pit. Monitoring to assess potential water quality change from pit seepage, and interaction with pit lake level.
SB03	Observation	Level	Site is located to the south (downgradient) of TSF4. Monitoring to assess potential influence of TSF4 on groundwater table.
SB04	Observation	Level	Site is located to the south (downgradient) of TSF4. Monitoring to assess potential influence of TSF4 on groundwater table.
SB05	Observation	Level	Site is located to the south-east (downgradient) of TSF4. Monitoring to assess potential influence of TSF4 on groundwater table.
MB8	Compliance	Level and quality	New monitoring bore proposed to the northwest (downgradient) of the low-grade stockpile. Monitoring to assess potential water quality change from seepage. Proposed coordinates 299180 mE, 8173275 mE. Nominal depth of 30 mBGL.

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DANIEL BARCLAY
Principal Hydrogeologist

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LIMITATIONS OF REPORT

Rob Lait and Associates Pty Ltd (RLA) has prepared this report for the use of EQ Resources Pty Ltd in accordance with the usual care and thoroughness of the consulting profession. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report.

The methodology adopted and sources of information used by RLA are outlined in this report. RLA has made no independent verification of this information beyond the agreed scope of works and RLA assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to RLA was false.

This study was undertaken between September 2021 and November 2022 and is based on the conditions encountered and the information available at the time of preparation of the report. RLA disclaims responsibility for any changes that may occur after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. It may not contain sufficient information for the purposes of other parties or other users. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

This report contains information obtained by inspection, sampling, testing and other means of investigation. This information is directly relevant only to the points in the ground where they were obtained at the time of the assessment. Where borehole logs are provided, they indicate the inferred ground conditions only at the specific locations tested. The precision with which conditions are indicated depends largely on the frequency and method of sampling, and the uniformity of the site, as constrained by the project budget limitations. The behaviour of groundwater is complex.

Our conclusions are based upon the analytical data presented in this report and our experience.

Where conditions encountered at the site are subsequently found to differ significantly from those anticipated in this report, RLA must be notified of any such findings and be provided with an opportunity to review the recommendations of this report.

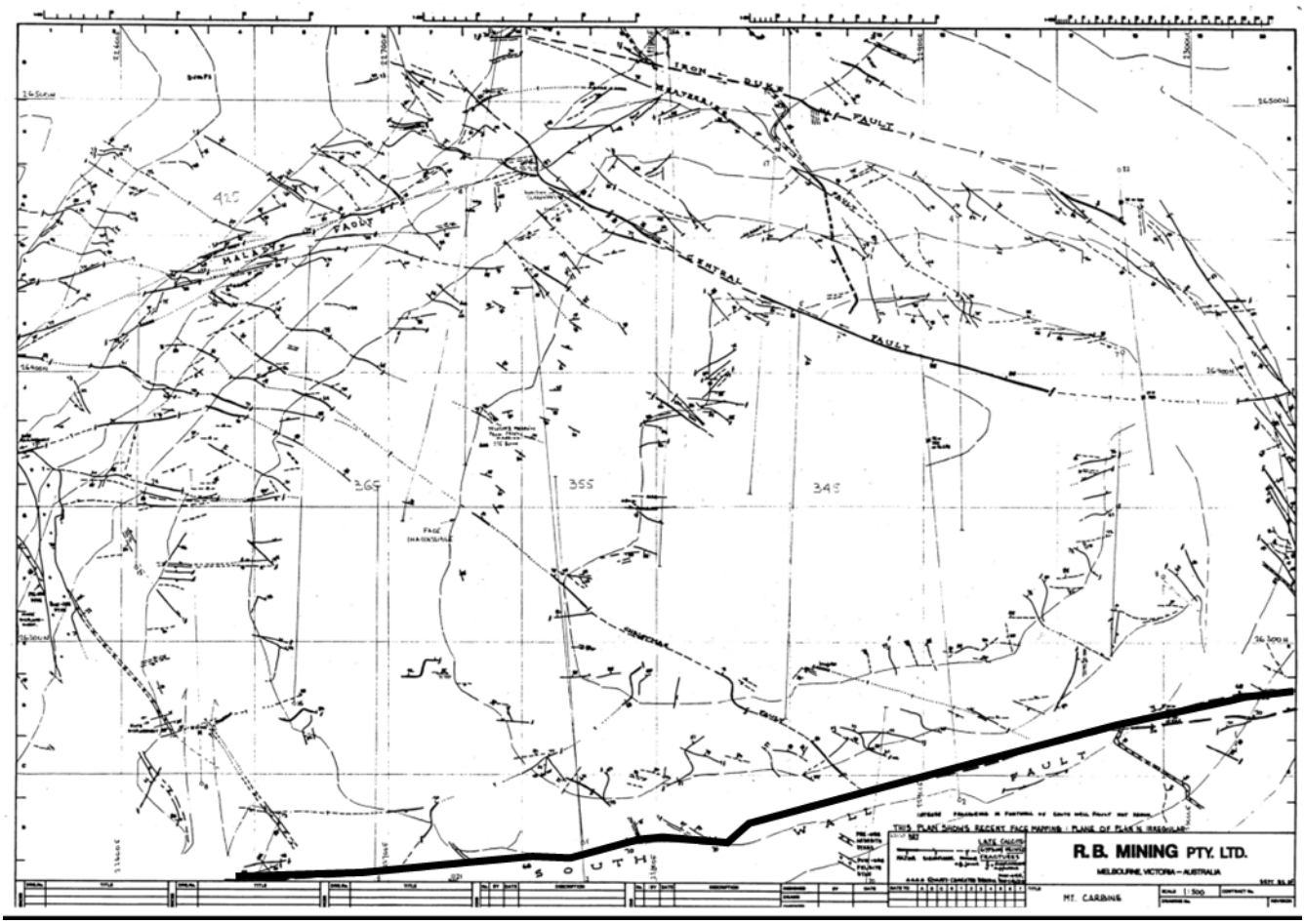
Whilst to the best of our knowledge, information contained in this report is accurate at the date of issue, subsurface conditions, including groundwater levels can change in a limited time. Therefore, this document and the information contained herein should only be regarded as valid at the time of the investigation unless otherwise explicitly stated in this report.

Appendix A - TECHNICAL REVIEW OF PIT STRUCTURES AT MT CARBINE

24 June 2022

FILE NOTE - TECHNICAL REVIEW OF PIT STRUCTURES AT MT CARBINE.

At Mt Carbine the ore deposits sits in hornfelsed margins of the Mossman Granite with several granite dykes cutting thru the deposit. The rocks are hard and siliceous in general and in the pit area have a late quartz vein overprint of mineralization that has over 50 veins of 10-700cm width observed forming approximately 10% of the host rock. Geotechnical logging has shown a 96% RQD with only minor fractures observed that typically are parallel to the quartz veins. The single major fault that occurs in the planned pit area is the South Wall Fault.



Historical Pit Mapping of Structures showing the dominance of the fault on the southern extent of the pit known as the South Wall Fault which truncates the mineralization. Other fractures do not move the mineralization.

SOUTH WALL FAULT

TIMING

The South Wall Fault truncates the ore body and forms the southern boundary of the pit. This is a steep (75 degrees) reverse fault that has been last active in Mid Palaeozoic when extension occurred in this region of the Hodkinson Basin. It was not a source of hydrothermal fluids as no alteration or mineralization exists on the fault of its margins as envelopes to it. Rather the fault is a result of clastic movement represented by 0.5-1.0m clay zone that has been developed due to crushed rock at the time of movement.

CHARACTERISTICS

The south wall fault is here illustrated in drill core from 5 intersections over the length of the planned pit. The fault is clearly seen in each of these intersections and, to date, the company has intersected this fault in over 42 separate intersections. The fault typically occurs as one central 0.5-1.0m zone of intense clay crushed rock or, less frequently, in two parts separated by 1-2m of fractured rock. The clay is greasy dense montmorillonite clay with 20-30% ground-up, but visible, rock particles of mostly metavolcanic rock. It is a clastic fault of high elasticity due to the clay content.
The orientation and extent of the fault is well known from the above 42 intersections and it is seen to be very consistent in its 75° dip to the grid north direction.

TABLE OF INTERCEPTS

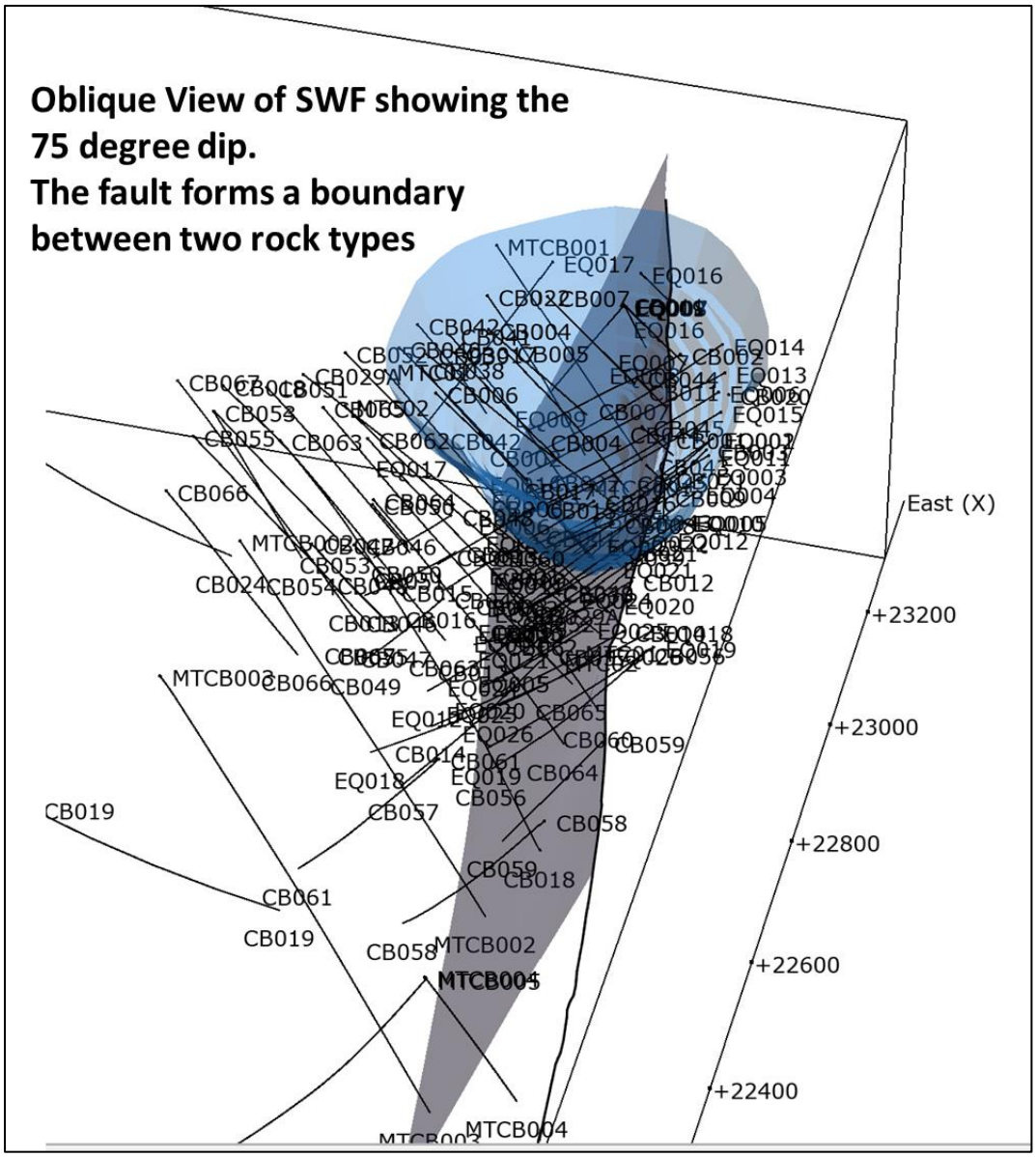
A total of 42 intercepts of SWF as follows:

- 18 intercepts in EQ Resources drilling that are orientated in drilling of 2021/22 era
- 24 intercepts of previous drilling that we have the drill core from historical drilling.

Hole_ID	Hangingwall	Rock
CB002	19	SWF
CB003	161.42	SWF
CB009	17.1	SWF
CB011	57.33	SWF
CB014	12.64	SWF
CB018	576.5	SWF
CB020	140.76	SWF
CB020	140.7	SWF
CB022	240.19	SWF
CB038	303.5	SWF
CB039	275.78	SWF
CB040	323.55	SWF
CB041	272.32	SWF
CB043	12	SWF
CB044	26.41	SWF
CB045	22.08	SWF
CB052	392.76	SWF
CB056	92.5	SWF
CB060	227.1	SWF
CB064	365.9	SWF
CB065	414.53	SWF
EQ001	121.3	SWF
EQ002	158.2	SWF
EQ003	112.7	SWF
EQ004	104	SWF
EQ005	109	SWF
EQ006	107.5	SWF
EQ007	44.35	SWF
EQ008	55.32	SWF
EQ010	67.7	SWF
EQ011	96.2	SWF
EQ012	35	SWF
EQ013	134.53	SWF
EQ014	132.5	SWF
EQ015	112.8	SWF
EQ016	37	SWF
EQ018	66.5	SWF
EQ019	86.7	SWF
MTC01	337	SWF
MTC02	371.5	SWF
MTCB001	244.5	SWF
MTCB002	549	SWF

Along the fault on the ground over the extent of exposure (Drilling area) which is 1.2km there is no wet seepage is seen nor any particular greenery marking that the fault might be a water source for vegetation.

The fault forms a boundary to the two major rock units observed in the extended pit area, namely the metavolcanics (Consisting of lavas and submarine cherts) and the metasediments (Consisting of hornfelsed mudstones and siltstones). Both rock units can be found in fragments in the fault but typically it is the footwall rock type that is most prevalent.



No strike slip movements have been observed in any striations or clay imprints with all showing a dip slip movement to the north east. The fault has a fractured footwall for 1-5m in width with only minor extra fracturing observed in the hanging wall. In fact 3 holes (EQ003,012 and 016) all drilled below the old open cut and at various depths below the existing pit (25,40 and 60m) all were dry holes and required the drillers to continually pump water down them to enable drilling.

Each of the photos below highlights in yellow the fault and the text referenced on each photo refers to this section of the drill core.



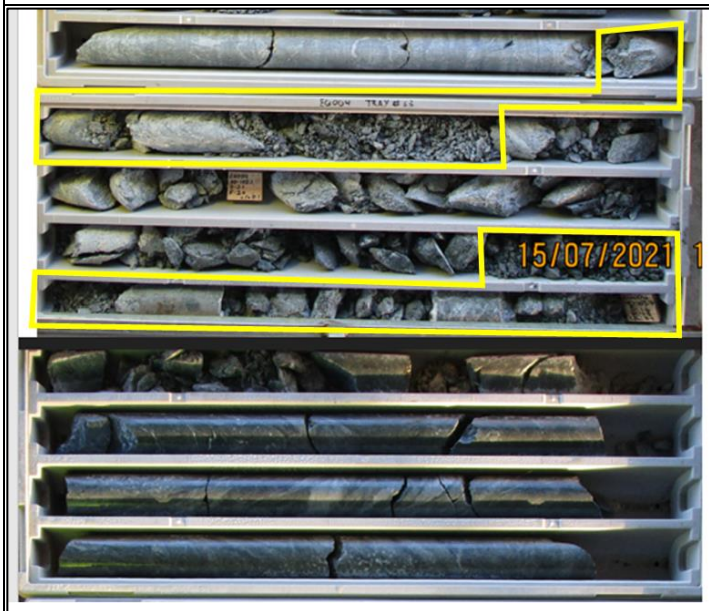
EQ001 - SWF

Tight competent rocks either side of the fault.



EQ002 - SWF

Fracturing observed in footwall of the fault (upper part of photo). The hanging wall, which is represented by the below fault in the photo has only the normal amount of fracturing. The photo is from a hole drilled from footwall thru the fault to hanging wall.



EQ004 – SWF – two sections



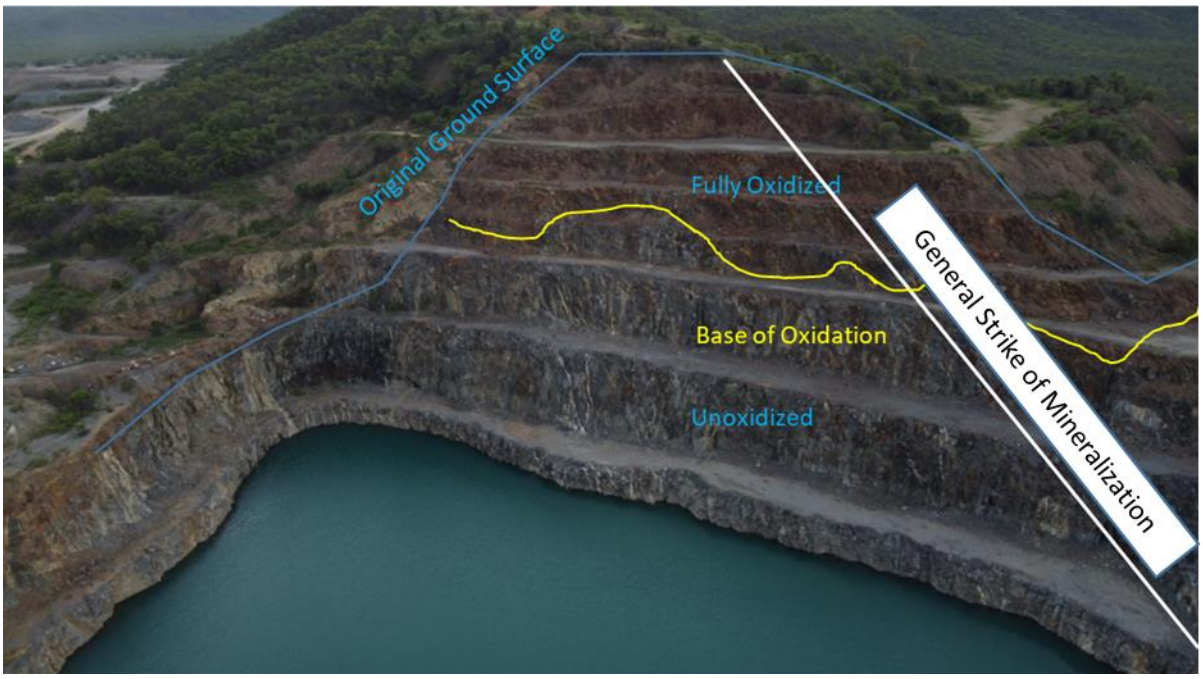
EQ005 – SWF

Fault displayed over two sections (0.8m & 1.2m) with fractured rocks in between. In 3 cases we see the fault bifurcate.	The SWF showing the level of fracturing around it. Clay zone only is 25cm in this case.

OXIDATION

The base of oxidation varies from 21-42m in down hole depth reflecting a base of oxidation at approximately 30m deep. This can be seen in the photo of the pit wall of the north high wall of the pit.

One of the most important points that show water is not moving along the SWF is the oxidation. As can be seen in these quite shallow intercepts of the SWF there is no oxidation present. The intercepts are less than 10m below the Base of Oxidation (BOX) and yet no surface water or oxidized pit water is infiltrating the fault. If the faults were open and had water movement and given the fault outcrops at surface there would be a draw down of oxidation on the fault. This is common in most deposits and even the pit wall shows a consistent base of oxidation and doesn't see rain waters oxidizing down faults.



Base of oxidation is consistent and doesn't show drawdown or water flow along structures.



Typical Zone from Oxidation to Fresh rocks in Metavolcanics

Base of Oxidation is sharp and consistent across fault showing no preference for oxidating waters to enter or move along faults



Typical Mineralized Qtz Zone in Metasediments

Weakly fractured core typical of the metasediments where the hole was dry in Hole EQ012 below the historical water filled pit.



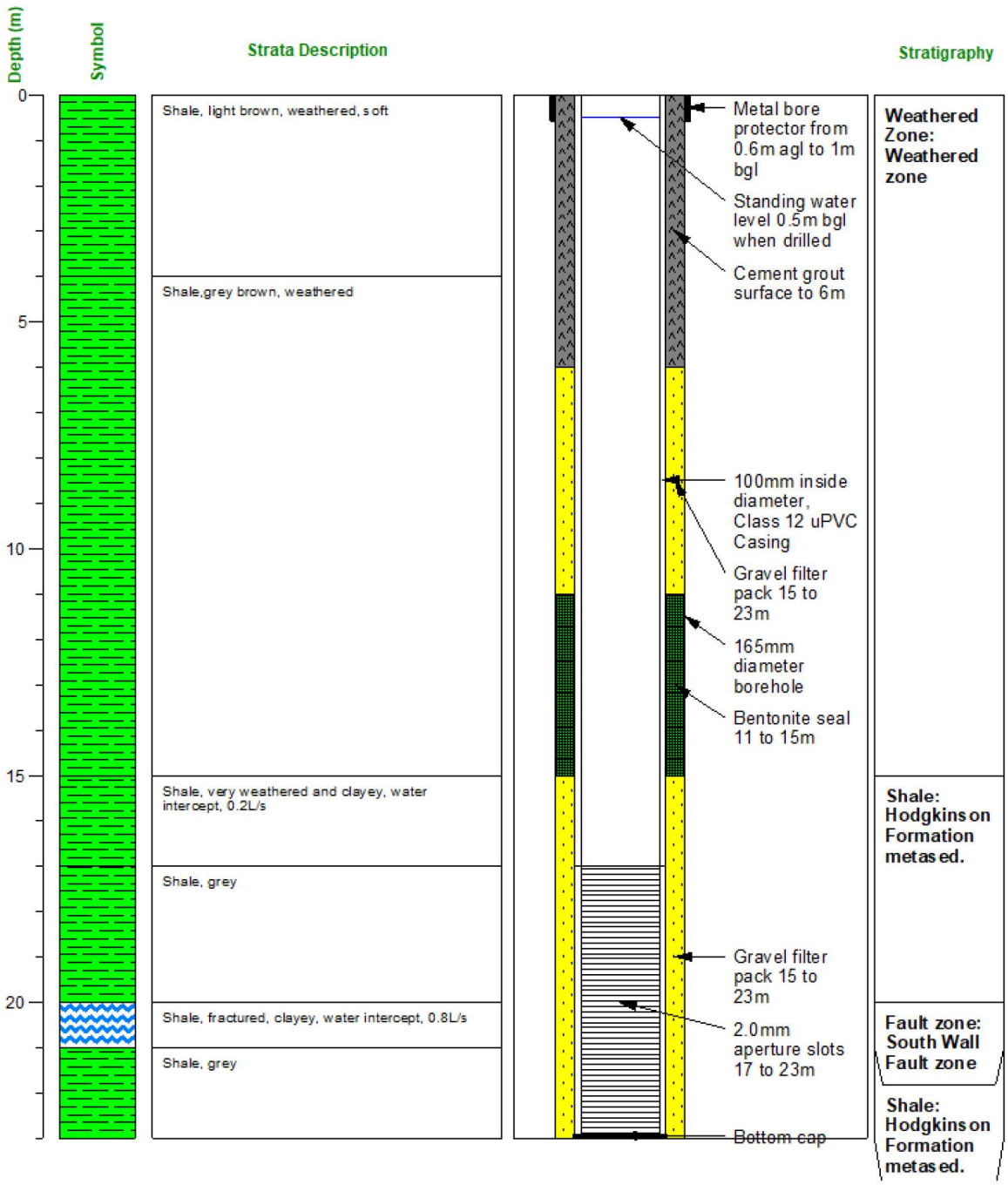
Drill Core – EQ012 40.1-47.1m. The dyke at the western end of the pit is competent and very tight in structures showing if forms a barrier to water flow at this end of the pit. The dyke is post mineralization.

Tony Bainbridge
Chief Geologist
Mt Carbine

Appendix B - IB BORE LOGS

Borehole No: IB01 **Client: EQ Resources**

Location:	Mt Carbine	**Date Drilled:**	**21/1/2022**	**Project No:**	222
Easting:	299429	**Northing:**	8173221	**Elevation (m):**	
Method:	Rotary air	**Driller:**	M Quinn	**Drilling Rig:**	Fraste



Notes:

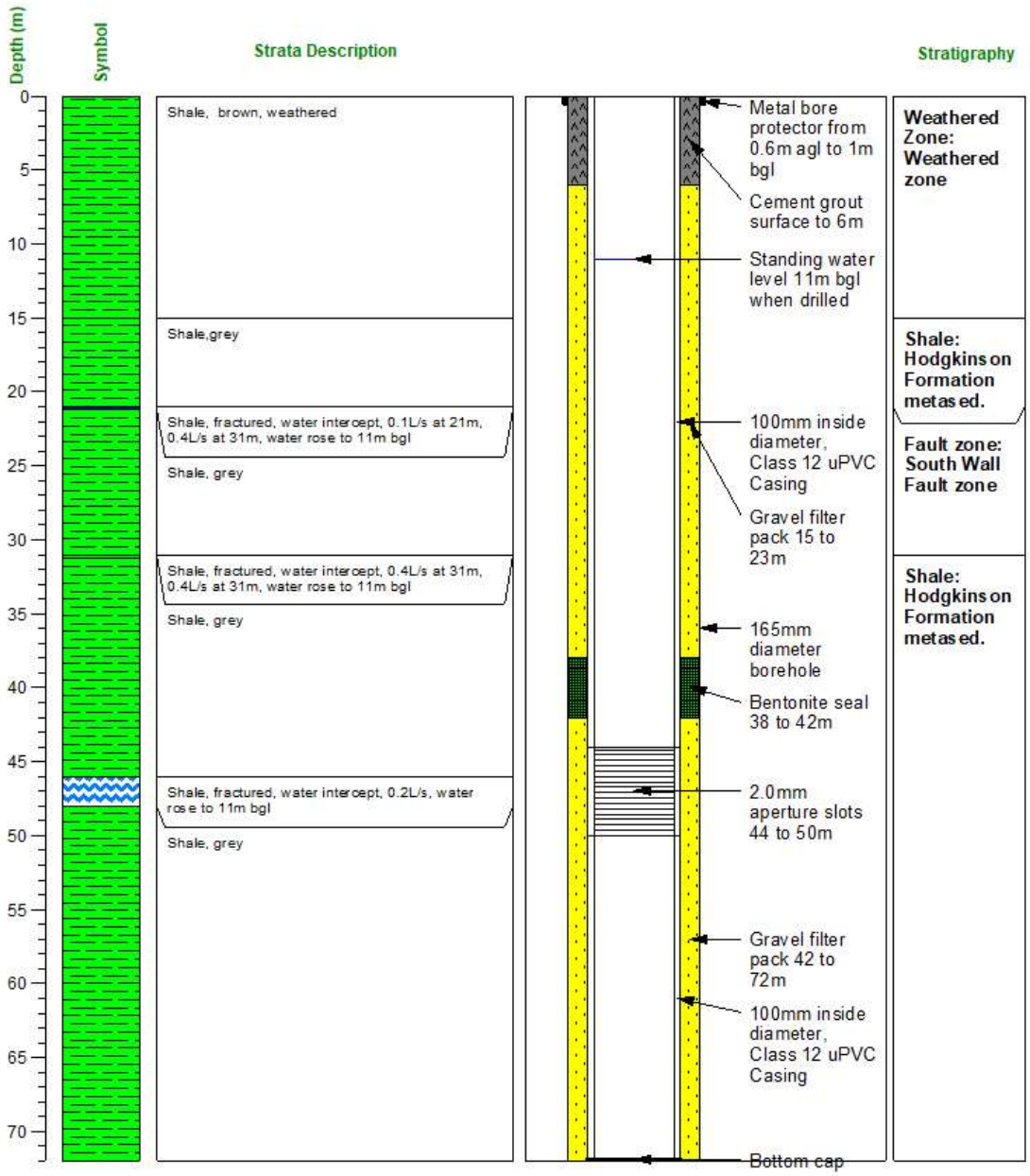
Datum: AHD/MGA

Borehole No: IB02 **Client: EQ Resources**

Location: Mt Carbine **Date Drilled:** 18/1/2022 **Project No:** 222

Easting: 300183 **Northing:** 8172486 **Elevation (m):**

Method: Rotary air **Driller:** M Quinn **Drilling Rig:** Fraste



Notes:

Datum: AHD/MGA

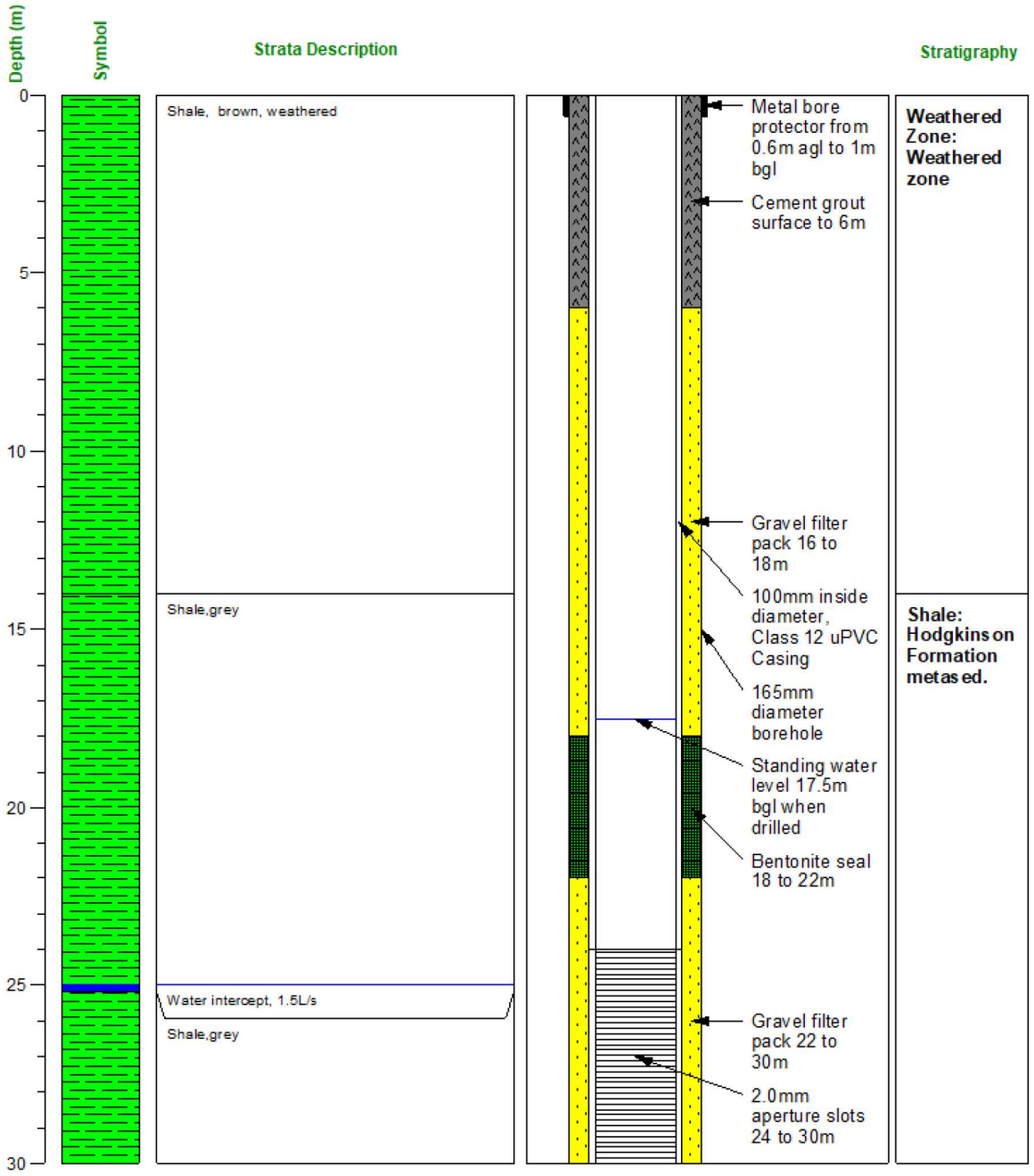
Borehole No: IB03 **Client: EQ Resources**

Location: Mt Carbine **Date Drilled:** 20/1/2022 **Project No:** 222

Easting: 300569 **Northing:** 8171746 **Elevation (m):**

Method: Rotary air **Driller:** M Quinn **Drilling Rig:** Fraste



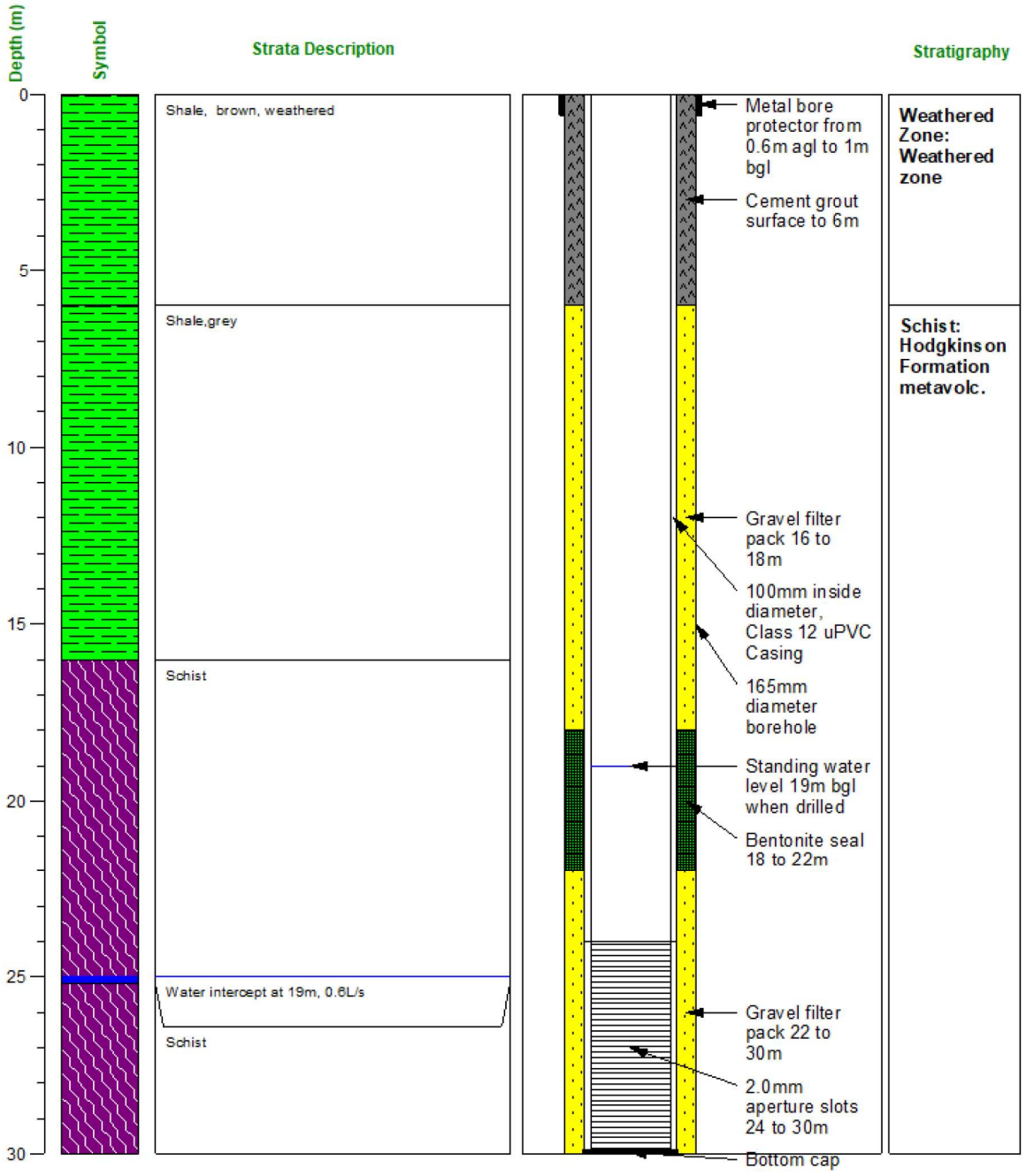


Notes:

Datum: AHD/MGA

Borehole No: IB04 **Client: EQ Resources**

Location:	Mt Carbine	**Date Drilled:**	**18/1/2022**	**Project No:**	222
Easting:	301029	**Northing:**	8172126	**Elevation (m):**	
Method:	Rotary air	**Driller:**	M Quinn	**Drilling Rig:**	Fraste

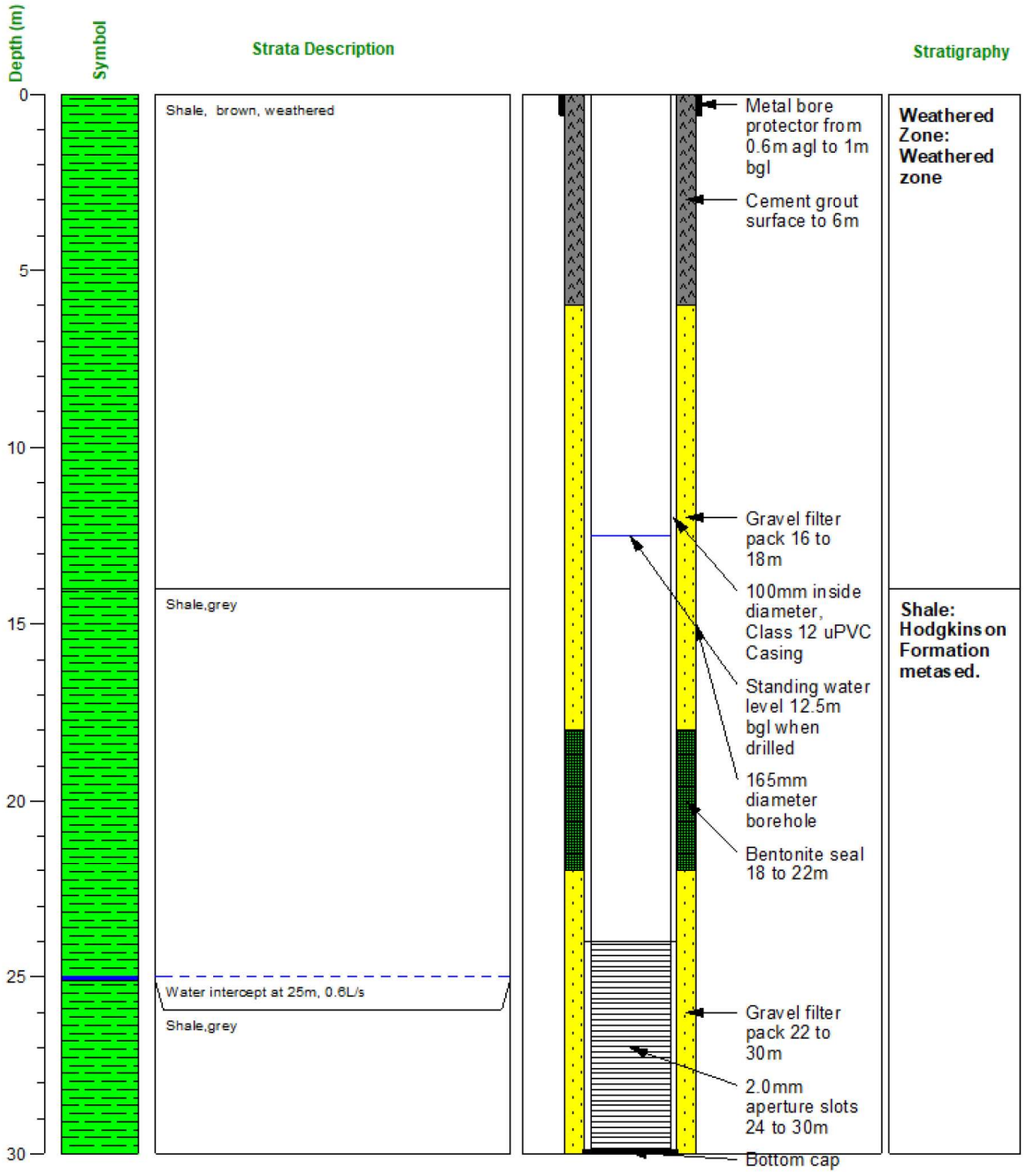


Notes:

Datum: AHD/MGA

Borehole No: IB05 **Client: EQ Resources**

Location:	Mt Carbine	**Date Drilled:**	19/1/2022	**Project No:**	222
Easting:	299915	**Northing:**	8171747	**Elevation (m):**	
Method:	Rotary air	**Driller:**	M Quinn	**Drilling Rig:**	Fraste

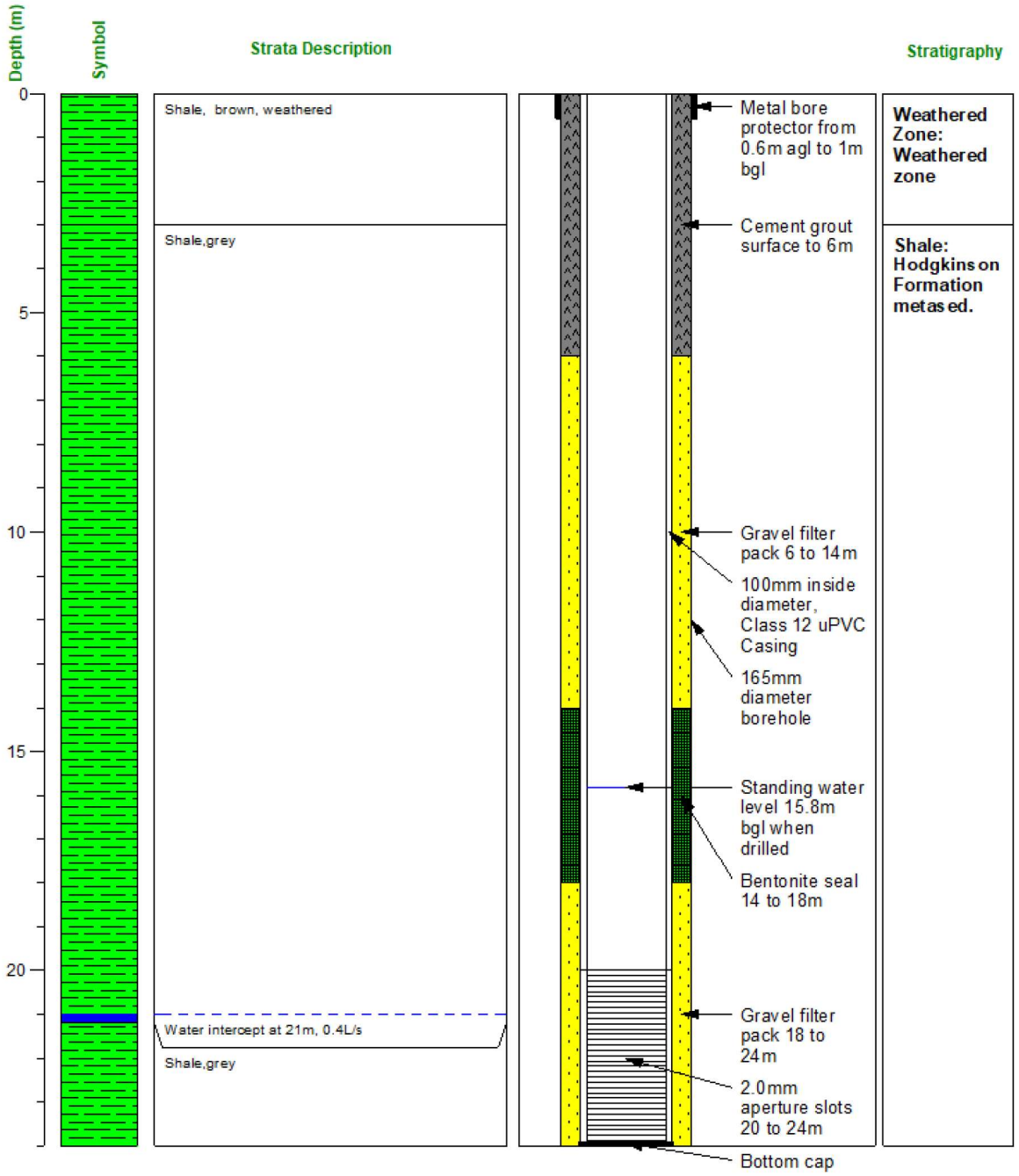


Notes:

Datum: AHD/MGA

Borehole No: IB06 **Client: EQ Resources**

Location:	Mt Carbine	**Date Drilled:**	19/1/2022	**Project No:**	222
Easting:	298743	**Northing:**	8171345	**Elevation (m):**	
Method:	Rotary air	**Driller:**	M Quinn	**Drilling Rig:**	Fraste



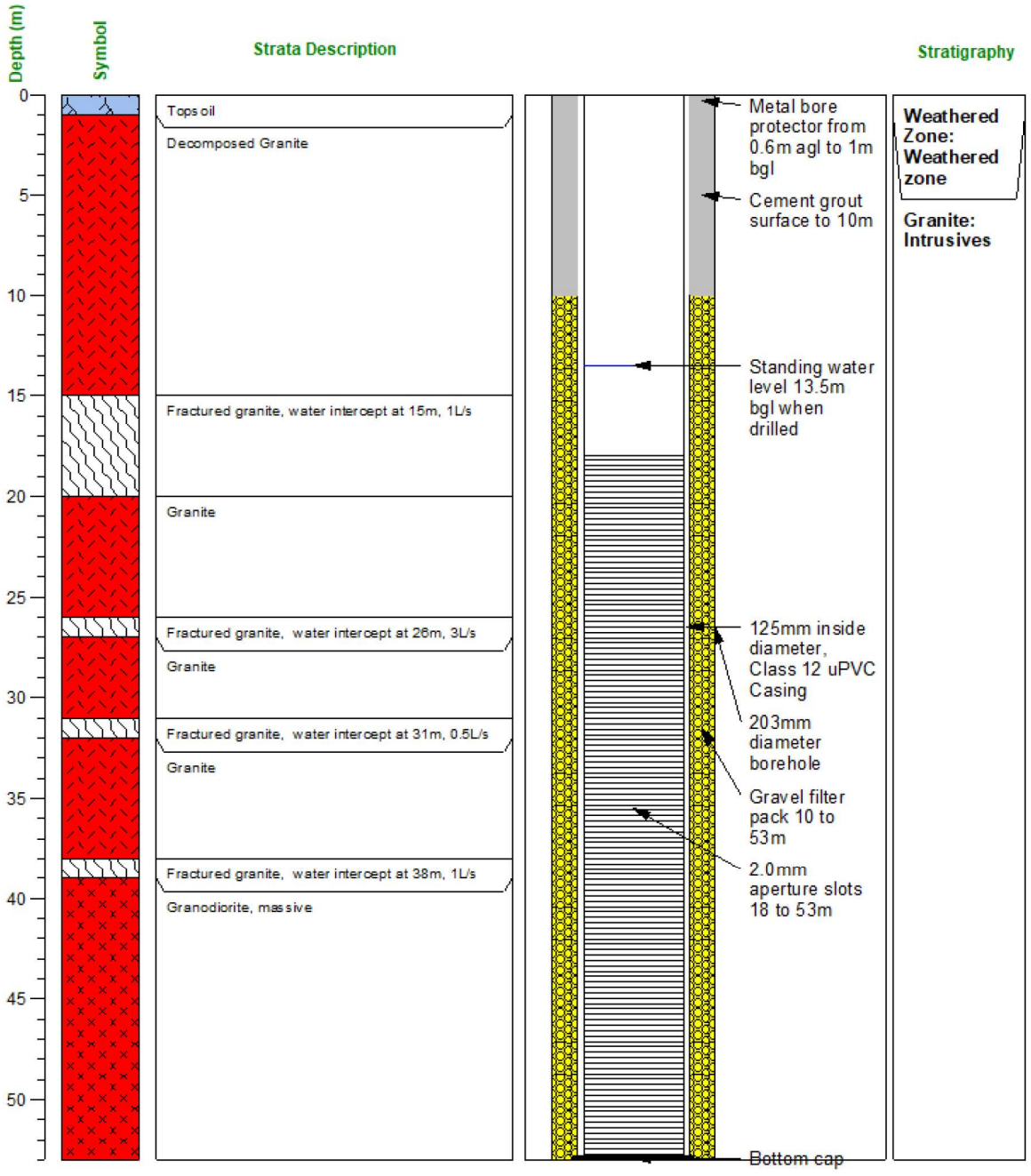
Notes:

Datum: AHD/MGA

Borehole No: IB07

Client: EQ Resources

Location:	Mt Carbine	**Date Drilled:**	**22/6/2022**	**Project No:**	222
Easting:	299574	**Northing:**	8170830	**Elevation (m):**	
Method:	Rotary air	**Driller:**	M Serra	**Drilling Rig:**	T4W



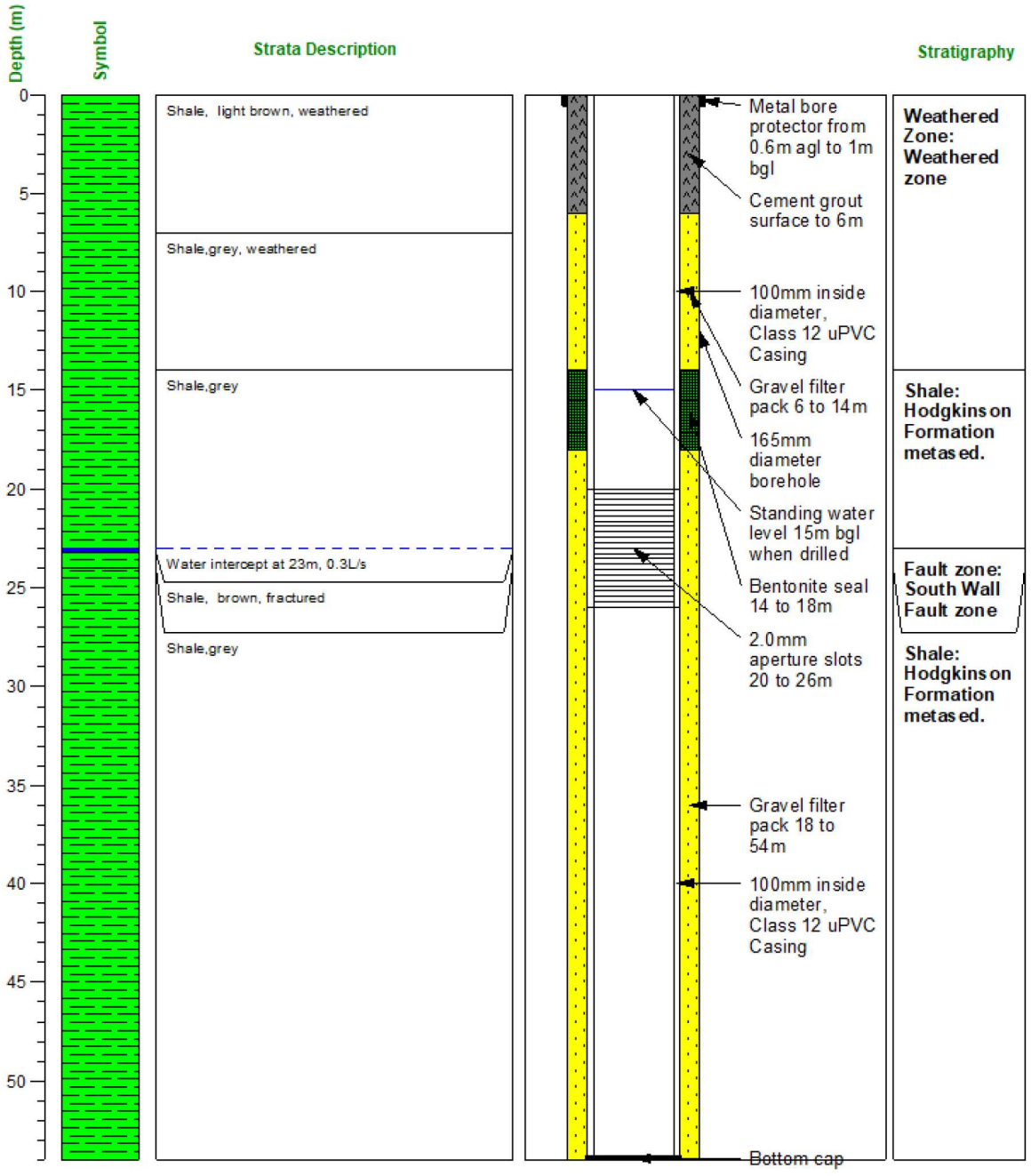
Notes:

Datum: AHD/MGA

Strata description by driller

Borehole No: IB08 **Client: EQ Resources**

Location:	Mt Carbine	**Date Drilled:**	**20/1/2022**	**Project No:**	222
Easting:	300893	**Northing:**	8171793	**Elevation (m):**	
Method:	Rotary air	**Driller:**	M Quinn	**Drilling Rig:**	Fraste



Notes:

Datum: AHD/MGA

Appendix L:
Mount Carbine Void Water Quality, Groundwater Relationship and Spill Risk (NRA 2023b)

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Technical Note

To	EQ Resources/Mount Carbine Quarries
Job no.	380013.04
Author	John Broughton
Technical Review	Tim Anderson
Date	25 May 2023

NRA Reference: F:\AAA\380_EQ Resources\380013_EA Amends_Mine from 2020\380013.04_Void\rpt\TN Mount Carbine Void Water Quality_TN01.docx

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Mount Carbine void water quality, groundwater relationship and spill risk

Introduction

The water quality, groundwater relationship (*ie* sink or source) and spill risk of the Mount Carbine void are examined to assist with its management and long-term planning.

Void water quality

Void water quality was examined to inform the environmental risk associated with spills (*ie* the void over-topping) and seepage (loss from the wall and floor). The examination compared all available void water quality data (*ie* from 1992 to 2023) to:

1. aquatic ecosystem protection guideline values
2. the quality of water previously released from site
3. livestock drinking water quality guidelines.

Before assessments were undertaken, water quality data for each site-analyte was screened for outliers. Outliers were nominated as values greater than the 75th percentile plus 1.5 times the interquartile range (*ie* 75th percentile – 25th percentile) or less than the 25th percentile minus 1.5 times the interquartile range (*ie* the inter-quartile range method described in DES (2021)). Due to the reduction in analytical reliability as determinations approach the limit of reporting (LOR), values that were less than 10 times the LOR were not considered outliers. Outliers were excluded from the assessment. Data summaries and outliers are in **Attachment 1**.

Aquatic ecosystems

Void water quality was assessed against aquatic ecosystem protection guideline values using:

- the Mount Carbine receiving environment monitoring program (REMP), (NRA 2020) site-specific guideline values (SSGVs) for Manganese Creek[1] for pH, electrical conductivity (EC), sulfate, fluoride, filtered aluminium, filtered antimony, filtered arsenic, filtered cadmium, filtered chromium, filtered cobalt, filtered copper, filtered lead, filtered manganese, filtered molybdenum, filtered nickel, filtered selenium, filtered tungsten, and filtered zinc. Medians are the assessment values used with SSGVs.
- toxicant default guideline values (DGVs) for the protection of moderately disturbed aquatic ecosystems (ANZG 2018) for aluminium, antimony, arsenic, boron, cadmium, chromium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, uranium, and zinc (all filtered concentrations). The 95th percentiles are the assessment values used with toxicant DGVs.

Assessment values had to be greater than (or less than for pH assessment against lower guideline values) all relevant guideline values (*ie* DGVs and SSGVs) for the analyte to report an exceedance. Exceedances were reported for pH, EC, fluoride, sulfate, filtered arsenic, filtered cadmium, filtered molybdenum, filtered tungsten and filtered uranium.

Comparison to release water quality

Void water was compared to water quality of releases[2] from TSF4 that occurred from:

- 24 January – 12 February 2013
- 15 April – 8 May 2014
- 3–14 February 2022.

Maximum values in void water were compared to maximum values during releases, and the minimum pH value in the void water was compared to the minimum pH recorded during the releases. pH, EC, sulfate, fluoride, sodium, calcium, magnesium, chloride and filtered and unfiltered concentrations of aluminium, antimony, arsenic, boron, cadmium, chromium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, and uranium were assessed.

The maximum value for void water exceeded the maximum value record during releases for pH, EC, sulfate, fluoride, sodium, calcium, magnesium, chloride, filtered antimony, filtered and unfiltered arsenic, filtered and unfiltered boron, filtered and unfiltered cadmium, filtered and unfiltered cobalt, filtered lead, filtered and unfiltered nickel, filtered and unfiltered selenium, filtered and unfiltered tungsten, filtered and unfiltered uranium, and unfiltered zinc. The minimum void water pH was not lower than the lowest pH recorded during a release.

Livestock

Void water quality was assessed against livestock (beef cattle) drinking water quality guideline values (ANZG 2018). The assessment compared the maximum, median and minimum of each analyte in the void water to the guideline value. Analytes assessed were EC, sulfate, fluoride, aluminium, arsenic, boron, cadmium, chromium, cobalt, copper, lead, molybdenum, nickel, selenium, uranium and zinc.

[1] If the void were to spill, Manganese Creek is expected to be the receiving water.

[2] Only release events where the REMP reporting has been concluded.

The only reported exceedance was for fluoride. The maximum, median and minimum values all exceed the fluoride guideline value for livestock (beef cattle) drinking water.

Relationship to groundwater

The water balance modelling indicates that the void is expected to act as a groundwater sink under three modelled climate scenarios (see **Spill risk** section immediately below). This has been interpreted using the equilibrium water levels from the modelled scenarios and the reported elevation of the in-flow/out-flow transition point[3] (365 m AHD[4]) in the void. The transition point is consistent with the highest groundwater level recorded in proximity to the void by Piteau & Associates (1982) prior to the void's expansion to its current dimensions.

The equilibrium water levels given by ATCW (2022a) for each climate scenario are:

- for the no-change scenario: oscillating between 357 m and 369 m RL (mid-point 363 m RL), indicating the void will swap between in-flows and outflows; as the mid-point of the oscillation range is below the transition elevation, the void is expected to act as a net groundwater sink
- for the RCP4.5 scenario: oscillating between 355 m and 365 m RL, indicating that the void will act as a groundwater sink
- for the RCP8.5 scenario: oscillating between 352 m and 364 m RL, indicating that the void will act as a groundwater sink.

The void acting as a groundwater sink reduces the risk of void water migration and the associated environmental concerns.

Groundwater flow near the void is expected to be relatively inhibited by the geology. RLA & Hydrogeologist (2022) identifies that the hydraulic conductivity of the void host rocks (Hodgkinson Formation hornfels) may be reduced relative to the surrounding rock. This suggests that where groundwater flows to or from the void occur, they are likely to be limited relative to the wider geology.

Spill risk

ATCW (2022a) modelled the water balance for the final void with the objective of assessing the long-term water balance of the void following cessation of mining operations. Climatic condition and groundwater in-flows (as described in ATCW (2022b)) were included in the models. The water balance was simulated for 650 years (from 2027 to 2677).

Three climate scenarios were modelled to examine the possible effects of climate change:

1. no change in climate
2. Queensland Future Climate Change Model for the scenario RCP4.5 (gradual increase to stable levels of carbon dioxide at 2060 AD)
3. Queensland Future Climate Change Model for the scenario RCP8.5 (continually increasing levels of carbon dioxide).

[3] The transition point is where water levels that are higher result in outflows from the void, and void water levels that are lower result in inflows (Diagram 19 of ATCW 2022b).

[4] ATCW (2022a) reports elevations in relative level (RL); ATCW (2022b) reports elevations in RL and Australian Height Datum (AHD). As RL and AHD are used for the same elevations (*eg* spill elevation) they are assumed to be equivalent between the ATCW (2022a, 2022b) reports.

Results of the void water balance model for the no change scenario:

- The Mount Carbine final void water level is predicted to take approximately 51 years to reach an equilibrium and will then oscillate between approximately RL 357 m and 369 m. The maximum forecast water level is approximately 11 m below the final void spill level.
- There is a very low risk of spill from the final void.

Results of the void water balance model for RCP4.5 scenario:

- The final void water level is predicted to take approximately 84 years to reach an equilibrium and will then oscillate between approximately RL 355 m and 365 m. The maximum forecast water level is approximately 15 m below the final void spill level.
- There is a very low risk of spill from the final void.

Results of the void water balance model for RCP8.5 scenario:

- The final void water level is predicted to take approximately 154 years to reach an equilibrium and will then oscillate between approximately RL 352 m RL and 364 m RL. The maximum forecast water level is approximately 16 m below the final void spill level.
- There is a very low risk of spill from the final void.

ATCW (2022a) modelling indicates that the void has a very low risk of spill under prevailing and predicted climatic conditions.

Summary

The quality of the waters in the void may pose a greater risk of environmental impact than waters previously released from site. Impacts from a release would be dependent on the quality, volume and duration of the release, as well as climatic and flow conditions in the receiving environment. Water balance modelling of the void under no change and climate change scenarios show that there is a very low risk of spill. The modelling has also been interpreted to indicate that the void will be a net groundwater sink, which will reduce the risk of groundwater migration.

References

ANZG 2018, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, Australian and New Zealand Governments and Australian state and territory governments, Canberra, viewed July 2022, https://www.waterquality.gov.au/anz-guidelines/guideline-values.

ATCW 2022a, *Mount Carbine Mining Stage 3 Water Management Plan – Final Void Water Balance Model*, Memorandum prepared by ATC Williams, 8 December 2022 (119190.04-M001Rev0).

ATCW 2022b, *Mount Carbine Mining Stage 3 Water Management Plan*, Report prepared by ATC Williams, November 2022 (119190.04R01_0).

DES 2021, *Using monitoring data to assess groundwater quality and potential environmental impacts, Version 2*, Department of Environment and Science, Queensland Government, Brisbane.

NRA 2020, *Mt Carbine Mine Receiving Environment Monitoring Program Version 2.0*, R01, prepared by NRA Environmental Consultants for Mt Carbine Quarries Pty Ltd, 30 October 2020.

Piteau & Associates, 1982, *Report on Slope Stability Analysis and Design of Open Pit Slopes*. Project 81-358, April 1982.

RLA & Hydrogeologist 2022, *Mount Carbine Operations – Revised Conceptual Groundwater Model*, prepared for EQ Resources by Rob Lait and Associates Pty Ltd and hydrogeologist.com.au, 15 November 2022.

Attachment 1 – Water quality

Table 1: Void water quality data summary (monitoring site OW1)

Analyte	Start	Finish	Count	Minimum	5%ile	20%ile	50%ile	80%ile	95%ile	Maximum
Aluminium, filtered mg/L	08/02/2011	06/01/2023	62	0.011	0.013	0.02	0.023	0.032	0.041	0.048
Aluminium, unfiltered mg/L	16/03/2011	26/08/2021	56	0.01	0.018	0.022	0.029	0.045	0.068	0.094
Antimony, filtered mg/L	31/03/2011	06/01/2023	26	<0.002	<0.002	<0.003	<0.003	<0.003	<0.003	0.003
Antimony, unfiltered mg/L	31/03/2011	06/01/2023	26	<0.002	<0.002	<0.003	<0.003	<0.003	<0.003	<0.003
Arsenic, filtered mg/L	08/02/2011	06/01/2023	69	0.016	0.086	0.11	0.14	0.15	0.16	0.17
Arsenic, unfiltered mg/L	30/05/2002	06/01/2023	73	0.045	0.088	0.11	0.15	0.16	0.16	0.18
Boron, filtered mg/L	04/06/2013	26/08/2021	39	<0.005	0.014	0.023	0.028	0.039	<0.05	<0.05
Boron, unfiltered mg/L	04/06/2013	26/08/2021	39	<0.005	0.013	0.022	0.027	0.04	<0.05	<0.05
Cadmium, filtered mg/L	08/02/2011	06/01/2023	66	<0.0001	<0.0001	0.0003	0.0007	0.0008	0.001	0.0012
Cadmium, unfiltered mg/L	30/05/2002	06/01/2023	73	<0.0001	<0.0001	0.0001	0.0007	0.0009	0.0012	0.0014
Calcium mg/L	16/03/2011	06/01/2023	58	51	62	74	90	94	95	100
Chloride mg/L	16/03/2011	06/01/2023	56	8	34	43	59	62	63	68
Chromium, filtered mg/L	08/02/2011	06/01/2023	69	0.0005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium, unfiltered mg/L	25/02/2011	06/01/2023	67	0.0005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt, filtered mg/L	08/02/2011	06/01/2023	69	0.0005	<0.001	<0.001	<0.001	<0.001	<0.005	<0.005
Cobalt, unfiltered mg/L	25/02/2011	06/01/2023	67	0.0005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.005
Copper, filtered mg/L	08/02/2011	06/01/2023	69	0.0005	<0.001	<0.001	<0.001	<0.001	0.003	0.005
Copper, unfiltered mg/L	09/01/2003	06/01/2023	73	0.0005	<0.001	<0.001	<0.001	0.002	0.004	0.007
EC µS/cm	30/05/2002	06/01/2023	77	550	620	744	820	858	872	950
Fluoride mg/L	08/02/2011	06/01/2023	67	6.6	6.7	7.8	8.4	9	9.4	10
Lead, filtered mg/L	08/02/2011	06/01/2023	65	0.0005	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
Lead, unfiltered mg/L	25/02/2011	06/01/2023	63	0.0005	<0.001	<0.001	<0.001	<0.001	<0.001	0.002

Analyte	Start	Finish	Count	Minimum	5%ile	20%ile	50%ile	80%ile	95%ile	Maximum
Magnesium mg/L	16/03/2011	06/01/2023	58	17	19	22	25	26	27	27
Manganese, filtered mg/L	08/02/2011	06/01/2023	63	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.006
Manganese, unfiltered mg/L	25/02/2011	06/01/2023	61	<0.005	<0.005	<0.005	<0.005	0.006	0.028	0.038
Molybdenum, filtered mg/L	08/02/2011	06/01/2023	63	0.041	0.046	0.051	0.059	0.063	0.065	0.069
Molybdenum, unfiltered mg/L	25/02/2011	06/01/2023	61	0.041	0.045	0.052	0.059	0.064	0.067	0.07
Nickel, filtered mg/L	31/03/2011	06/01/2023	26	<0.001	<0.001	<0.001	<0.001	0.001	<0.002	0.002
Nickel, unfiltered mg/L	31/03/2011	06/01/2023	26	<0.001	<0.001	<0.001	<0.001	0.001	<0.002	0.002
pH unitless	10/11/1992	06/01/2023	79	7	7.3	7.87	8.1	8.2	8.3	8.5
Potassium mg/L	16/03/2011	06/01/2023	56	2.3	2.5	2.6	2.8	2.9	3	3.1
Selenium, filtered mg/L	27/11/2014	06/01/2023	24	0.002	0.002	<0.003	<0.003	<0.003	<0.003	0.003
Selenium, unfiltered mg/L	27/11/2014	06/01/2023	24	<0.003	<0.003	<0.003	<0.003	<0.003	0.004	0.004
Sodium mg/L	16/03/2011	06/01/2023	57	24	27	34	40	41	42	45
Sulfate mg/L	08/02/2011	06/01/2023	69	160	190	230	250	260	280	290
Tin, filtered mg/L	31/03/2011	27/04/2011	2	<0.005	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Tin, unfiltered mg/L	31/03/2011	27/04/2011	2	<0.005	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Total alkalinity mgEq$CaCO_3$/L	26/11/2020	06/01/2023	8	57	59	63	70	73	73	73
Tungsten, filtered mg/L	31/03/2011	6/01/2023	43	<0.0001	0.001	0.023	0.036	0.041	0.047	0.051
Tungsten, unfiltered mg/L	31/03/2011	6/01/2023	42	<0.0001	0.0018	0.025	0.036	0.045	0.048	0.057
Uranium, filtered mg/L	04/06/2013	26/08/2021	39	<0.0005	<0.0005	0.0006	0.001	0.001	0.0013	0.0015
Uranium, unfiltered mg/L	04/06/2013	26/08/2021	39	<0.0005	0.0006	0.0007	0.001	0.001	0.0012	0.0018
Zinc, filtered mg/L	08/02/2011	06/01/2023	64	0.0025	<0.005	<0.005	<0.005	0.007	0.016	0.019
Zinc, unfiltered mg/L	09/01/2003	06/01/2023	66	0.0025	<0.005	<0.005	<0.005	<0.01	0.025	0.042

Table 2: Release water quality data summary (monitoring site OW4)

Analyte	Start	Finish	Count	Minimum	5%ile	20%ile	50%ile	80%ile	95%ile	Maximum
Aluminium, filtered mg/L	31/01/2013	10/02/2022	15	0.007	0.008	0.011	0.018	0.025	0.063	0.12
Aluminium, unfiltered mg/L	24/01/2013	10/02/2022	20	0.035	0.043	0.07	1.01	2.1	3.3	3.3
Antimony, filtered mg/L	03/02/2022	10/02/2022	8	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Antimony, unfiltered mg/L	03/02/2022	10/02/2022	8	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Arsenic, filtered mg/L	24/01/2013	10/02/2022	23	<0.003	<0.003	0.003	0.029	0.071	0.08	0.085
Arsenic, unfiltered mg/L	24/01/2013	10/02/2022	23	0.004	0.005	0.007	0.04	0.084	0.09	0.093
Boron, filtered mg/L	15/04/2014	09/02/2022	10	0.02	0.021	0.023	0.026	0.043	0.044	0.044
Boron, unfiltered mg/L	15/04/2014	09/02/2022	10	0.029	0.029	0.03	0.031	0.042	0.044	0.044
Cadmium, filtered mg/L	24/01/2013	10/02/2022	23	<0.0001	<0.0001	<0.0001	<0.0001	0.0004	0.0004	0.0004
Cadmium, unfiltered mg/L	24/01/2013	10/02/2022	23	<0.0001	<0.0001	<0.0001	0.0001	0.0004	0.0006	0.0006
Calcium mg/L	24/01/2013	10/02/2022	23	12	23	25	32	51	54	55
Chloride mg/L	24/01/2013	10/02/2022	23	4	4	5	10	35	39	39
Chromium, filtered mg/L	24/01/2013	10/02/2022	23	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chromium, unfiltered mg/L	24/01/2013	10/02/2022	23	<0.001	<0.001	<0.001	<0.001	0.002	0.003	0.004
Cobalt, filtered mg/L	24/01/2013	10/02/2022	23	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001
Cobalt, unfiltered mg/L	24/01/2013	10/02/2022	23	<0.001	<0.001	<0.001	<0.001	0.001	0.002	0.003
Copper, filtered mg/L	24/01/2013	10/02/2022	17	<0.001	<0.001	<0.001	0.001	0.003	0.007	0.01
Copper, unfiltered mg/L	24/01/2013	10/02/2022	16	<0.001	<0.001	<0.001	0.002	0.004	0.007	0.008
EC µS/cm	24/01/2013	10/02/2022	23	120	128	224	280	629	682.1	710
Fluoride mg/L	24/01/2013	10/02/2022	23	0.89	2.1	2.2	2.6	7.3	7.6	7.7
Lead, filtered mg/L	24/01/2013	10/02/2022	23	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead, unfiltered mg/L	24/01/2013	10/02/2022	23	<0.001	<0.001	<0.001	<0.001	0.002	0.003	0.003
Magnesium mg/L	24/01/2013	10/02/2022	23	2.1	4.2	4.3	12	21	23	23
Manganese, filtered mg/L	24/01/2013	10/02/2022	20	<0.005	<0.005	<0.005	<0.005	0.033	0.066	0.068

Analyte	Start	Finish	Count	Minimum	5%ile	20%ile	50%ile	80%ile	95%ile	Maximum
Manganese, unfiltered mg/L	24/01/2013	10/02/2022	22	0.007	0.012	0.019	0.054	0.108	0.21	0.22
Molybdenum, filtered mg/L	24/01/2013	10/02/2022	23	0.03	0.031	0.038	0.079	0.11	0.13	0.15
Molybdenum, unfiltered mg/L	24/01/2013	10/02/2022	23	0.032	0.032	0.037	0.08	0.11	0.13	0.16
Nickel, filtered mg/L	03/02/2022	10/02/2022	8	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel, unfiltered mg/L	03/02/2022	10/02/2022	8	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
pH unitless	24/01/2013	10/02/2022	23	6.4	6.6	6.8	7.28	7.54	7.6	7.7
Potassium mg/L	24/01/2013	10/02/2022	23	1.5	1.5	2.1	3.5	5.9	6.4	6.6
Selenium, filtered mg/L	03/02/2022	10/02/2022	8	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Selenium, unfiltered mg/L	03/02/2022	10/02/2022	8	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Sodium mg/L	24/01/2013	10/02/2022	23	3.5	7.4	7.6	17	32	34	34
Sulfate mg/L	24/01/2013	10/02/2022	23	31	62	63	110	170	180	200
Total alkalinity mgEq$CaCO_3$/L	03/02/2022	10/02/2022	8	19	43	87	98	100	106	110
Tungsten, filtered mg/L	15/04/2014	10/02/2022	14	0.001	0.001	0.001	0.024	0.029	0.031	0.032
Tungsten, unfiltered mg/L	15/04/2014	10/02/2022	14	0.001	0.001	0.001	0.026	0.032	0.033	0.034
Uranium, filtered mg/L	15/04/2014	09/02/2022	10	<0.0005	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001
Uranium, unfiltered mg/L	15/04/2014	09/02/2022	10	<0.0005	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001
Zinc, filtered mg/L	24/01/2013	10/02/2022	23	<0.005	<0.005	<0.005	<0.005	0.006	0.009	0.022
Zinc, unfiltered mg/L	24/01/2013	10/02/2022	23	<0.005	<0.005	<0.005	<0.005	0.013	0.026	0.033

Table 3: Values identified as outliers using the inter-quartile range method in the void and release datasets

Site	Analyte	Date	Value
OW1	Total alkalinity mgEq$CaCO_3$/L	10/11/1992	162
OW1	Aluminium, filtered mg/L	14/02/2011	0.54
OW1	Aluminium, filtered mg/L	25/02/2011	0.055
OW1	Aluminium, filtered mg/L	16/03/2011	0.056
OW1	Aluminium, filtered mg/L	31/03/2011	0.058
OW1	Aluminium, filtered mg/L	09/01/2017	0.057
OW1	Aluminium, filtered mg/L	09/02/2017	0.06
OW1	Aluminium, filtered mg/L	02/05/2019	0.052
OW1	Aluminium, unfiltered mg/L	25/02/2011	0.11
OW1	Aluminium, unfiltered mg/L	09/01/2013	0.1
OW1	Aluminium, unfiltered mg/L	21/01/2013	0.13
OW1	Aluminium, unfiltered mg/L	06/02/2013	0.37
OW1	Aluminium, unfiltered mg/L	24/07/2013	0.52
OW1	Aluminium, unfiltered mg/L	10/03/2016	0.12
OW1	Aluminium, unfiltered mg/L	09/01/2017	0.36
OW1	Aluminium, unfiltered mg/L	09/02/2017	0.34
OW1	Aluminium, unfiltered mg/L	26/08/2021	0.24
OW1	Aluminium, unfiltered mg/L	05/01/2023	0.2
OW1	Aluminium, unfiltered mg/L	06/01/2023	0.19
OW1	Arsenic, unfiltered mg/L	05/12/2005	0.2
OW1	Cadmium, filtered mg/L	28/10/2011	0.0013
OW1	Cadmium, filtered mg/L	21/11/2013	0.0013
OW1	Cadmium, filtered mg/L	27/03/2014	0.0013
OW1	Cadmium, unfiltered mg/L	22/08/2013	0.009
OW1	Calcium mg/L	10/11/1992	165.0
OW1	Calcium mg/L	05/04/1994	184.0
OW1	Chloride mg/L	10/11/1992	210
OW1	Chloride mg/L	05/04/1994	111.0
OW1	Chloride mg/L	01/05/2015	85
OW1	Copper, unfiltered mg/L	30/05/2002	0.024
OW1	EC µS/cm	10/11/1992	2100.0
OW1	EC µS/cm	05/04/1994	1320.0
OW1	EC µS/cm	09/01/2003	990
OW1	EC µS/cm	15/10/2007	980
OW1	Fluoride mg/L	28/10/2011	20
OW1	Fluoride mg/L	26/11/2020	11
OW1	Magnesium mg/L	10/11/1992	66.0
OW1	Magnesium mg/L	05/04/1994	47.0
OW1	pH unitless	30/05/2002	8.7
OW1	Potassium mg/L	10/11/1992	4.9
OW1	Potassium mg/L	05/04/1994	4.4
OW1	Potassium mg/L	06/11/2017	3.3
OW1	Potassium mg/L	08/11/2018	3.3

Site	Analyte	Date	Value
OW1	Sodium mg/L	10/11/1992	89.0
OW1	Sodium mg/L	05/04/1994	80.0
OW1	Sodium mg/L	27/06/2012	90
OW1	Sodium mg/L	31/07/2012	92
OW1	Sodium mg/L	21/01/2013	48
OW1	Sulfate mg/L	10/11/1992	460
OW1	Sulfate mg/L	05/04/1994	620.0
OW1	Tungsten, unfiltered mg/L	24/07/2013	0.077
OW1	Zinc, unfiltered mg/L	30/05/2002	0.21
OW1	Zinc, unfiltered mg/L	06/02/2004	0.15
OW1	Zinc, unfiltered mg/L	05/12/2005	0.1
OW4	Aluminium, filtered mg/L	24/01/2013	0.19
OW4	Aluminium, filtered mg/L	25/01/2013	0.24
OW4	Aluminium, filtered mg/L	26/01/2013	0.16
OW4	Aluminium, filtered mg/L	27/01/2013	0.16
OW4	Aluminium, filtered mg/L	28/01/2013	0.14
OW4	Aluminium, filtered mg/L	29/01/2013	0.18
OW4	Aluminium, filtered mg/L	30/01/2013	0.16
OW4	Aluminium, filtered mg/L	06/02/2013	0.15
OW4	Aluminium, unfiltered mg/L	15/04/2014	8.4
OW4	Aluminium, unfiltered mg/L	16/04/2014	8.8
OW4	Aluminium, unfiltered mg/L	18/04/2014	6.1
OW4	Copper, filtered mg/L	25/01/2013	0.011
OW4	Copper, filtered mg/L	26/01/2013	0.013
OW4	Copper, filtered mg/L	27/01/2013	0.013
OW4	Copper, filtered mg/L	28/01/2013	0.013
OW4	Copper, filtered mg/L	29/01/2013	0.012
OW4	Copper, filtered mg/L	30/01/2013	0.012
OW4	Copper, unfiltered mg/L	25/01/2013	0.023
OW4	Copper, unfiltered mg/L	26/01/2013	0.015
OW4	Copper, unfiltered mg/L	27/01/2013	0.023
OW4	Copper, unfiltered mg/L	28/01/2013	0.019
OW4	Copper, unfiltered mg/L	29/01/2013	0.015
OW4	Copper, unfiltered mg/L	30/01/2013	0.015
OW4	Copper, unfiltered mg/L	31/01/2013	0.016
OW4	Manganese, filtered mg/L	25/01/2013	0.2
OW4	Manganese, filtered mg/L	26/01/2013	0.12
OW4	Manganese, filtered mg/L	06/02/2013	0.44
OW4	Manganese, unfiltered mg/L	06/02/2013	0.57

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Appendix M:
Mt Carbine Mine Receiving Environment Monitoring Program (NRA 2020)

Environmental Approval & Compliance Solutions

Mt Carbine Mine Receiving Environment Monitoring Program

Version 2.0

Mt Carbine Quarries Pty Ltd

Document Control Summary

NRA Environmental Consultants

NRA Filepath:	F:\AAA\380_SMI\380005_SurfWater\380005.07 REMP Design Update 2020\Rpt\MtCarbine_REMP design rpt_v2.0_2020_R01.doc		
Status:	R01	**Date of Issue:**	30 October 2020
Project Manager:	Shannon Wetherall		
Title:	Mt Carbine Mine Receiving Environment Monitoring Program, V 2.0		
Client:	Mt Carbine Quarries Pty Ltd		
Client Contact:	Natasha Troughton, Administration Manager		
Copies Dispatched:	1 PDF		
Other Info or Requirements:	-		

Report Summary	
Key Words	Mt Carbine Mine, Mt Carbine Quarries Pty Ltd, MCQ, Receiving Environment Monitoring Program, REMP, design report, surface water, stream sediment, aquatic ecosystem, environmental values, Holmes Creek, Manganese Creek, Mitchell River
Abstract	The report outlines the design of the Receiving Environment Monitoring Program for the Mt Carbine tungsten mine as required by EA EPML00956913 (dated 4 August 2017). The program aims to identify and describe the extent of potential impacts on the local environmental values, and monitor changes in the receiving environment.

Citation
This report should be cited as: NRA 2020, *Mt Carbine Mine Receiving Environment Monitoring Program V. 2.0*, R01, prepared by NRA Environmental Consultants for Mt Carbine Quarries Pty Ltd, 30 October 2020.

Quality Assurance					
Author	**Technical Review**	**Editor**	**Document Version**	**Approved for Issue by QA Manager**	
				Date	**Signature**
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Summary of REMP Updates

Version	Issue date	Issued by
1.0	1 August 2014	NRA
2.0	30 October 2020	NRA

Version 2.0 of the Mt Carbine REMP includes the following changes.

- Update to the background water quality and stream sediment data summary, using data collected 2011–2020.
- Review of the default guideline values (DGVs) for water quality and stream sediment, due to the review and release of published guideline values (ANZG 2018).
- Update of the site-specific guideline values (SSGVs) with reference data collected since 2014 for the REMP.
- Clarification that the aquatic ecosystem environmental value is 'moderately disturbed', consistent with Queensland Government classification (Queensland *Environmental Protection (Water and Wetland Biodiversity) Policy* 2019).
- Removal of SW2 from the routine REMP sampling, due to sufficient data now available for Holmes Creek reference site SW16 and similarities in surface water and stream sediment quality between SW2 and SW16.
- Addition of SW14 as a Holmes Creek receiving site, for improved spatial distribution of monitoring sites.
- Clarification of monitoring triggers for Mitchell River sites, and associated recommendations to amend the receiving environment definition in the Environmental Authority (EA), dated 4 August 2017.

1. Introduction

The Mt Carbine tungsten mine is on mining leases (MLs) 4867 and 4919, which are held by Mt Carbine Quarries Pty Ltd (MCQ)[1]. The mining activities are conducted under EA EPML00956913 dated 4 August 2017. Quarry activities are also undertaken on the mining lease under a separate EA (EPPR00438313).

The REMP for Mt Carbine mine (NRA 2014a) was prepared per EA conditions D5 and D6 and has been implemented. Data, findings, and recommendations from implementing the REMP have been reported and provided to the administering authority in annual REMP reports (GHD 2015, NRA 2017a, 2018, 2019, 2020a)[2].

NRA Environmental Consultants (NRA) was commissioned by MCQ to review and update the REMP. The REMP has been prepared, reviewed, and updated by appropriately qualified individuals who have the necessary technical competencies and practical experience.

EA condition D5 sets the requirements for the REMP, as reproduced in **Table 1** with reference to the section of this report where the condition is addressed.

Table 1: List of EA Conditions specific to the REMP

EA condition[1]		Report section
D5	*The environmental authority holder must develop and implement a Receiving Environment Monitoring Program (REMP) sufficient to monitor, identify and describe any adverse impacts to surface water environmental values, quality and flows due to the authorised mining activity. For the purposes of the REMP, the receiving environment is the waters of Holmes Creek, Manganese Creek and connected or surrounding waterways within 15 kilometres downstream of the licensed place. At minimum, the REMP must include:*	This report, in its entirety, constitutes a REMP under the EA.
	a) monitoring of all parameters specified in Schedule D – Table D2 (Release Quality Objectives) at all locations specified in Schedule D – Table D4 (Receiving Waters Monitoring Locations) and at the following minimum frequency:	**Section 2**
	(i) for receiving waters and sediment quality, biannually (once at the end of the wet season and once at the end of the dry season); and	**Section 2.2**
	(ii) for water quality of receiving waters during a release or flow event, one sample must be taken within 12 hours of the event commencing. Where release or flow events have duration of greater than 24 hours, samples must be taken daily for 1 week and once a week thereafter until the release or flow event ceases.	**Section 2.2**
	b) monitoring of suitable biological indicators or aquatic ecosystem health.	**Section 2.6**

[1] EA EPML00956913, dated 4 August 2017.

[1] MCQ was acquired by Speciality Metals International Limited (formerly Carbine Tungsten Ltd) in 2019.

[2] An annual REMP report was not commissioned in 2016.

1.1 Background

The Mt Carbine township is approximately 80 km north-west of Cairns, in north Queensland, and the Mt Carbine tungsten mine is north and west of the township (**Figure 1**).

The tungsten mining operations that resulted in the layout of the Mt Carbine mine site started in 1973 (Carbine Tungsten Limited 2013). In 1991, the mine's plant and equipment were sold, and the site was left in a condition similar to that which existed when the contemporary operations commenced (Carbine Tungsten Limited 2013). The contemporary mining operations started in 2012 and included a tailings re-processing pilot plant immediately north of tailings storage facility number 4 (TSF4). The contemporary mining activities were placed into care and maintenance in May 2016 (NRA 2017b). In January 2020, retreatment of tailings recommenced (NRA 2020b); and in mid-2020, reject material from the quarry operations (*ie* mineralised material recovered from the historical low grade material stockpile (LGMS) and removed from quarry product) commenced treatment with the tailings.

Quarry operations occur within disturbed areas on the mining lease and are operated by MCQ under a separate EA. The quarry repurposes waste rock from stockpiles on-site and is not thought to have significantly altered the site since the cessation of previous mining operations (NRA 2014b).

1.1.1 Overview of water management on-site

The following water management practices are implemented to minimise the amount of mine-affected water on-site and to manage releases to surface water. Major water management features are shown on **Figure 1**, and site water management is described in the site water balance (ATC Williams 2019).

- Clean water diversion around TSF4 to minimise clean water entering the water storage.
- Clean water diversion upslope of the LGMS to minimise the volume of water entering, and draining from, the LGMS.
- Sump at the toe of the LGMS to collect water draining from the LGMS.
- Water transfer (via pumps and pipes) from the LGMS sump to the open pit, and from TSF4 to the open pit (if needed).
- Recovery of water from the clean water dam (CWD) and open pit (OW1) for use in the tailings retreatment process.
- Licensed release point at the TSF4 spillway.

1.2 Overview of Mt Carbine surface water

The Mt Carbine mine site is in the Mitchell River basin. The Mt Carbine mine site drains to the Mitchell River via Manganese Creek and Holmes Creek (**Figure 1**). Manganese Creek and Holmes Creek are ephemeral streams that discharge into the perennial Mitchell River approximately 5 km south of the mine site. The section of Mitchell River near Mt Carbine features multiple branches that divide and re-join around vegetated sand bars. The flow conditions of these branches range from perennial to intermittent. Manganese and Holmes creeks join channels of the Mitchell River that are reduced to disconnected pools during base flow conditions (*pers. obs*. Paul Godfrey, NRA, 2014).

The receiving environment of the mine site is defined in EA condition D5 as 'waters of Holmes Creek, Manganese Creek and connected or surrounding waterways within 15 kilometres downstream of the licensed place'. These temporary seasonal streams cease to flow within weeks after the rainfall has stopped, and they dry out for many kilometres over the dry season.

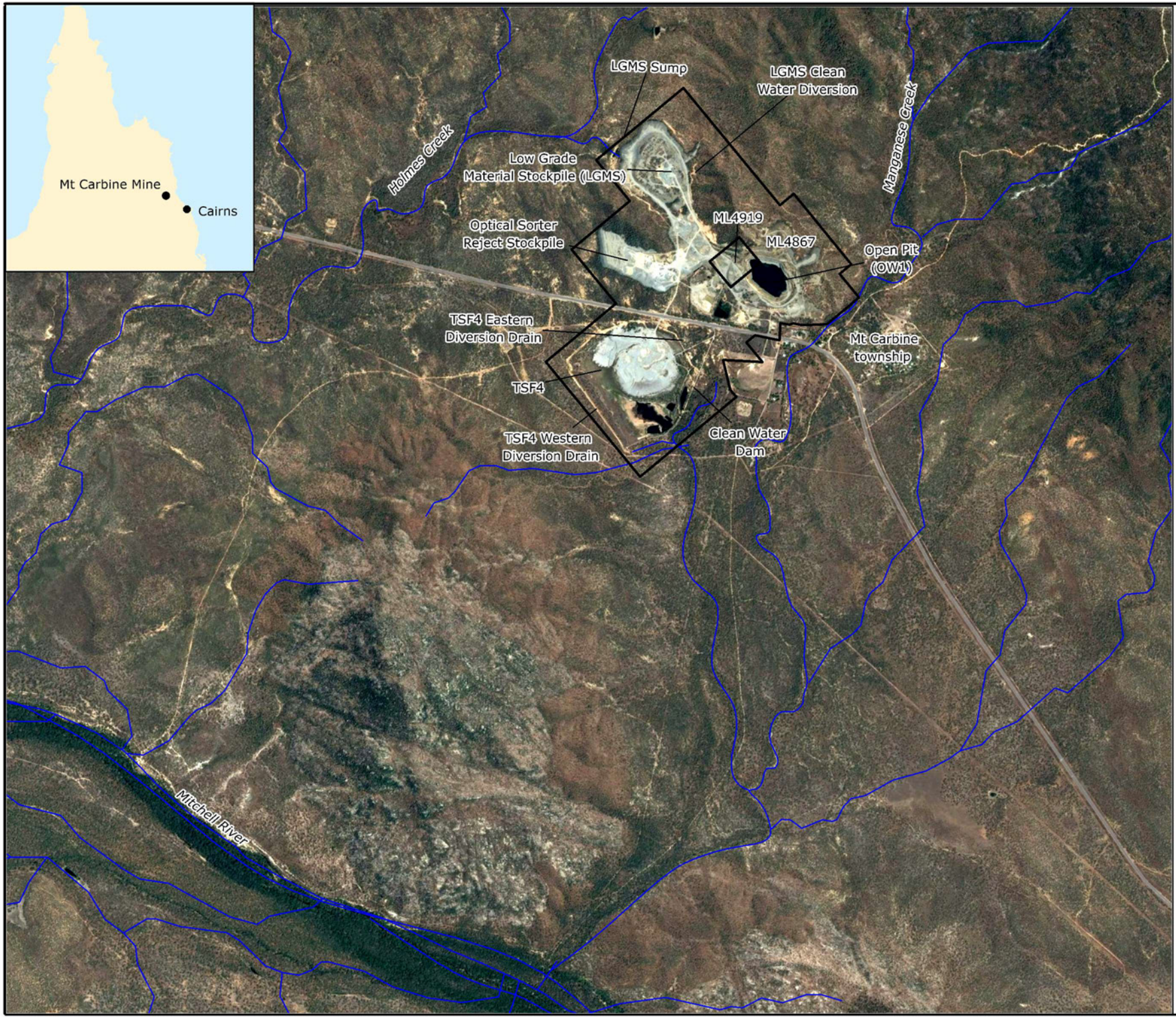


Figure 1: Project location

Project: Mt Carbine Mine Receiving Environment Monitoring Program, V. 2.0

Mining lease boundaries

Mulligan Highway

Drainage

N

0 1.5

Kilometres

Source:
© State of Queensland (Department of Natural Resources, Mines and Energy) 2018. Updated data available at http://qldspatial.information.qld.gov.au/catalogue//, Mt Carbine Quarries Pty Ltd, Google Earth

NRA Ref: 380005.07
Date: October 2020

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Recommended print size: A4

1.2.1 Water quality

Background water

To describe background surface water quality characteristics near Mt Carbine mine, surface water data for reference sites SW16 on Holmes Creek, SW1 on Manganese Creek and SW10 on the Mitchell River, and Holmes Creek upstream (control) site SW2 was collated and compared to published default guideline values (DGVs) for the environmental values (EVs) nominated for this REMP (**Section 1.3**).

Summaries of surface water quality data are presented in **Table 2** and have been updated with reference/background site data collected since the REMP was established in 2014. Summary data is shown by the range and median values for each reference/background site for water quality parameters listed in the EA (Schedule D – Table D3). Most of the metals recorded concentrations below the laboratory limit of reporting (LOR), indicating that these parameters are either not present in the background surface water or are in extremely low concentrations (*ie* below detection limits).

When compared against DGVs, the data summary (**Table 2**) reveals the following information about the reference site water quality at Mt Carbine.

- **Aquatic ecosystems**: water quality at reference sites SW16, SW1 and SW10 was not consistent with aquatic ecosystem protection levels based on the concentration of some filtered aluminium (elevated concentrations at all three reference sites on multiple occasions and the median exceeding the DGV). pH at SW1, and concentrations of filtered arsenic at SW16, filtered zinc at SW1 and SW10, and filtered copper at SW1 and SW16 were recorded on at least one occasion, but generally these parameters were below the laboratory LOR (as indicated by the median values).
- **Livestock drinking water**: water quality was suitable for livestock drinking water most of the time, noting that all the median results at reference sites were within the livestock drinking water quality guideline values. Although total aluminium concentrations at all reference sites exceeded the guideline value on at least one occasion (shown by the maximum value), the median data suggests that this is not a sustained occurrence.
- **Recreation**: results for all three reference sites were within the DGVs for primary and secondary recreational use.

Therefore, background water quality met guideline values (for most indicators) for the protection of moderately disturbed aquatic ecosystems and appeared to be suitable for use as stock drinking water and recreation.

Summaries of surface water data for upstream (control) site SW2 are also presented in **Table 2** to provide a context for assessing background conditions. There are historical abandoned mine workings in the upper Holmes Creek catchment, and water from these workings reports to site SW2. The median data reveals that the quality of water at SW2 is similar to the reference sites on Holmes and Manganese creeks, recording median concentrations of filtered aluminium above the DGV for aquatic ecosystem protection. Occasional elevated concentrations of filtered arsenic, copper and zinc at SW2 were also similar to SW16.

Receiving water

The Mt Carbine Tungsten Project Stage 1 Environmental Management Plan June 2013 (Carbine Tungsten Limited 2013) provides an account of water quality monitoring through to 2013 as follows.

- Surface water quality data exists from the following sampling periods.
  - 1992–1993: Sampling of surface water from 15 sites (sample locations unverified) and analysis of physico-chemical properties (electrical conductivity (EC), pH, alkalinity, total dissolved solids, total hardness, anions and cations) and metals.
  - 2002–2013: Sampling of surface water from receiving sites (SW3, SW4, SW5) and analysis of EC, pH and total metals (arsenic, cadmium, copper and zinc).
  - 2011–2013: Sampling of surface water from downstream sites (SW3, SW4, SW5) and analysis of physico-chemical properties and total and dissolved (filtered) metals.
- Surface water quality of the Mt Carbine receiving environment was not consistent with aquatic ecosystem protection levels provided in EHP (2009) and ANZECC and ARMCANZ (2000) due to elevated levels of stressors and toxicants.
  - Immediately downstream of TSF4 (site SW3), EC and levels of fluoride, sulfate, arsenic and molybdenum exceeded guideline values and background (reference) levels.
  - Seepage flows from the low-grade stockpiles (OW2) include EC and levels of fluoride, sulfate, aluminium, arsenic, copper, nickel and zinc above the guideline values and background levels. At downstream site SW4, EC and levels of fluoride, sulfate, cadmium and zinc remained in excess of guideline values and background (reference) levels.
  - Fluoride was elevated above the livestock drinking water guideline value (2 mg/L) at receiving sites SW3 (4.3 mg/L) and SW4 (2.9 mg/L). This is in comparison to background (reference) concentrations of 0.1 mg/L for the Manganese Creek catchment and 0.2 mg/L for the Holmes Creek catchment.

Surface water quality has continued to be monitored for the Mt Carbine project as part of the REMP, and results are reported in annual REMP reports (*eg* GHD 2015, NRA 2017a, 2018, 2019, 2020a). To date, there are no increasing trends, and water quality is generally consistent each wet season. Similar to the above summary from pre-contemporary mining, the following exceedances of DGVs occur in the Holmes and Manganese creek receiving environments (per data reported in the annual REMP reports) (**Figure 2**).

- Holmes Creek: EC is elevated above the aquatic ecosystem DGV (125 µS/cm) at all sites on most occasions (ranging 140–1,767 µS/cm), and fluoride is above the draft aquatic ecosystem guideline value (2.4 mg/L) on the natural drainage feature between the toe of the LGMS and Holmes Creek (sites SW17 and SW20, up to 8.5 mg/L). Aquatic ecosystem and livestock drinking water DGVs for aluminium are occasionally exceeded at Holmes Creek sites during the wet season, and these exceedances are associated with turbid water quality conditions. Occasionally, copper concentrations (0.003–0.004 mg/L) exceed the aquatic ecosystem DGV (0.0014 mg/L).
- Manganese Creek: EC is elevated above the aquatic ecosystem DGV (125 µS/cm) at all sites on most occasions (ranging 137–1,165 µS/cm). Some other parameters exceeded the aquatic ecosystem DGVs, but these elevated concentrations have been occasional and do not indicate a trend (relevant for fluoride, aluminium, arsenic, cobalt, copper, manganese, selenium).

Table 2: Summary of Mt Carbine reference/background surface water quality results (2011–2020)

Parameter		Units	DGV			Manganese Creek		Holmes Creek				Mitchell River	
			Aquatic ecosystem[1]	Livestock[2]	Recreation[3]	SW1		SW16		SW2		SW10	
						n	Range (median)	*n*	Range (median)	*n*	Range (median)	*n*	Range (median)
pH		pH units	6.0 - 7.5[a]	4.0 - 9.0	6.5 - 8.5	*42*	6.5 - **7.6** (7.1)	*19*	6.6 - 7.4 (7.0)	*28*	6.6 – **8.0** (7.2)	*8*	6.7 - 7.1 (7.0)
Electrical Conductivity		µS/cm	125[b]	5970	-	*36*	40 - 93 (56)	*14*	46 - 120 (67)	*25*	48 - **750** (80)	*6*	67 - 94 (79)
Sulfate		mg/L	-	1000	-	*42*	<0.5 - 2.3 (<0.5)	*19*	0.3 - 1.7 (0.8)	*28*	0.5 - 46 (1.2)	*8*	0.8 - 1.2 (1.0)
Fluoride		mg/L	2.4[c]	2	15	*42*	0.08 - 0.51 (0.12)	*19*	0.10 - 0.48 (0.16)	*28*	0.10 - 0.22 (0.15)	*8*	0.06 - 0.66 (0.08)
Aluminium	total	mg/L	-	5	-	*40*	0.3 - 14 (3.7)	*19*	0.1 - 6.8 (1.2)	*26*	0.03 - 5.9 (0.8)	*8*	0.16 - 6.3 (0.6)
	filtered	mg/L	0.055[d]	-	-	*42*	0.02 - **7.2** (**1.05**)	*19*	0.02 - **1.7** (**0.31**)	*28*	0.01 - **2.1** (**0.26**)	*8*	0.03 - **0.53** (**0.26**)
Antimony	total	mg/L	-	-	0.03	*17*	<0.003 - <0.003 (<0.003)	*14*	<0.003 - <0.003 (<0.003)	*11*	<0.003 - <0.003 (<0.003)	*2*	<0.003 - <0.003 (<0.003)
	filtered	mg/L	0.009[e]	-	-	*17*	<0.003 - <0.003 (<0.003)	*14*	<0.003 - <0.003 (<0.003)	*11*	<0.003 - <0.003 (<0.003)	*2*	<0.003 - <0.003 (<0.003)
Arsenic	total	mg/L	-	0.5	0.1	*40*	<0.003 - 0.007 (<0.003)	*19*	0.005 - 0.019 (0.008)	*26*	0.005 - 0.024 (0.009)	*8*	<0.003 - 0.004 (<0.003)
	filtered	mg/L	0.013[f]	-	-	*42*	<0.003 - 0.006 (<0.003)	*19*	0.004 - **0.019** (0.006)	*28*	0.004 - **0.023** (0.008)	*8*	<0.003 - 0.003 (<0.003)
Cadmium	total	mg/L	-	0.01	0.02	*40*	<0.0001 - 0.0002 (<0.0001)	*19*	<0.0001 - 0.0002 (<0.0001)	*26*	<0.0001 - 0.0002 (<0.0001)	*8*	<0.0001 - <0.0001 (<0.0001)
	filtered	mg/L	0.0002	-	-	*42*	<0.0001 - 0.0001 (<0.0001)	*19*	<0.0001 - 0.0001 (<0.0001)	*28*	<0.0001 - 0.0001 (<0.0001)	*8*	<0.0001 - <0.0001 (<0.0001)
Chromium	total	mg/L	-	1	0.5	*40*	<0.001 - 0.001 (<0.001)	*19*	<0.001 - 0.002 (<0.001)	*26*	<0.001 - 0.001 (<0.001)	*8*	<0.001 - 0.002 (<0.001)
	filtered	mg/L	0.001[g]	-	-	*42*	<0.001 - <0.001 (<0.001)	*19*	<0.001 - <0.001 (<0.001)	*28*	<0.001 - <0.001 (<0.001)	*8*	<0.001 - <0.001 (<0.001)
Cobalt	total	mg/L	-	1	-	*39*	<0.001 - 0.001 (<0.001)	*19*	<0.001 - 0.001 (<0.001)	*25*	<0.001 - <0.001 (<0.001)	*8*	<0.001 - 0.001 (<0.001)
	filtered	mg/L	0.0014[e]	-	-	*37*	<0.001 - <0.001 (<0.001)	*19*	<0.001 - <0.001 (<0.001)	*23*	<0.001 - <0.001 (<0.001)	*8*	<0.001 - <0.001 (<0.001)
Copper	total	mg/L	-	1	20	*40*	<0.001 - 0.002 (<0.001)	*19*	<0.001 - 0.004 (<0.001)	*26*	<0.001 - 0.004 (<0.001)	*8*	<0.001 - 0.002 (<0.001)
	filtered	mg/L	0.0014	-	-	*42*	<0.001 - **0.002** (<0.001)	*19*	<0.001 - **0.004** (<0.001)	*28*	<0.001 - **0.003** (<0.001)	*8*	<0.001 - 0.001 (<0.001)
Lead	total	mg/L	-	0.1	0.1	*39*	<0.001 - 0.003 (0.001)	*19*	<0.001 - 0.002 (<0.001)	*26*	<0.001 - 0.002 (<0.001)	*8*	<0.001 - 0.002 (<0.001)
	filtered	mg/L	0.0034	-	-	*40*	<0.001 - 0.001 (<0.001)	*19*	<0.001 - 0.001 (<0.001)	*27*	<0.001 - 0.001 (<0.001)	*8*	<0.001 - <0.001 (<0.001)
Manganese	total	mg/L	-	-	5	*39*	<0.005 - 0.039 (0.011)	*18*	<0.005 - 0.059 (0.011)	*26*	<0.005 - 0.053 (0.009)	*8*	0.011 - 0.064 (0.022)
	filtered	mg/L	1.9	-	-	*41*	<0.005 - 0.013 (<0.005)	*19*	<0.005 - 0.045 (<0.005)	*28*	<0.005 - 0.028 (<0.005)	*8*	<0.005 - 0.015 (<0.005)
Molybdenum	total	mg/L	-	0.15	0.5	*24*	<0.001 - 0.003 (<0.001)	*18*	<0.001 - 0.004 (<0.001)	*10*	<0.001 - <0.001 (<0.001)	*6*	<0.001 - <0.010 (<0.001)
	filtered	mg/L	0.034[e]	-	-	*24*	<0.001 - 0.003 (<0.001)	*18*	<0.001 - <0.001 (<0.001)	*10*	<0.001 - <0.001 (<0.001)	*6*	<0.001 - <0.010 (<0.001)
Nickel	total	mg/L	-	1	0.2	*20*	<0.001 - 0.001 (<0.001)	*15*	<0.001 - 0.002 (<0.001)	*11*	<0.001 - 0.005 (<0.001)	*3*	<0.001 - <0.001 (<0.001)
	filtered	mg/L	0.011	-	-	*19*	<0.001 - 0.001 (<0.001)	*15*	<0.001 - 0.002 (<0.001)	*11*	<0.001 - 0.001 (<0.001)	*3*	<0.001 - <0.001 (<0.001)
Selenium	total	mg/L	-	0.02	0.1	*15*	<0.003 - <0.003 (<0.003)	*14*	<0.003 - <0.003 (<0.003)	*9*	<0.003 - <0.003 (<0.003)	*2*	<0.003 - <0.003 (<0.003)
	filtered	mg/L	0.005	-	-	*15*	<0.003 - <0.003 (<0.003)	*14*	<0.003 - <0.003 (<0.003)	*9*	<0.003 - <0.003 (<0.003)	*2*	<0.003 - <0.003 (<0.003)
Tungsten	total	mg/L	-	-	-	*13*	<0.001 - 0.001 (<0.001)	*15*	<0.001 - <0.001 (<0.001)	*9*	<0.001 - <0.001 (<0.001)	*2*	<0.001 - 0.003 (0.002)
	filtered	mg/L	-	-	-	*13*	<0.001 - 0.001 (<0.001)	*14*	<0.001 - <0.001 (<0.001)	*9*	<0.001 - <0.001 (<0.001)	*2*	<0.001 - 0.003 (0.002)
Zinc	total	mg/L	-	20	-	*40*	<0.005 - 0.020 (<0.005)	*19*	<0.005 - 0.011 (<0.005)	*26*	<0.005 - 0.023 (<0.005)	*8*	<0.005 - 0.020 (<0.005)
	filtered	mg/L	0.008	-	-	*42*	<0.005 - **0.012** (<0.005)	*19*	<0.005 - <0.005 (<0.005)	*28*	<0.005 - **0.016** (<0.005)	*8*	<0.005 - **0.013** (<0.005)

Data used in this table is from the collated water and sediment quality database maintained by MCQ (dated 30 September 2020) augmented with data from laboratory certificates where available and required.

NRA evaluated the data for monitoring purposes. Outliers were removed, and less than limit of reporting (<LOR) values were removed when:

- the LOR was higher than the DGV or
- the LOR was not consistent with the majority of the <LOR values for the parameter.

[1] Default guideline values (DGVs) for the protection of moderately disturbed (MD) aquatic ecosystems derived from ANZG (2018, accessed 19/10/2020); unless otherwise indicated.

[2] Guideline values for the protection of livestock drinking water derived from ANZECC and ARMCANZ (2000) section 4.

[3] Guideline values for the protection of water for recreation derived from NHMRC (2008). Waters contaminated with chemicals that are toxic or irritating to the skin or mucous membranes are unsuitable for recreational waters. In all cases, chemical and physical contaminants must be assessed on a local basis (NHMRC 2008). For chemicals, recreation guideline values have been calculated as 10 times the values stipulated in the Australian Drinking Water Guidelines (NHMRC & NRMMC 2018).

[a] pH guideline value derived from ANZECC and ARMCANZ (2000) Table 3.3.4 (noting that these values are for the protection of 'slightly disturbed' ecosystems, and have been used in the absence of a DGV for 'moderately disturbed' ecosystems).

[b] Electrical conductivity guideline value derived from EHP (2013) Table G.1 for the Cape York Salinity Zone (*ie* including Mitchell River basin) (75th percentile – SMD waters).

[c] Draft guideline value for fluoride from ANZGFMWQ (2015). This guideline value is under review and has not been finalised or formally adopted. NRA has permission to use this guideline value (*pers. comm*. Chris Hepplewhite, Assistant Director, National Water Policy Section, Australian Government Department of Agriculture and Water Resources, 19 June 2017).

[d] Guideline value for aluminium is a 'low reliability' value, derived for waters of pH >6.5 (ANZG 2018). If pH is <6.5, the DGV 0.008 mg/L should be used for aluminium (ANZG 2018).

[e] Interim value from section 8.3.7.1 of ANZECC and ARMCANZ (2000); reliability 'unknown' in ANZG (2018).

[f] For As(V), the lowest guideline value for arsenic; 'moderate' reliability (ANZG 2018).

[g] For Cr(VI), the lowest guideline value for chromium; 'very high' reliability (ANZG 2018).

- Denotes no DGV.

Bold values exceeded the DGV for the protection of MD aquatic ecosystems.

Underlined values exceeded the DGV for the protection of livestock (beef cattle) drinking water.

There were no exceedances of DGVs for recreation.

1.2.2 Stream sediment quality

Stream sediment data collected from reference sites SW1, SW16 and SW10, and upstream (control) site SW2 is summarised in **Table 3** and has been updated with data collected since the REMP was established in 2014.

Comparisons of the summary data (<2 mm sediment fraction) with sediment quality DGVs for the protection of aquatic ecosystems show that all parameters were below the DGVs except for arsenic in Holmes Creek (SW16 and SW2), which exceeded the DGV, indicating the natural presence of elevated arsenic concentrations in this watercourse.

Table 3: Summary of Mt Carbine background stream sediment quality results (2011–2020)

Parameter (whole sediment fraction, *ie* <2 mm)	Unit	DGV[1]	Manganese Creek		Holmes Creek				Mitchell River	
			SW1		SW16		SW2		SW10	
			n	Range (median)	*n*	Range (median)	*n*	Range (median)	*n*	Range (median)
Sulfate	mg/kg	-	*18*	<3 - 30 (4)	*14*	<3 - 37 (5)	*5*	<3 - 9 (5)	*4*	3 - 54 (5)
Fluoride	mg/kg	-	*5*	<50 - 72 (63)	*6*	200 - 2300 (305)	*4*	120 - 300 (215)	*1*	96
Aluminium	mg/kg	-	*32*	980 - 3800 (1900)	*20*	5000 - 10000 (7500)	*10*	4000 - 9500 (6500)	*6*	960 - 6800 (1500)
Antimony	mg/kg	2	*15*	<1 - <3 (<3)[#]	*14*	<2 - <3 (<3)[#]	*3*	<1 - <3 (<3)[#]	*2*	<1 - <3 (<3)[#]
Arsenic	mg/kg	20	*44*	0.5 - 17 (4)	*20*	18 - **53** (**34**)	*22*	**23** - **60** (**39**)	*7*	1 - 7 (3)
Cadmium	mg/kg	1.5	*42*	<0.1 - 0.2 (<0.1)	*19*	<0.1 - 0.4 (0.2)	*20*	0.1 – 0.5 (0.3)	*6*	<0.1 - <0.1 (<0.1)
Chromium	mg/kg	80	*44*	1.3 - 8.7 (2.5)	*20*	7.9 - 14 (11)	*22*	6.8 - 13 (8.7)	*7*	1.9 - 7 (2.6)
Cobalt	mg/kg	-	*44*	<0.5 - 2.4 (0.7)	*20*	0.6 - 6.3 (4.6)	*22*	2.4 - 7.1 (4.9)	*7*	0.5 - 5.3 (1)
Copper	mg/kg	65	*44*	0.5 - 6 (1.5)	*20*	9.5 - 25 (15.5)	*22*	7.2 - 27 (11.5)	*7*	0.9 - 6.9 (1.8)
Lead	mg/kg	50	*44*	2.6 - 12 (4)	*20*	5 - 11 (8.3)	*22*	6.1 - 10 (8)	*7*	2.2 - 12 (4)
Manganese	mg/kg	-	*44*	46 - 230 (75)	*20*	110 - 440 (165)	*22*	130 - 260 (170)	*7*	50 - 400 (130)
Molybdenum	mg/kg	-	*42*	<0.5 - 2 (<0.5)	*18*	<0.5 - 0.6 (<0.5)	*19*	<0.5 - 1.5 (<0.5)	*6*	<0.5 - 0.6 (<0.5)
Nickel	mg/kg	21	*20*	<0.5 - 5.3 (1)	*17*	5.6 - 9.5 (8.2)	*6*	4.3 - 10 (7.6)	*3*	0.6 - 1.2 (0.8)
Selenium	mg/kg	-	*15*	<3 - <3 (<3)	*13*	<3 - <3 (<3)	*3*	<3 - <3 (<3)	*2*	<3 - <3 (<3)
Tungsten	mg/kg	-	*40*	<0.5 - 42 (<0.5)	*20*	<0.5 - 17 (0.9)	*21*	<0.5 - 15 (<0.5)	*7*	<0.5 - 26 (<0.5)
Zinc	mg/kg	200	*44*	<0.5 - 17 (7)	*20*	20 - 42 (33)	*22*	8 - 43 (28)	*7*	3.6 - 27 (8)

Data used in this table is from the collated water and sediment quality database maintained by MCQ (dated 30 September 2020) augmented with data from laboratory certificates where available and required.

NRA evaluated the data for monitoring purposes. Outliers were removed, and less than limit of reporting (<LOR) values were removed when:

- the LOR was higher than the DGV or
- the LOR was not consistent with the majority of the <LOR values for the parameter.

[1] Default guideline value for aquatic ecosystems (ANZG 2018).

- No value / data.

Bold values exceeded the DGV for the protection of aquatic ecosystems.

[#] Although the maximum and median values are above the DGV for antimony, the concentrations were recorded below laboratory limits of reporting; therefore, they have not been identified as exceeding the DGV.

1.2.3 Aquatic ecology

The first aquatic ecology survey for the Mt Carbine REMP was conducted in June 2014 at six receiving sites (SW4, SW7, SW12, SW19[3], SW15 and SW20) and three reference sites (SW1, SW16 and SW10) to quantify potential impacts on the receiving environment from mine site water releases in April–May 2014 (NRA 2014c).

Since then, aquatic ecology surveys have continued at Mt Carbine on an annual basis (excluding 2016 when sampling was not commissioned), and reports have been prepared as part of the REMP reporting requirements.

The results of the aquatic ecology surveys provide an indication of the aquatic ecosystem health of waterways at Mt Carbine at the time of sampling. Statistical analysis of aquatic macroinvertebrates collected to date revealed no discernible difference in the aquatic macroinvertebrate assemblages recorded at receiving sites on Holmes and Manganese creeks and the corresponding reference sites, with the exception of receiving site SW4 on Holmes Creek in 2018, 2019 and 2020, and receiving site SW7 on Manganese Creek in 2017 and 2020 (NRA 2020a) despite no releases from the TSF4 to Manganese Creek in these years. Indications from the studies are that the receiving waters are relatively 'healthy' as indicated by the diversity of aquatic macroinvertebrate groups (*ie* feeding and taxonomic) recorded at receiving sites in the Holmes Creek and Manganese Creek catchments.

1.3 Environmental values

EVs are not nominated under the Queensland *Environmental Protection (Water and Wetland Biodiversity) Policy* 2019 for the part of the Mitchell River basin relevant to the Mt Carbine mine receiving environment.

The surrounding land-use is rural-urban, low-intensity grazing, mining and exploration and conservation (*ie* Brooklyn Wildlife Sanctuary). NRA understands that the section of the Mitchell River near Mt Carbine is used for swimming and other recreational activities. It is understood that raw water is not drawn directly from the mine site's receiving water for drinking water.

Based on the review of the quality of receiving surface water of the Mt Carbine mine site, and reflecting the previous human activities of the area (*ie* grazing and mining), the receiving environment is expected to comprise moderately disturbed (MD) aquatic ecosystems, as defined in the Queensland *Environmental Protection (Water and Wetland Biodiversity) Policy* 2019.

Considering the above information, the nominated EVs for the receiving surface water of the Mt Carbine mine site include the following[4].

- Aquatic ecosystems—moderately disturbed (MD) systems.
- Human use:
  - primary industries—livestock drinking water
  - cultural and spiritual values
  - recreation and aesthetics
  - industrial use.

[3] Site SW19 is within the same reach as the EA (and REMP) site SW17.

[4] These values (except for refining the aquatic ecosystem protection level) are consistent with the previous version of the Mt Carbine REMP.

1.4 Water quality objectives

Water quality objectives (WQOs) are required to protect the nominated EVs. WQOs have not been nominated in the Queensland *Environmental Protection (Water and Wetland Biodiversity) Policy* 2019 for the receiving environment; therefore, appropriate guideline values for the protection of the EVs are used. The guideline values were derived based on the direction provided in the *Queensland Water Quality Guidelines* (EHP 2013), the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG 2018)[5], and the *Monitoring and Sampling Manual: Environmental Protection (Water) Policy* (DES 2018).

Aquatic ecosystems

Guideline values for the protection of MD aquatic ecosystems are either published DGVs or site-specific guideline values (SSGVs). The approach for deriving and applying guideline values is summarised in **Table 4**.

When selecting the guideline value to use for determining potential impacts to MD aquatic ecosystems, the guideline value is either the DGV or the 80th percentile SSGV, whichever is higher. In the case of pH, a low range guideline value is assigned as either the DGV or the 20th percentile SSGV, whichever is lower.

Table 4: Guideline values for aquatic ecosystems

DGVs	SSGVs	Guideline values	
		Interim	Final
Toxicants: A. DGVs available online[1]. Stressors: B. Table G.1 of EHP (2013) (EC percentiles for Queensland Salinity Zones, Cape York zone – 75th percentile – SMD waters), and DGVs available online[1,2].	Interim: 1. 20th/80th percentile value, based on the results of 8 or more reference values collected at each site over at least 12 months and applies until sufficient data is acquired to develop final guideline values[3]. Final: 2. 20th/80th percentile value, based on a minimum of 18 reference values collected at each site over at least 12 months (preferably 24 months)[3].	Use highest value between (A/B) or (1).	Use highest value between (A/B) or (2)

[1] DGVs are available online (ANZG 2018) and are updated as the values are reviewed. Access the DGVs from: https://www.waterquality.gov.au/anz-guidelines/guideline-values/default.

[2] At the time of preparing this REMP design update, the DGVs for the Gulf of Carpentaria drainage division were not yet provided. Therefore, Tables 3.3.4 and 3.3.5 (ANZECC & ARMCANZ 2000) for Upland Rivers in Tropical Australia should be used.

[3] If less than 8 values (for interim), or less than 18 (for final) have been collected at a reference site, that data cannot be included in the calculation of the interim/final SSGV until at least 8, or 18, sample values have been collected at that site.

In version 1.0 of the Mt Carbine REMP design report (NRA 2014a), there was insufficient data available to calculate SSGVs for Holmes Creek or the Mitchell River. Since then, water

[5] These guidelines update and replace those issued by ANZECC and ARMCANZ (2000). It is anticipated that the Water Quality Guidelines (ANZG 2018) will continue to undergo regular review and update.

quality monitoring has been undertaken, and there is sufficient data to calculate SSGVs for Manganese Creek and Holmes Creek, and interim SSGVs can be determined for most parameters for Mitchell River. The SSGVs and DGVs are presented in **Appendix A**. SSGVs should be reviewed and updated as additional reference data is collected from SW1, SW16 and SW10.

Deriving SSGVs for water quality

The SSGVs for each site were calculated by combining all data collected, encompassing a range of flow conditions. The seasonal nature of Holmes and Manganese creeks means that surface water is present either flowing shortly after a rainfall event, or as isolated pools. These differing states of flow can significantly influence water quality values, particularly physico-chemical parameters such as turbidity, dissolved oxygen and EC. SSGVs for flow and no flow conditions should be considered once sufficient data is available for different flow conditions (*ie* 8 values for each flow condition). In the meantime, appropriate information regarding a site's flow status should be recorded at the time of surface water sampling (*ie* on field data sheets) and entered into the water quality database with the water quality results. This data can be retrieved and manipulated to calculate SSGVs based on defined flow conditions.

Livestock drinking water

Guideline values for the protection of livestock (beef cattle) drinking water are the DGVs from Sections 4.3 (livestock drinking water quality) and 4.2.10.1 (pH) of ANZECC and ARMCANZ (2000). The DGVs for the REMP are provided in **Appendix A**.

Recreation and aesthetics

Guideline values for the protection of water for recreation and aesthetics are from *Guidelines for Managing Risks in Recreational Water* (NHMRC 2008), which are based the Australian Drinking Water Guidelines (NHMRC & NRMMC 2018). The DGVs for the REMP are presented in **Appendix A**.

Other environmental values

Currently, there are no published water quality guidelines to protect cultural and spiritual or industrial use values. The Mt Carbine Environmental Management Plan contains environmental control strategies implemented at the mine site to meet the EA conditions (Carbine Tungsten Limited 2013), and the mine site's operational plans required by the EA provide more detailed management measures. It is understood that the strategies and actions outlined in these plans are intended to protect all receiving environmental values.

1.5 Sediment quality objectives

ANZG (2018) provides guidance on selecting and applying guideline values for sediment quality for aquatic ecosystems, and this guidance has been applied in this REMP.

Where DGVs for sediment quality have been recommended (in ANZG 2018)[6], these values should be used for toxicants in sediment. Where no DGVs have been specified for a toxicant, an interim approach using reference site data to calculate an SSGV should apply (per ANZG 2018). The 'reference site approach' in ANZG (2018) derives an SSGV using the 80th percentile of reference site concentrations, which is compared with the median concentration

[6] https://www.waterquality.gov.au/anz-guidelines/guideline-values/default/sediment-quality-toxicants

at the receiving site. Sediment quality guideline values (SQGVs) for the Mt Carbine REMP are summarised in **Appendix A**, and these apply to the <2 mm sediment fraction.

Deriving SSGVs for sediment

When deriving and using SSGVs for metals in sediment, grain sizes must be similar between the reference sites and the receiving sites (ANZG 2018). Review of particle size distribution results for stream sediment collected during aquatic ecology surveys at Mt Carbine (NRA 2017a, 2018, 2019, 2020a) shows that reference site SW16 on Holmes Creek had similar grain size as the receiving sites on Holmes Creek (excluding site SW17 on a drainage feature between the LGMS and Holmes Creek). Manganese Creek reference site SW1 also had a similar grain size as receiving site SW7; however, site SW15 often contained a higher proportion of finer sediments. Therefore, SSGVs for sediment quality can be derived using the reference site data from sites SW16 and SW1.

The number of reference site values to use in deriving SSGVs for sediment follows the approach for water quality SSGVs. This is consistent with ANZG (2018), which applies the water quality SSGV approach to stream sediment data sets. For waters in Queensland, ANZG (2018) recognises that the Queensland Government has a specific method for deriving SSGVs for moderately disturbed catchments, as document in EHP (2013). This approach has been applied in this REMP for deriving sediment SSGVs using reference site data, *ie* <8 values = no SSGV; 8–17 values = interim SSGV; ≥18 values = SSGV.

Sufficient data is not currently available to calculate SSGVs for Mitchell River, or to derive SSGVs for fluoride for Holmes Creek and Manganese Creek. The SSGVs for the REMP (**Appendix A**) should be updated as additional reference data is collected from SW1, SW16 and SW10.

2. Monitoring Program

Surface water data will be used to assess potential impacts on the livestock drinking water and recreation and aesthetics EVs, while a 'multiple lines of evidence' approach (including surface water, sediment and biological indicators) will be used for aquatic ecosystem condition assessment.

The sampling approach in the *Monitoring and Sampling Manual: Environmental Protection (Water) Policy* (DES 2018)[7] has been followed, whilst maintaining consistency with the existing REMP design to retain the integrity of the long-term monitoring program.

2.1 Monitoring sites

Sites nominated for the Mt Carbine mine REMP are listed in **Table 5** and shown on **Figure 2**. The EA licensed release point OW4 is also shown on **Figure 2** for context. The relevance of each monitoring site to the potential contaminant source is provided in **Table 5**.

2.1.1 Reference sites

Reference sites for the REMP (*ie* SW16 on Holmes Creek, SW1 on Manganese Creek, and SW10 on Mitchell River) were selected based on EA requirements and the findings of the 2013–2014 aquatic ecology survey (NRA 2014c). Subsequent REMP monitoring (NRA 2017a, 2018, 2019, 2020a) has confirmed that the reference sites are appropriate.

An additional reference site—SW24—is included in **Table 5** to compare aquatic ecosystem results with receiving sites on the drainage feature downstream of the TSF4 (*ie* site SW15). SW24 has not been established as it is not certain that a suitable site can be located. To date, surface water conditions at SW15 have not been suitable for aquatic ecosystem monitoring (insufficient water present). However, site SW24 should remain in the REMP as a 'place-holder'. The location of reference site SW24 will need to be situated on a drainage feature with similar habitat conditions to site SW15.

Site SW2 on Holmes Creek is upstream of the Mt Carbine mining operations and was used in the REMP as an upstream (control) site for water quality and stream sediment data interpretation; it is not included in the EA as a reference site. This site was included in the original REMP due to its existing monitoring data set and its location relative to Mt Carbine mine (*ie* upstream of the licenced activity) and historical abandoned mine workings in the upper Holmes Creek catchment (*ie* downstream of potential historical contaminant sources). In 2013, site SW16 was established as a reference site in the EA and was monitored in the REMP. Water quality and sediment data for SW16 and SW2 (**Tables 2** and **3**) show similar results between the sites. SW16 now has sufficient data to calculate SSGVs, and given the similarity of the conditions with SW2, the ongoing routine monitoring of SW2 as part of the REMP is considered not necessary. However, the site should remain in the monitoring database as it may be beneficial in the future for additional monitoring or to recall data.

[7] This document is an update to the *Monitoring and Sampling Manual 2009* issued by the Department of Environment and Heritage Protection in July 2013.

2.1.2 Receiving sites

Receiving sites are on Holmes Creek, Manganese Creek, and Mitchell River. The selection of receiving sites considered:

- EA REMP requirements, including EA listed sites (EA Table D4) and the extent of the 'receiving environment' (EA condition D5)
- location of potential contaminant sources on the Mt Carbine mine site
- suitability of sites for monitoring potential impacts from mining operations
- site access.

EA Table D4 nominates receiving sites to include in the REMP (as per EA condition D5). The location of these sites was considered for the REMP; however, variations[8] have been made to reflect site conditions associated with site SW17, as follows.

- EA site SW17 has been replaced with site SW20, which is approximately 200 m downstream of SW17. This change has been implemented in the REMP monitoring since 2014 and remains a suitable change due to the following.
  - Longer surface water retention at SW20 due to larger catchment; allows for aquatic macroinvertebrate monitoring.
  - Habitat conditions at SW20 are more similar to reference site SW16 than SW17 is to SW16; allows better comparison between sites for aquatic macroinvertebrate data analysis.
  - SW20 receives runoff from two drainage features at the toe of the LGMS, rather than only one drainage feature being monitored by SW17.
  - Installation of the LGMS sump (for collection and pump-back to site of LGMS drainage water) has intercepted water from the LGMS reporting to SW17. The over-topping point of the sump is north of the SW17 drainage feature. Therefore, site SW17 receives runoff from the surrounding land rather than drainage from the LGMS.

Receiving site SW14 on Holmes Creek was added to the REMP in 2017 to provide improved spatial distribution of monitoring along Holmes Creek (NRA 2017a). This site has continued to be monitored as part of the REMP and has been included in this REMP design update.

[8] EA Condition D5 will need to be amended should the alteration to sites be agreed on. Until the EA is amended, site SW17 will continue to be sampled for water and stream sediment quality in the REMP (as required by EA condition D5).

Sites on Mitchell River (SW10, SW12 and SW18) are included in the REMP due to the 'receiving environment' area defined in EA condition D5 (*ie the waters of Holmes Creek, Manganese Creek and connected or surrounding waterways within 15 kilometres downstream of the licensed place*). However, monitoring Mitchell River to identify adverse impacts of Mt Carbine mine on the receiving environment surface water EVs is unreasonable because of the following, and the requirement for this receiving environment area should be amended in the EA[9].

- The hydrological conditions of Mitchell River are vastly different to those of Holmes Creek and Manganese Creek; *eg* Mitchell River is a multi-branched perennial stream order 6 watercourse, and Holmes and Manganese creeks are non-perennial stream order 3 and 4 watercourses respectively at their EA receiving water monitoring points (DES 2020).
- The REMP is a continual program with annual targeted surveys and reporting. For most years, a release event does not occur from Mt Carbine mine, and adverse impacts due to non-point source release from the mine would not be detected as far as the Mitchell River. Therefore, monitoring such an extensive receiving environment area as part of the REMP is superfluous. If a release event occurs from the mine, and contaminants have the potential to enter Mitchell River and result in an adverse impact to the EVs, investigation monitoring as required by EA condition A17 should be conducted, and the monitoring should be specific to the nature and scale of potential impact.

[9] A more suitable receiving environment extent for the REMP, which is implemented as routine monitoring, would be 'the waters of Holmes and Manganese creeks to their confluence with Mitchell River'. In the event of a release from site that results in an actual or potential impact on the Manganese and Holmes creeks receiving environment, further and targeted investigations should be undertaken, which may include monitoring on Mitchell River.

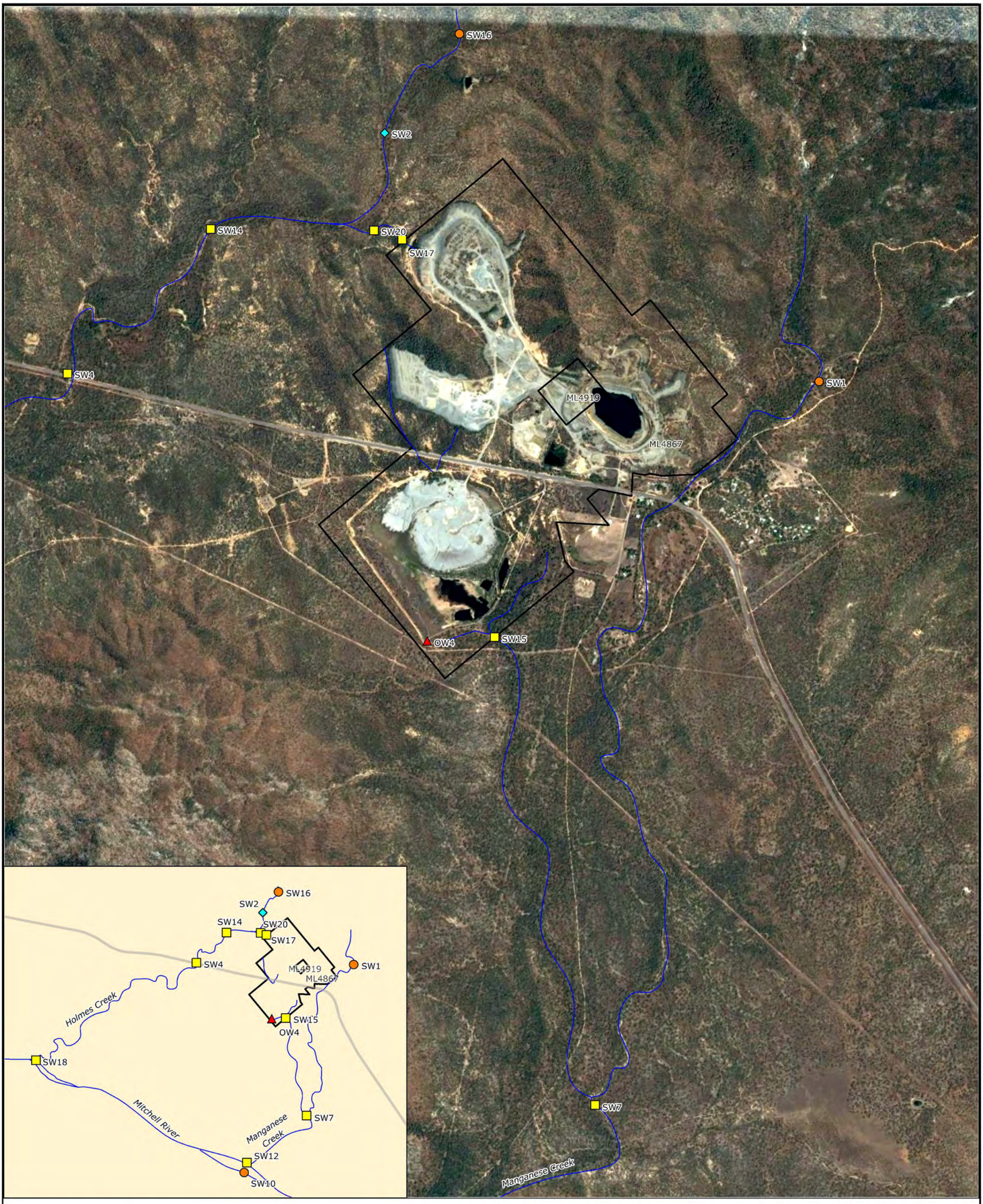


Figure 2: REMP monitoring sites

Project: Mt Carbine Mine Receiving Environment Monitoring Program, V. 2.0

Mining lease boundaries
Mulligan Highway
Major drainage

Monitoring sites
Receiving site
Reference site
Upstream control site
Licensed release point

N

0 1
Kilometres

NRA Ref: 380005.07
Date: October 2020

Source: © State of Queensland (Queensland Deparment of Natural Resources, Mines and Energy) 2018. Updated data available at http://qldspatial.information.qld.gov.au/catalogue//. Google Earth

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2.2 Timing

EA Condition D5 details the requirements for monitoring Mt Carbine mine receiving waters as part of the REMP. These requirements, as well as site conditions, have been considered when establishing the monitoring timing for the REMP. Timings are summarised in **Table 5** and include the following.

- Surface water and stream sediment monitoring at sites listed in EA Table D4 (*ie* SW1, SW16, SW15, SW17[10], SW4 and SW7) should be undertaken at the frequency nominated in the EA[11]. In addition, biological indicators (*ie* aquatic macroinvertebrates), surface water and stream sediment are to be monitored annually in the aquatic ecology survey.
- Surface water, stream sediment and aquatic macroinvertebrate monitoring at non-EA listed sites in the Holmes Creek catchment (*ie* SW20, SW14) should occur in conjunction with the annual aquatic ecology survey.
- Surface water, stream sediment and aquatic macroinvertebrates should be monitored at non-EA reference site SW24 only when aquatic macroinvertebrates are collected at SW15 (noting that the location of site SW24 has not been established).
- Mitchell River sites (*ie* SW10, SW12, SW18) should be monitored (for surface water, stream sediment and aquatic macroinvertebrates) during the annual aquatic ecology survey in response to a release event from the Mt Carbine mining operations to Holmes or Manganese creeks, where the release is likely to enter the Mitchell River watercourse.
- Surface water release monitoring at non-EA sites SW6, SW8 and SW11[12] should be monitored where mine site water releases occur from TSF4, for the purpose of informing release assessments and reporting (consistent with the previous REMP and release investigations (refer to **Appendix B** for locations of SW6, SW8 and SW11).

The timing of the annual aquatic ecology survey is subject to rainfall and stream flow conditions and is generally undertaken approximately 4–6 weeks after rapid creek flows (caused by rainfall or a release event) have ceased[13]. This allows time for aquatic macroinvertebrate communities to establish.

Where a release from Mt Carbine mine occurs after the annual aquatic ecology survey has been conducted, and water quality in the receiving environment during the release exceeds the nominated guideline values for the protection of aquatic ecosystems, a second aquatic ecology survey may need to be undertaken to inform the investigation. This information would be incorporated in the annual REMP report.

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[10] Until the EA is amended to remove SW17, or replace SW17 with SW20, monitoring should be undertaken at SW17 to comply with the EA.

[11] EA Condition D5 states '*at minimum, the REMP must include: a) monitoring of all parameters specified in Schedule D – Table D2 (Release Quality Objectives) at all locations specified in Schedule D – Table D4 (Receiving Waters Monitoring Locations) and at the following minimum frequency: (i) for receiving waters and sediment quality, biannually (once at the end of the wet season and once at the end of the dry season); and (ii) for water quality of receiving waters during a release or flow event, one sample must be taken within 12 hours of the event commencing. Where release or flow events have duration of greater than 24 hours, samples must be taken daily for 1 week and once a week thereafter until the release or flow event ceases*'.

[12] Co-ordinates (GDA94, zone 55 datum): SW6 300422E, 8168199N; SW8 300522E, 8168157N; SW11 298894E, 8166815N.

[13] Nominally the survey occurs March to May, due to seasonal rainfall at Mt Carbine.

2.3 Stream flow and hydrology

Observations of stream flow conditions at monitoring sites (*eg* high flow, base flow and no flow) at the time of sampling should be recorded on field data sheets and stored in the water quality database with water quality results to inform REMP reporting.

EA Conditions D1 and D2 detail the requirements for stream flow monitoring at Mt Carbine at the time of a release. Flow data from this EA monitoring may be used to assist in interpreting water quality and biological data collected from sites in the Manganese Creek catchment.

Table 5: Monitoring matrix for the Mt Carbine mine REMP

Site name	Location[1]	Waterbody type				Monitoring
		Watercourse		Drainage feature		
		Ref.	Rec.	Ref.	Rec.	
SW16*	299715E; 8174372N Holmes Creek, approximately 3.8 km upstream of the Mulligan Highway; upstream of inputs from the mine site and historical abandoned mine workings.	✓				Water – as per EA Condition D5 (refer to **Table 1**) for biannual, release event and flow event monitoring. Sediment – biannually. Aquatic macroinvertebrates – annually.
SW17*,^	299381E; 8173168N Un-named drainage feature between the LGMS sump and Holmes Creek tributary. Note: this site replaces SW19 in the previous REMP, which was closer to the toe of the LGMS but has been removed by the LGMS sump.				✓	Water – as per EA Condition D5 (refer to **Table 1**) for biannual, release event and flow event monitoring. Sediment – biannually.
SW4*	297426E; 8172386N Holmes Creek, approximately 50 m upstream of the Mulligan Highway and approximately 2.5 km downstream of the confluence between Holmes Creek and the un-named drainage feature below the LGMS.		✓			Water – as per EA Condition D5 (refer to **Table 1**) for biannual, release event and flow event monitoring. Sediment – biannually. Aquatic macroinvertebrates – annually.
SW20	299216 E; 8173223N On an un-named drainage feature approximately 350 m downstream of the LGMS. Note: this site has been referred to as OW2d/s in previous monitoring.				✓	Water – annually. Sediment – annually. Aquatic macroinvertebrates – annually.
SW14	298262E; 8173231N On Holmes Creek approximately 1 km downstream of the confluence between Holmes Creek and the un-named drainage feature below the LGMS.				✓	Water – annually. Sediment – annually. Aquatic macroinvertebrates – annually.
SW24	Location – To be advised (assuming it can be established). Reference waterbody for monitoring of drainage features downstream of the TSF4 (comparable to site SW15 habitat conditions). Note: this site was referred to as SW21 in the previous REMP design; however, this site name has since been allocated to an on-site monitoring point in the Mt Carbine water quality database.			✓		Water – annually. Sediment – annually. Aquatic macroinvertebrates – annually.
SW15*	299920E; 8170844N On an un-named drainage feature approximately 250 m downstream of the TSF4 spillway. This site is the compliance site in EA Table D4.				✓	Water – as per EA Condition D5 (refer to **Table 1**) for biannual, release event and flow event monitoring. Sediment – biannually. Aquatic macroinvertebrates – annually.
SW1*	301816E; 8172340N Manganese Creek, approximately 1 km upstream of the Mulligan Highway; upstream of site inputs.	✓				Water – as per EA Condition D5 (refer to **Table 1**) for biannual, release event and flow event monitoring. Sediment – biannually. Aquatic macroinvertebrates – annually.
SW7*	300507E; 8168109N Manganese Creek, approximately 50 m downstream of the Manganese Creek – TSF4 drainage confluence, and 3 km downstream of TSF4.		✓			Water – as per EA Condition D5 (refer to **Table 1**) for biannual, release event and flow event monitoring. Sediment – biannually. Aquatic macroinvertebrates – annually.
SW10	298758E; 8166523N On a southern branch of Mitchell River, approximately 250 m south of the Manganese Creek – Mitchell River confluence.	✓				Water, sediment and aquatic macroinvertebrates—in response to a release event to either Manganese Creek or Holmes Creek where the release is likely to have entered Mitchell River; monitoring is to be undertaken during the annual aquatic ecology monitoring survey.
SW12	298832E; 8166797N On a northern branch of Mitchell River, approximately 50 m downstream of the Mitchell River – Manganese Creek confluence.		✓			Water, sediment and aquatic macroinvertebrates—in response to a release event to Manganese Creek where the release is likely to have entered Mitchell River; monitoring is to be undertaken during the annual aquatic ecology monitoring survey.
SW18	292936E; 8169664 On a branch of Mitchell River, approximately 100 m downstream of the Mitchell River – Holmes Creek confluence.		✓			Water, sediment and aquatic macroinvertebrates—in response to a release event to Holmes Creek where the release is likely to have entered Mitchell River; monitoring is to be undertaken during the annual aquatic ecology monitoring survey
SW2#	299278E; 8173792N Holmes Creek, approximately 3 km upstream of the Mulligan Highway; upstream of site inputs and downstream of historical abandoned mine workings (unrelated to Mt Carbine mining lease). Note: this site was removed from the routine REMP monitoring in October 2020.					Investigation purposes only.

Ref. = reference site; Rec. = receiving site.

* = EA listed monitoring site.

^ = Recommended that SW17 is removed from the EA and the REMP (refer to **Section 2.1**).

= Upstream (control) site.

[1] Co-ordinates provided in datum GDA 94, Zone 55 (note this datum is consistent with the datum used in the EA).

2.4 Surface water

Surface water monitoring will be used in the REMP to determine the potential risk of water quality to the EVs (aquatic ecosystem, livestock drinking water, recreation and aesthetics). The parameters, sample collection, laboratory analysis and data analysis are provided below.

2.4.1 Parameters

Parameters for REMP monitoring are presented in **Table 6**. Most of the parameters have been selected due to their inclusion in the EA. Turbidity, dissolved oxygen and temperature are included for their relevance to aquatic ecology monitoring.

Surface water quality data for Mt Carbine has shown that some parameters have not been detected above the laboratory LOR at reference and receiving sites (*eg* antimony). Future EA amendments should review the relevance of the surface water quality parameters for the project, taking into consideration background and receiving water quality and the likelihood of the contaminant entering the system through the mining operations (*eg* geochemistry of ore and waste rock, use of processing chemicals on-site). The parameter list in the REMP should then be updated accordingly.

Table 6: Surface water parameters

Parameter	Units	Sampling method
pH	pH units	*In situ**
Electrical conductivity (EC)	µS/cm	
Turbidity	NTU	
Dissolved Oxygen	% saturation	
Temperature (for interpretation of dissolved oxygen)	°C	
Hardness	mg/L	Laboratory
Major ions	mg/L	
Fluoride	mg/L	
Sulfate	mg/L	
Filtered metals/metalloids: aluminium, antimony, arsenic, cadmium, chromium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, tungsten and zinc	mg/L	
Total metals: aluminium, antimony, arsenic, cadmium, chromium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, tungsten and zinc	mg/L	

* Where *in situ* analytes cannot be measured directly in the field, they should be included on the laboratory analysis request (excluding dissolved oxygen and temperature, which can only be measured *in situ* unless specific bottles are provided by the laboratory).

2.4.2 Field sampling

Water samples will be collected directly from the waterbody into sample containers provided by a NATA accredited laboratory. Field-filtered water samples will be collected (prepared using disposable syringes and 0.45 µm filters[14]) for filtered metals analysis[15]. Samples will be preserved and stored according to laboratory instructions and delivered to the laboratory

[14] A 0.8 µm pre-filter may be used in conjunction with the 0.45 µm filter if needed for turbid samples.

[15] DES (2018) notes that filtering samples through a 0.45 µm filter provides a sample suitable for 'dissolved' metal concentrations.

within the specified holding times. *In situ* measurements will be taken for physico-chemical parameters using water quality meters calibrated according to manufacturer's specifications.

2.4.3 Laboratory analysis

Surface water samples will be analysed by a NATA accredited laboratory for indicators specified in **Table 6** and analysed to the LOR at or below the DGVs (*ie* ANZG (2018) and EHP (2013), as provided in **Appendix A**) for aquatic ecosystem protection. If, after two years, monitoring data adequately demonstrates negligible environmental risk associated with a parameter, that parameter should be considered for removal from the EA by amendment.

2.4.4 Data analysis

To assess the potential impact of mining activities on the receiving environment, surface water data will be compared to guideline values nominated for the protection of MD aquatic ecosystems, livestock drinking water and recreation and aesthetics (per **Appendix A**). The following approaches will be used in data analysis for each of the EVs.

- **Aquatic ecosystem (MD)**. To assess potential impacts on the aquatic ecosystem EV, the median or 95th percentile[16] of the last 5 values collected at each receiving site (within the reporting period) is compared against the guideline values (DGV or SSGV)[17]. If surface water conditions do not support 5 or more values per site in a reporting period, the median or 95th percentile will be determined on the available data set. The results will provide an indication of the potential risk of the receiving water quality to the aquatic ecosystem EV. This risk should be considered with other lines of evidence (*ie* stream sediment and aquatic macroinvertebrate results).
- **Livestock (beef cattle) drinking water**. Water quality data will be directly compared (*ie* comparison of maximum value of test values) to the DGVs for livestock drinking water (**Appendix A**). Further data analysis may be conducted following any exceedance of guideline values.
- **Recreation and aesthetics**. Monitoring results collected during the REMP will be directly compared with the DGVs in **Appendix A** to determine potential risk to the recreation EV. In applying the guidelines, NHMRC (2008) recommends using a simple screening approach whereby a substance occurring in recreational water at a concentration of 10 times that stipulated in the drinking water guidelines may 'require further consideration'.

2.5 Stream sediment

Stream sediment is one of the lines of evidence used to determine potential impacts of the activity on the aquatic ecosystem EV in the receiving environment. The approach provided here considers the current monitoring and sampling guidance (DES 2018), consistency with the EA and previous REMP, and updates in the water quality guidelines (ANZG 2018).

[16] For toxicants (*eg* metals), the median of receiving site values is used for comparison against the SSGV, and the 95th percentile of receiving site values is used for comparison against the DGV. For stressors (*eg* pH and EC), the median value of receiving site values is used for comparison against the SSGV and the DGV.

[17] For aquatic ecosystems, water and sediment quality objectives (DGV or SSGV) are intended to be a tool for monitoring conditions. If receiving site values exceed the guideline values, ANZG (2018), ANZECC and ARMCANZ (2000) and Simpson *et al*. (2013) advise that further investigations should be undertaken to determine if there is an environmental risk associated with the exceedance.

2.5.1 Parameters

The chemical and physical properties to be analysed for stream sediment are in **Table 7**. The list of parameters is consistent with the EA.

Stream sediment monitoring for Mt Carbine has shown that some parameters have not been detected above the laboratory LOR at reference and receiving sites (*eg* antimony and selenium). Future EA amendments should review the relevance of the sediment quality parameters for the project, taking into consideration background and receiving site data, the likelihood of the contaminant entering the system through the mining operations (*eg* geochemistry of ore and waste rock, use of processing chemicals on-site), and the usefulness of the parameter for determining potential impacts (*eg* aluminium in sediment is not useful for determining impacts to EVs due to its natural abundance and variability in sediments). The parameter list in the REMP should then be updated accordingly.

Table 7: Stream sediment parameters

Parameter	Units	Size class	Fraction size range (mm)	Analytical method
Particle size distribution	µm	Gravel	<2.0	Laboratory
		Coarse sand	0.6 to 2.0	
		Large-medium sand	0.3 to 0.6	
		Small-medium sand	0.212 to 0.3	
		Fine sand	0.063 to 0.212	
		Silt and clay	<0.063	
Fluoride	mg/kg	-	-	Laboratory
Sulfate	mg/kg	-	-	Laboratory
Metals/metalloids: aluminium, antimony, arsenic, cadmium, chromium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, tungsten and zinc	mg/kg	-	-	Laboratory

2.5.2 Field sampling

Stream sediment samples for chemical analysis on the whole (<2 mm) sediment fraction will be collected from the stream bed in accordance with AS/NZS 5667.12 – *Guidance on Sampling of Bottom Sediments* (as required by the EA). A composite sample will be collected from 10 points within the sampling area to a depth of approximately 5 cm. Stones greater than approximately 25 mm will be manually removed from the sample. The composite sample will be placed into a plastic sediment bag or jar supplied by the laboratory. The potential for cross contamination between sites will be minimised by washing the sampling equipment between sites.

2.5.3 Laboratory analysis

Stream sediment samples will be analysed by a NATA accredited laboratory for the chemical and physical properties specified in **Table 7** and analysed to the LOR at or below the DGVs (*ie* ANZG (2018), as provided in **Appendix A**) for aquatic ecosystem protection.

Chemical analysis (strong acid digestion *eg* using aqua regia) will be undertaken on the whole (<2 mm) sediment fraction, allowing for comparison against the DGVs. Where results indicate a potential risk to the aquatic ecosystem (*ie* receiving site data exceeds the DGV), the sediment samples should be analysed using a dilute acid extractable (DAE) method. This approach follows the guidance in ANZG (2018) and the decision tree framework in Simpson

et al (2013). Analysis on the <63 µm fraction may be undertaken where the results will be useful to determine potential risks to the aquatic ecosystem.

Particle size distribution (PSD) analysis describes the proportions of stream sediments that occur across the sediment size classes listed in **Table 7**. The PSD results can be used to interpret the chemical analysis data and, in combination with site observations, infer whether substrate smothering has occurred (smothering can reduce microhabitat suitability for aquatic fauna). Sediment size classes can be used to assist with interpretation of differences (if any) between the aquatic macroinvertebrates identified over time. PSD analysis will be undertaken by grading the sample to the six sieve sizes listed in **Table 7**.

2.5.4 Data analysis

Sediment quality data will be compared to DGVs or SSGVs (**Appendix A**) to assess the potential risk of contaminants in stream sediment to the aquatic ecosystem EV. Following guidance in ANZG (2018), receiving site data will be compared with DGVs (where available) for the total recoverable metals analysis on the <2 mm sediment fraction. Where DGVs are not available, receiving site data will be compared with SSGVs derived from reference site data (per **Appendix A**).

Where receiving site data exceeds the DGV, DAE analysis should be conducted on the <2 mm sediment fraction from the same sample. The DAE concentrations are compared with the DGV to determine bioavailability and corresponding risk of the parameter to the receiving environment. Further investigation may be required if the results indicate a potential high risk to the aquatic ecosystem, which may include analysing the <63 µm sediment fraction.

2.6 Aquatic ecology

Water quality can fluctuate at a site, and individual water quality samples may not necessarily reflect overall site conditions. Aquatic macroinvertebrates provide a measure of ecosystem health that, in combination with water and sediment quality data, can be used to identify and describe the potential impacts of mining activities on the receiving environment in the short-, medium- and long-term.

Aquatic macroinvertebrate sampling and analysis are used in this REMP as part of a multiple lines of evidence approach to determine potential impacts from the mining activity on the receiving surface waters. The field sampling and laboratory analysis described in **Sections 2.6.1** and **2.6.2** consider the methods outlined in DES (2018) whilst maintaining the integrity of the long-term Mt Carbine REMP. Because the original REMP design for Mt Carbine was developed and implemented prior to the DES (2018) publication, there may be some variations between the methods applied. Nevertheless, the approach provided for this REMP is suitable for the purposes of the monitoring program. The approach involves a rapid assessment of the aquatic macroinvertebrate community using replicate quantitative macroinvertebrate sampling for assessing point source pollution.

The use of AusRivAS sampling and models is not appropriate for this REMP because the AusRivAS method is primarily used for broad scale monitoring (*eg* in a regional or catchment context) (DNRM 2001). Further, formal WQOs have not been established for the receiving environment; therefore, the aquatic ecology survey has been prepared based on the requirements of the REMP (*ie* monitor, identify and describe any adverse impacts to surface water EVs) and the professional experience of appropriately qualified and experienced environmental scientists.

2.6.1 Field sampling

Field sampling will be performed by an AusRivAS accredited scientist or by an individual with appropriate relevant demonstrated technical skills and experience. Samples will be collected from the habitat type that occurs at reference and receiving sites, *ie* pool bed habitat, noting that monitoring sites at Mt Carbine are in shallow pools.

Two aquatic macroinvertebrate kick samples will be collected from the bed of the stream at each site. Kick samples involve the operator using their feet to disturb a 10 m stretch of substrate over a 2 minute period and sweeping an aquatic macroinvertebrate net (250 µm mesh aperture) downstream of the plume to collect dislodged material. Material collected from each of the kick samples will be emptied into separate white sorting trays. Live animals will be picked from the tray using forceps and pipettes for 30 minutes[18]. Field-picking will be performed by an AusRivAS accredited scientist, or by personnel who have been instructed in and have undergone the quality assurance (QA) process to verify picking skills. Collected specimens will be preserved in methylated spirits for laboratory identification.

For each site, a rapid assessment of biophysical conditions will be undertaken and recorded on standard data sheets. The assessment will include water depth, substrate composition, flow conditions, the occurrence of aquatic fauna and vegetation, riparian habitat condition, and site disturbances. This information assists with data interpretation and serves as a permanent record for future reference.

2.6.2 Laboratory identification

Aquatic macroinvertebrates will be identified by appropriately trained personnel, using a stereo microscope. Aquatic macroinvertebrate specimens will be preserved in methylated spirits and identified to family level (or a lower/higher taxonomic level as recommended by AusRivAS and other literature), and abundance of each taxon will be recorded.

2.6.3 Statistical analysis

A range of statistical analyses will be used to identify spatial and temporal variation in the aquatic macroinvertebrate assemblages. The results will be interpreted in the context of variation in surface water and sediment quality, to identify potential impacts on biota.

Statistical analysis may include univariate and multivariate analyses (including cluster analysis and multidimensional scaling (MDS)), and sensitivity indices (where appropriate indices have been developed).

2.7 Quality assurance/quality control

Quality assurance/quality control (QA/QC) procedures will be applied to water, sediment and aquatic macroinvertebrate sampling and analysis to:

- validate the sampling and analysis process
- check whether bias or sample contamination has affected the results
- quantify errors.

[18] This approach provides a systematic method that reduces variability between samples by establishing a set picking time. When picking, the relative abundance of taxa collected in the kick sample is obtained, rather than the presence/absence approach used in DES (2018).

2.7.1 Sampling

Surface water

A duplicate surface water sample will be collected from one site during each sampling event to confirm the analytical reliability of laboratory analyses.

A blank sample will be prepared in the field using deionised water provided by the laboratory to determine if field sample handling procedures, equipment and/or laboratory analyses have introduced gross contamination. Where field-filtering equipment has been used, a field-filtered blank sample will be prepared using the same type of filtering equipment (*eg* syringes with filters, or vacuum pump and stericups).

Stream sediment

A duplicate stream sediment sample will be collected from one site during each sampling event to confirm the analytical reliability of the laboratory results. The sediment sample will be split into two using coning and quartering. This involves pouring sediment into a cone shape onto clean paper using clean cardboard as a funnel. The sediment is flattened and divided into four equal wedges (quarters). Split samples are generated by taking material from opposing quarters so the two plastic sediment bags contain relatively equal portions of the sample.

Aquatic macroinvertebrates

Laboratory identification of aquatic macroinvertebrate samples will be subject to QA/QC checks by a second appropriately trained person. A portion (10%) of samples will be re-processed, and any discrepancies in identifications or miscounts will be investigated further (*ie* by re-checking the remaining samples for those taxa).

The residual kick sample material remaining in the tray of each operator at the end of live-picking will be collected at one site and checked in the laboratory by appropriately trained personnel under a stereo microscope and all aquatic macroinvertebrates present will be recorded. This process is used to verify the live-picking capability of each operator. The proportion of taxa collected by each field operator will be assessed and compared to identify whether live-picking data for the field operator can be considered adequate or whether results may need to be interpreted with due caution.

DES (2018) (sections 7.3.4.2 and 7.5.3.2) provides guidance on analysing the QA/QC results.

2.8 Reporting

An annual report is required for each reporting period. The annual report should detail the approach, results and findings of the REMP, and recommendations based on these findings. The report will assess the condition of the receiving environment in regard to potential impacts, and consider the suitability of the current discharge limits to protect downstream environmental values.

A copy of the annual report and associated data is to be made available, on request, to the administering authority[19].

[19] Nominally, the annual REMP report is prepared before 1 August each year, and a complete wet season is incorporated into the reporting period.

2.9 REMP review

The REMP design report should be reviewed every two years, or earlier, if there are changes to mine operations or EA conditions. This frequency allows any recommendations from annual reports, and changes in statutory requirements, to be considered and incorporated in the updated REMP.

3. Recommendations

Based on the information in this REMP design document, the following recommendations are provided.

- Enter information about a site's flow status at the time of sampling into the Mt Carbine water quality database with water quality results (*eg* flood, base flow, pool).
- Review the need to develop surface water trigger values for different flow conditions (*eg* high flow, base flow and no flow) in approximately two years, when a larger data set, and appropriate flow information, has been collected.
- Install a flow gauge on Manganese Creek to monitor receiving water flow volumes, as required by the EA.
- Investigate a suitable reference site for comparison to site SW15 (*ie* a drainage feature with similar in-stream habitat). If it is possible to establish this site, it will be labelled SW24.
- Seek to amend the EA to improve REMP monitoring and compliance reporting. Amendments include the following.
  - EA Table D4: replace site SW17 with SW20, as SW20 is more appropriate for monitoring potential contaminants from the LGMS area entering the receiving environment.
  - EA Table D3: review and update the parameters listed for surface water and stream sediment, removing analytes that are not of concern to the project, not present (above laboratory LORs), and are not useful for determining potential impacts from the licensed activity (*eg* aluminium, antimony, selenium). The review should consider the likelihood of the contaminant occurring from the activity.
  - EA condition D5: amend the extent of the receiving environment to 'the waters of Holmes and Manganese creeks to the confluence with Mitchell River' to allow a more meaningful and appropriate routine program for monitoring, identifying and describing adverse impacts (if any) of the authorised mining activity on the surface water EVs, quality and flows.

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Appendix A:
Nominated Surface Water and Stream Sediment Guideline Values for the Mt Carbine REMP

Nominated surface water quality guideline values for the Mt Carbine REMP – aquatic ecosystem EV

Parameter		Units	DGV (aquatic ecosystem)[1]	Manganese Creek SW1		Holmes Creek SW16		Mitchell River SW10	
				n	SSGV	*n*	SSGV	*n*	Interim SSGV
pH		pH units	6.0–7.5[a]	*42*	6.8–7.2	*19*	6.8–7.3	*8*	6.8–7.1
Electrical conductivity		µS/cm	125[b]	*36*	66	*14*	76	*6*	ID
Sulfate		mg/L	–	*42*	0.58	*19*	1.04	*8*	1.06
Fluoride		mg/L	2.4[c]	*42*	0.15	*19*	0.19	*8*	0.13
Aluminium	filtered	mg/L	0.055[d]	*42*	1.5	*19*	1.2	*8*	0.4
Antimony	filtered	mg/L	0.009[e]	*17*	<0.003	*14*	<0.003	*2*	ID
Arsenic	filtered	mg/L	0.013[f]	*42*	<0.003	*19*	0.009	*8*	<0.003
Cadmium	filtered	mg/L	0.0002	*42*	<0.0001	*19*	<0.0001	*8*	<0.0001
Chromium	filtered	mg/L	0.001[g]	*42*	<0.001	*19*	<0.001	*8*	<0.001
Cobalt	filtered	mg/L	0.0014[e]	*37*	<0.001	*19*	<0.001	*8*	<0.001
Copper	filtered	mg/L	0.0014	*42*	<0.001	*19*	0.001	*8*	<0.001
Lead	filtered	mg/L	0.0034	*40*	<0.001	*19*	<0.001	*8*	<0.001
Manganese	filtered	mg/L	1.9	*41*	<0.005	*19*	0.005	*8*	0.010
Molybdenum	filtered	mg/L	0.034[e]	*24*	<0.001	*18*	<0.001	*6*	ID
Nickel	filtered	mg/L	0.011	*19*	<0.001	*15*	<0.001	*3*	ID
Selenium	filtered	mg/L	0.005	*15*	<0.003	*14*	<0.003	*2*	ID
Tungsten	filtered	mg/L	–	*13*	<0.001	*14*	<0.001	*2*	ID
Zinc	filtered	mg/L	0.008	*42*	<0.005	*19*	<0.005	*8*	<0.005

Data used in this table is from the collated water and sediment quality database maintained by MCQ (dated 30 September 2020) augmented with data from laboratory certificates where available and required.

NRA evaluated the data for monitoring purposes. Outliers were removed, and less than limit of reporting (<LOR) values were removed when:

- the LOR was higher than the DGV or
- the LOR was not consistent with the majority of the <LOR values for the parameter.

[1] Default guideline values (DGVs) for the protection of moderately disturbed (MD) aquatic ecosystems derived from ANZG (2018) (accessed 19/10/2020) unless otherwise indicated.

[a] pH guideline value derived from ANZECC and ARMCANZ (2000) Table 3.3.4 (noting that these values are for the protection of 'slightly disturbed' ecosystems).

[b] Electrical conductivity guideline value derived from EHP (2013) Table G.1 for the Cape York Salinity Zone (*ie* including Mitchell River basin) (75th percentile).

[c] Draft guideline value for fluoride from ANZGFMWQ (2015). This guideline value is under review and has not been finalised or formally adopted. NRA has permission to use this guideline value (*pers. comm.* Chris Hepplewhite, Assistant Director, National Water Policy Section, Australian Government Department of Agriculture and Water Resources, 19 June 2017).

[d] Guideline value for aluminium is a 'low reliability' value, derived for waters of pH >6.5 (ANZG 2018). If pH is <6.5, the DGV 0.008 mg/L should be used for aluminium (ANZG 2018).

[e] Interim value from section 8.3.7.1 of ANZECC and ARMCANZ (2000); reliability 'unknown' in ANZG (2018).

[f] For As(V), the lowest guideline value for arsenic; 'moderate' reliability (ANZG 2018).

[g] For Cr(VI), the lowest guideline value for chromium; 'very high' reliability (ANZG 2018).

– Denotes no DGV.

SSGV: Site-specific guideline value, calculated as the 80th percentile of reference site data (and 20th percentile for pH).

ID: Insufficient data to calculate SSGVs.

Nominated surface water quality guideline values for the Mt Carbine REMP – human use EVs

Parameter		Units	Default guideline value	
			Livestock[1]	Recreation[2]
pH		pH units	4.0–9.0	6.5–8.5
Electrical conductivity		µS/cm	5970	–
Sulfate		mg/L	1000	–
Fluoride		mg/L	2	15
Aluminium	total	mg/L	5	–
Antimony	total	mg/L	–	0.03
Arsenic	total	mg/L	0.5	0.1
Cadmium	total	mg/L	0.01	0.02
Chromium	total	mg/L	1	0.5
Cobalt	total	mg/L	1	–
Copper	total	mg/L	1	20
Lead	total	mg/L	0.1	0.1
Manganese	total	mg/L	–	5
Molybdenum	total	mg/L	0.15	0.5
Nickel	total	mg/L	1	0.2
Selenium	total	mg/L	0.02	0.1
Tungsten	total	mg/L	–	–
Zinc	total	mg/L	20	–

[1] Guideline values for the protection of livestock drinking water derived from ANZECC and ARMCANZ (2000) section 4.

[2] Guideline values for the protection of water for recreation derived from NHMRC (2008). Waters contaminated with chemicals that are toxic or irritating to the skin or mucous membranes are unsuitable for recreational waters. In all cases, chemical and physical contaminants must be assessed on a local basis (NHMRC 2008). For chemicals, recreation guideline values have been calculated as 10 times the values stipulated in the Australian Drinking Water Guidelines (NHMRC & NRMMC 2011).

Nominated sediment quality guideline values for the Mt Carbine REMP

Parameter	Unit	DGV sediment[1]	Manganese Creek		Holmes Creek		Mitchell River	
			SW1		SW16		SW10	
			n	SSGV[2]	*n*	SSGV[2]	*n*	SSGV[2]
Sulfate	mg/kg	-	*18*	7	*14*	12.6	*4*	ID
Fluoride	mg/kg	-	*5*	ID	*6*	ID	*1*	ID
Aluminium	mg/kg	-	*32*	2380	*20*	9100	*6*	ID
Antimony	mg/kg	2	*NA*	NA	*NA*	NA	*NA*	NA
Arsenic	mg/kg	20	*NA*	NA	*NA*	NA	*NA*	NA
Cadmium	mg/kg	1.5	*NA*	NA	*NA*	NA	*NA*	NA
Chromium	mg/kg	80	*NA*	NA	*NA*	NA	*NA*	NA
Cobalt	mg/kg	-	*44*	1.1	*20*	5.2	*7*	ID
Copper	mg/kg	65	*NA*	NA	*NA*	NA	*NA*	NA
Lead	mg/kg	50	*NA*	NA	*NA*	NA	*NA*	NA
Manganese	mg/kg	-	*44*	97	*20*	202	*7*	ID
Molybdenum	mg/kg	-	*42*	<0.5	*18*	<0.5	*6*	ID
Nickel	mg/kg	21	*NA*	NA	*NA*	NA	*NA*	NA
Selenium	mg/kg	-	*15*	<3	*13*	<3	*2*	ID
Tungsten	mg/kg	-	*40*	1.1	*20*	1.7	*7*	ID
Zinc	mg/kg	200	*NA*	NA	*NA*	NA	*NA*	NA

Data used in this table is from the collated water and sediment quality database maintained by MCQ (dated 30 September 2020) augmented with data from laboratory certificates where available and required.

NRA evaluated the data for monitoring purposes. Outliers were removed, and less than limit of reporting (<LOR) values were removed when:

- the LOR was higher than the DGV or
- the LOR was not consistent with the majority of the <LOR values for the parameter.

[1] Default guideline value (DGV) for aquatic ecosystems (ANZG 2018).

[2] Site-specific guideline value (SSGV) derived from the 80th percentile of reference site data as per the approach in ANZG (2018) using the reference site data set guidance in EHP (2013). Calculated for parameters where a DGV is not available. Where the 80th percentile value was <LOR, the LOR value has been applied.

– No DGV available (ANZG 2018).

ID: Insufficient data to derive an SSGV, *ie* <8 data values.

NA: Not applicable—SSGVs do not apply where the DGV has been provided (per ANZG 2018).

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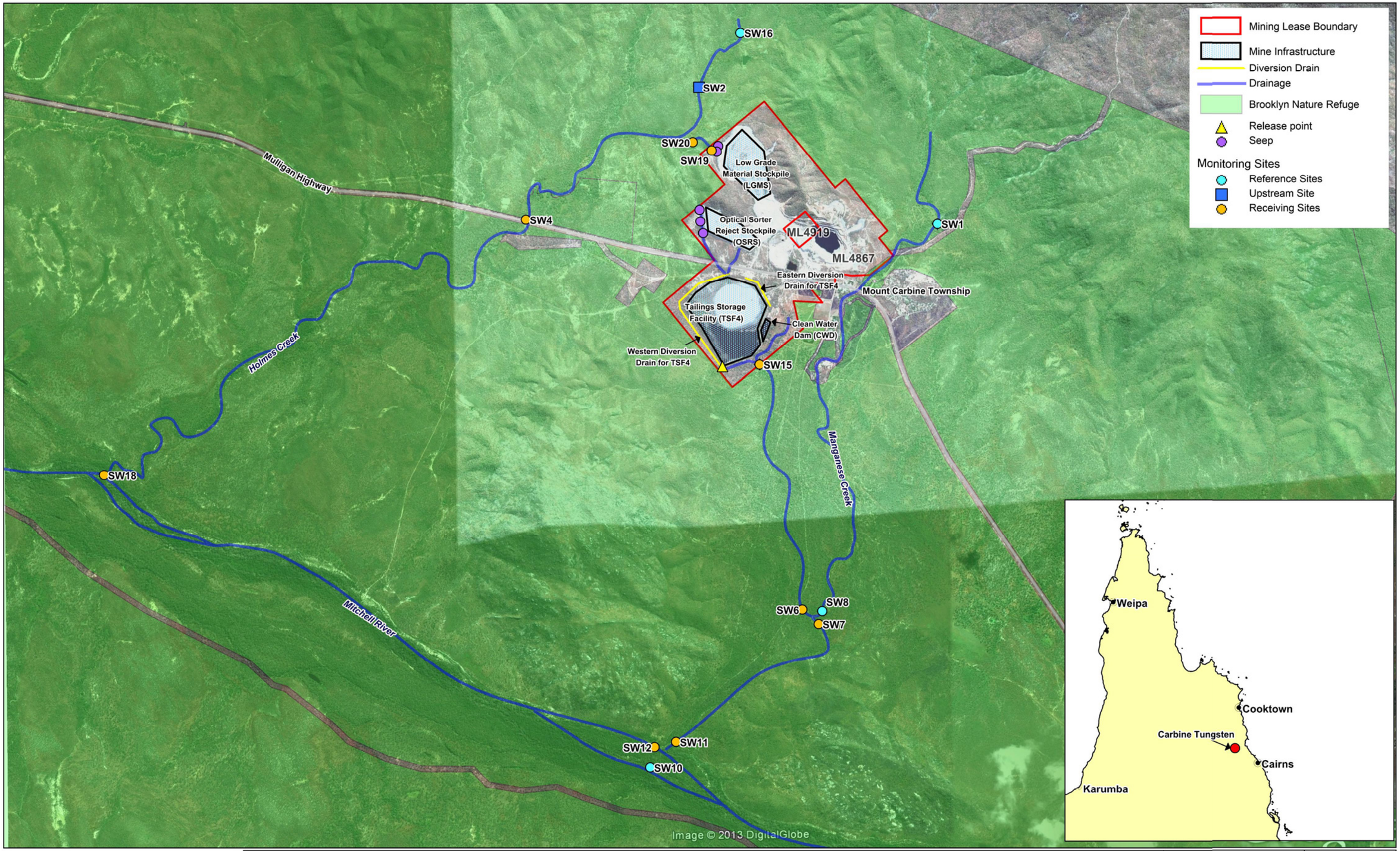
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NHMRC 2008, *Guideline for Managing Risks in Recreational Water*, National Health and Medical Research Council, Commonwealth of Australia, Canberra.

Appendix B:
Location of Sites SW6, SW8 and SW11



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PROJECT: Carbine Tungsten Receiving Environment Monitoring Program
TITLE: Monitoring site locations

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DATE: August 2014

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Appendix N:
Mt Carbine UG Scoping Study Report (21-4011) (Deswik 2022)



EQ Resources | Mt Carbine

UG SCOPING STUDY REPORT 21-4011

RELEASE DATE: 22/02/2022

DOCUMENT VERSION: 1.0

DOCUMENT DETAILS

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RELEASE DETAILS

Proposal Name:	Scoping Study Report		
Proposal Number:	21-4011		
Client Name:	EQ Resources | Mt Carbine		
Client ABN/ Tax Number:			
Author:	Joshua Kennedy | Tom Giffney | Alex Greenhalgh		
Approved by:	Joshua Kennedy	**Date Approved:**	22/02/2022

REVISION DETAILS

Date	Version	Modified By	Comments
14/02/2022	0.1	Joshua Kennedy | Tom Giffney	Initial draft
17/02/2022	0.2	Alex Greenhalgh	Review and additions
22/02/2022	0.3	Joshua Kennedy	Final review and completion

EXECUTIVE SUMMARY

The Mount Carbine Underground (MCU) study was undertaken to explore the potential of delineating and creating an underground mining inventory (design and schedule) that extended the life of the operation beyond the mining of the currently delineated open pit resource. The study drew on the geological, processing and site knowledge of the EQ Resources personnel, coupled it with the experience and software expertise of Deswik consultants, to produce a marginally economic solution to extending the life of the Mt Carbine operations (beyond the current open pit and stockpile resources).

The MCU study broadly consisted of:

- geological review (to understand geology, structural controls, grade distribution, resource status, inventory to be assessed for underground potential)
- stope optimiser runs (to spatially delineate stopes greater than 0.25%WO_3)
- mining method review (appropriate methods, assessment and exclusion exercise)
- review and update of supplied first-principles cost build up for underground mining costs
- level by level, stope by stope assessment of potentially economic stopes
- preliminary design, task creation, sequencing and scheduling of concept design
- financial cost model and SWOT analysis
- reporting and findings

Presented with the relatively *low tonnes per vertical metre*, a longhole stoping option (top down, no fill, leaving pillars) was progressed through the design process. After application of suitable mining recoveries factors (in-line with mining method selection above), an underground mining inventory of **4.19Mt @ 0.52%WO_3** (2.18 million mtu) was realised. In addition, this mining inventory is predominantly in the *inferred* resource category (around 80%), highlighting the lack of drilling below the open pit extents. The *remaining* resource inventory (not taken by pit or in the underground assessment) of ~5.7Mt @ 0.4%WO_3 consists mainly of isolated pods, discontinuous and narrow.

Scheduling of the underground inventory at an appropriate production rate (t/yr and vm/yr), (with the objective of continuing to, as close as possible, filling the processing plant after the completion of the open pit), resulted in **~10.5yr mine life** with peak ore delivery in Yr 7 (~620kt ore). Assuming processing in the year of mining, this produced (LoM) **~33.3kt** of concentrate (@50%WO_3). At a realised price of *$AUD18,200/t concentrate*, total revenue generated is **~AUD$607M** (exclusive royalties).

The resulting stand-alone cost model demonstrated a modest **$29.4M NPV** with an **IRR (excl. tax) of 12%.** A sensitivity analysis demonstrated project is *extremely* sensitive to grade/price fluctuations and *moderately* sensitive to operating and capital cost fluctuations.

The main contributing factors driving the financial result include:

- low viable economic stoping tonnes on each level
- level spacing of 20m driven by narrow orebodies (>80% of stopes less than 2m width)
- geographically spread lenses (relatively large footprint of modelled lenses on each level)

These contribute to a high proportion of *development tonnes: stoping tonnes* for the underground. From an acceptable 'financial return perspective' this could be tolerated if the grades were 10-20% higher

(i.e., more metal in existing inventory) or more inventory at a cut-off grade making an acceptable return (this would be 0.7%WO_3 or above).

While a clear and compelling underground option maximizing potential resource inventory (and exploitation inventory) did not eventuate, the study highlights that, given certain conditions, an underground operation at Mt Carbine could be feasible, albeit targeting a lower throughput (or similar to that proposed if more metal and/or more inventory was found).

The recommended path forward for EQ Resources to extend the life of the Mt Carbine operation (beyond the end of the current open pit) should involve:

- alignment of open pit/ underground input assumptions i.e., re-optimisation of the resource model based to determine whether the existing pit can be expanded (or a cut-back found)
    - Incorporate these changes into a working LoM pit CAD|schedule "ready for execution"
- following this (appreciating the remaining resource available to underground may have decreased), investigate a smaller scale, underground operation accessed potentially after pit has finished
- engagement of geotechnical discipline to carry out required work for open pit mining operations and provide input into further underground assessments
- prepare/modify existing site financial model making it 'fit-for-purpose' for when open pit operations begin (and the above open pit re-optimisations have been completed).

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1. INTRODUCTION

1.1. SCOPE

EQ Resources approached Deswik to conduct a desktop study into the viability of an underground operation at its Mt Carbine deposit in northern Queensland. It forms part of the study work delineated as "Phase 3" for the expansion of operations at Mt Carbine, aiming to extend the mine life once open pit operations have concluded (EQ Resources, 2021).

1.2. OVERALL APPROACH

The stated objective from EQ Resources was to present a mining method/approach that was:

- Feasible (practically and economically)
- Provided continuous feed to the processing plant beyond the end of the open pit at a rate that was achievable (aim for 2,000t/d)

The overall process followed for this study is summarised below:

- Project kick-off meeting (and weekly progress meetings) to outline objectives, vehicle for Q&A and information sharing between the parties
- Initial resource model review (grade shells, block model statistics, grade distribution)
- High-level stope inventory review based on supplied high grade zone wireframes
- Mining methods assessment
- Deswik.SO runs to produce mineable stope shapes
- First principles build-up of unit rates for primary mining activities
- First pass economic assessment of 'on-level' economically viable development and stoping areas
- Create concept mine design (centreline design)
- Create solids, schedule tasks and sequence mine
- High level stope mining recovery assessment (in the absence of any geotechnical information, which typically forms part of a scoping study)
- High level examination of primary ventilation requirements
- Multiple passes of resource levelling to produce LoM schedule physicals
- Detailed (for a scoping study) cost model used to evaluate the economics of conceptual design and schedule
- High level SWOT analysis on above work

In addition to the original scope, EQ Resources requested a report be provided. This document represents that report.

All work | models created during the study were created in such a way as to be flexible to be used in future assessments by EQ Resources or nominated parties and form part of the deliverables.

2. GEOLOGICAL RESOURCE REVIEW

Before conducting an economic analysis of mining inventory, it was important to understand the starting available resource inventory and the breakdown of resource classification as this indicates confidence.

2.1. STARTING INVENTORY

The published Mt Carbine resource is shown in Table 1.

Table 1 Mt Carbine resource – September 2021

Orebody	Resource Classification	Tonnes (Mt)	Grade (WO_3 %)	WO_3 (mtu)
Low-Grade Stockpile	Indicated	12	0.075	900,000
In Situ	Indicated	2.40	0.74	1,776,000
	Inferred	6.81	0.59	4,017,900
	Total	*9.21*	*0.63*	*5,793,900*
All	**Total**	**21.21**		**6,693,900**

From this, and extracting the resource contained in the designed open pit supplied by EQ Resources (approximately 1.1Mt), the remainder (~8.1Mt) represents the inventory that was considered for underground potential (see Figure 2-1) i.e. no 'open pit/underground interface work' work was scoped or completed as a part of this study.

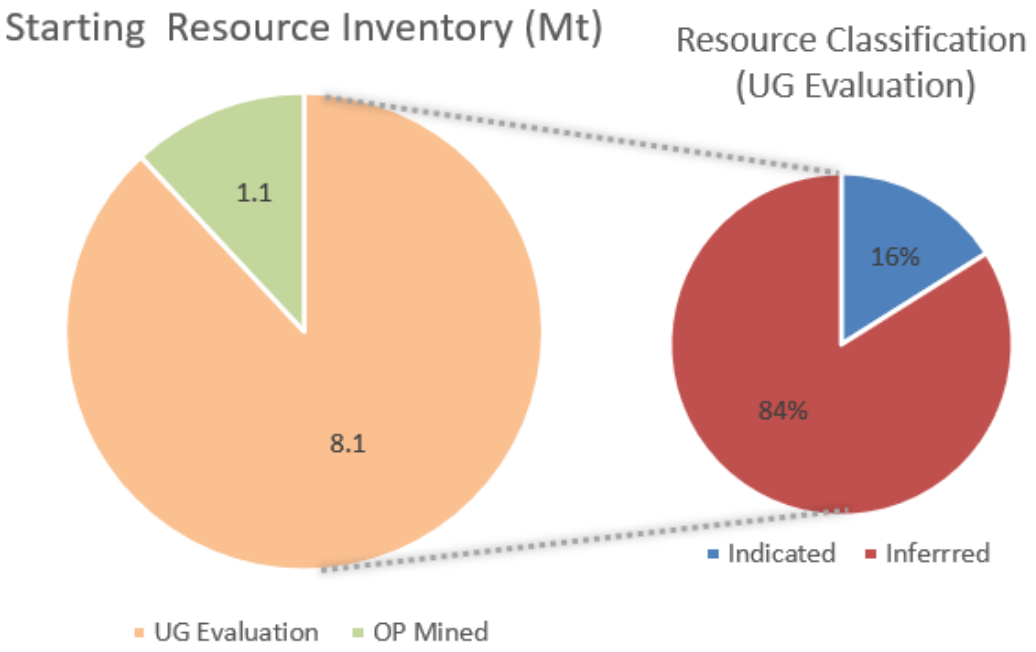


Figure 2-1 Starting Inventory Pie Chart breakdown

2.2. RESOURCE WIDTH AND GRADE DISTRIBUTION

An overview x-section (22775mE +/- 25m) through the pit deign displaying the block model grade distribution and drillhole spacing. This section (Figure 2-2) highlights the vertical interpolation bias applied to the grade distribution.

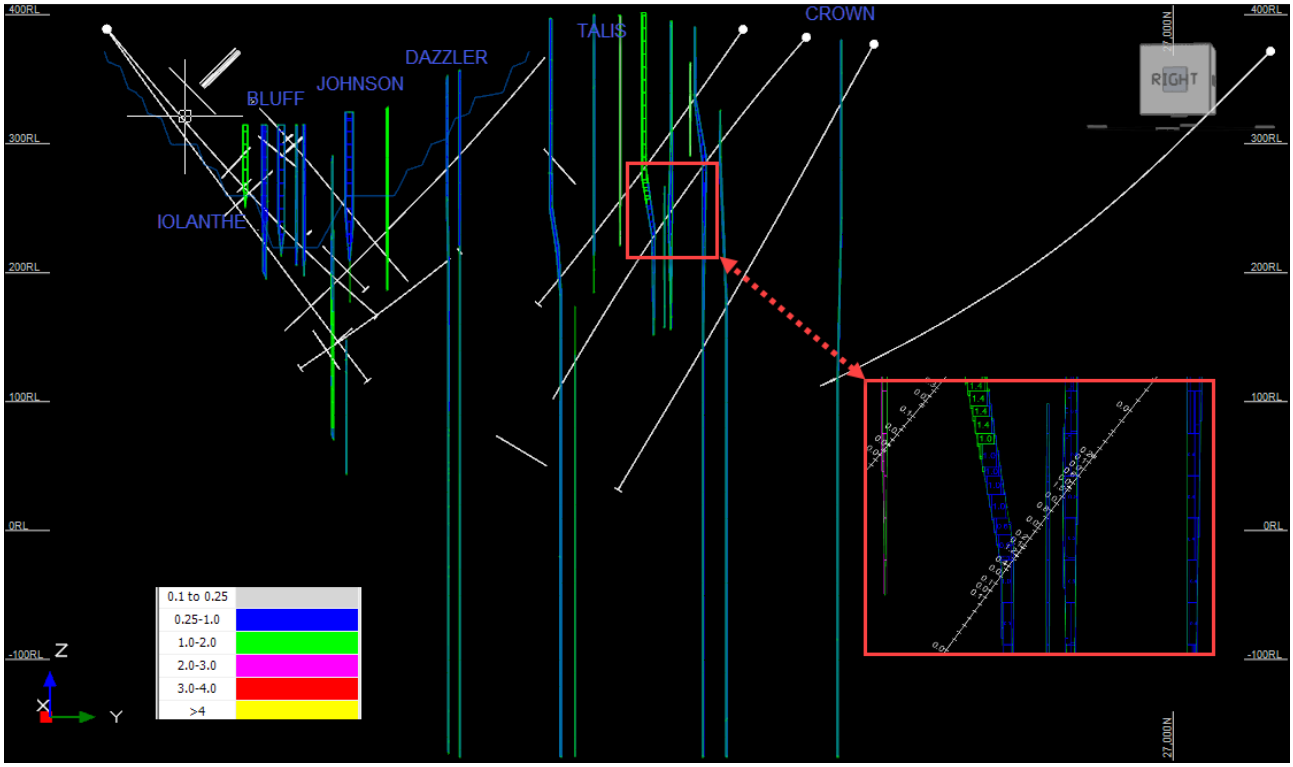


Figure 2-2 Block Model Grade Distribution

2.3. STOPE OPTMISER RUNS

Deswik.SO is a strategic mine planning tool that automates stoping design from an input block model. The goal is to maximize the value of an orebody within existing constraints using a specified mining method and design parameters, such as:

- Stope shape and orientation
- Cut-off grade
- Pillar sizes
- Dilution
- Minimum mining widths
- Utilize geological wireframes to govern stope shapes

Multiple scenarios were run through the optimization process to compare adjusted parameters so that the output was maximized. The below table summarizes the input parameters used in the base Stope Optimizer scenario.

Table 2 SO Parameters

Deswik.SO Parameters	
Block Model	Mt_Carbine_20210918.gmdlb
Cut-Off	WO_3: 0.25%
Stope Dimensions	Height: 20m, Strike: 20m
Stope Width	Min: 1.8, Max: 20m
Stope Pillars	Min: 4 m
Dip (Default)	90 deg

2.4. STOPES CARRIED FORWARD IN THE PROCESS

The Base Scenario used for further analysis produced 6.3Mt @0.6% WO_3 (for a total of 2596 stopes). Once SO parameters have been applied to the optimization process the inventory is reviewed again as displayed in Figure 2-3. These totals are prior to any mine costing, BEG (Break-Even Grade) analysis etc.

Figure 2-4 and Figure 2-5 below display the total SO scenario used in the design, scheduling and costing process of the study. Key observations are the continuous grade distribution with depth and the narrow stope widths which influence the mining methods to be assessed. Further attrition is applied to the scenario once operating and B.E.G costs are applied.

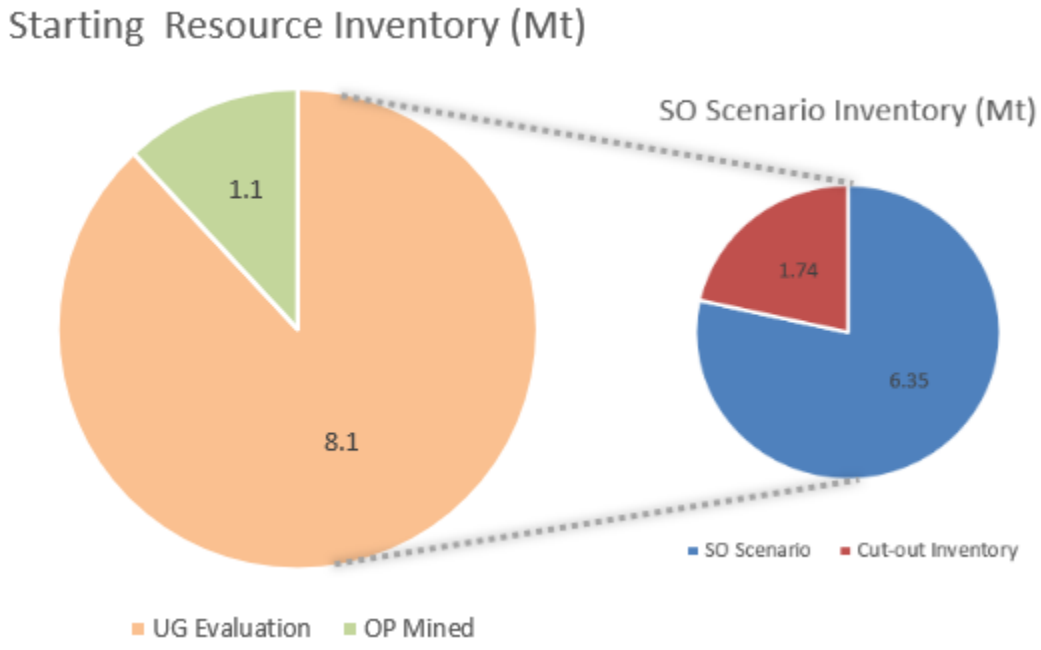


Figure 2-3 Stope Optimizer Inventory Chart

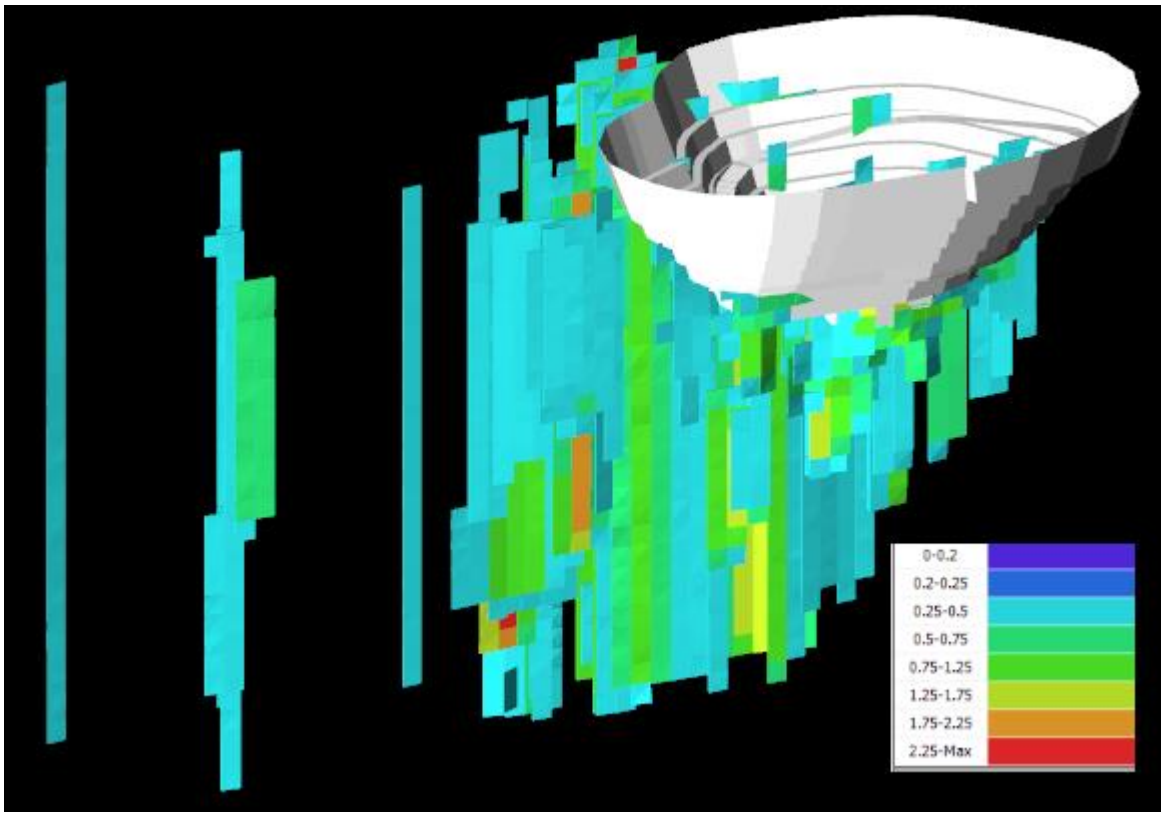


Figure 2-4 Base case SO scenario results (0.25% WO3 cut-off)

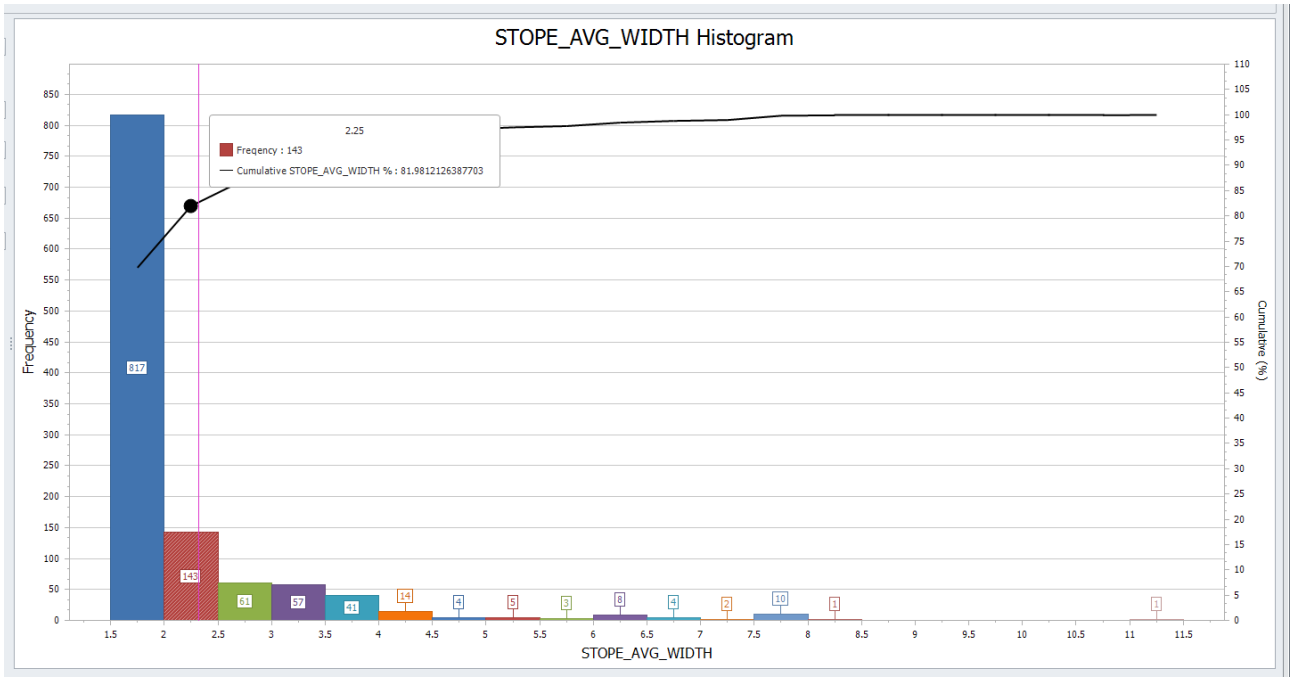


Figure 2-5 Stope width distribution curve resulting from the Deswik.SO runs

3. MINING METHODS ANALYSIS

Several initiatives were used to come up with a list of mining methods that should be considered in the study. The focus was on methods applicable to narrow orebodies and given the low tonnes per vertical metre of the Carbine deposit, the feasible mining methods are limited.

The mining study worked through an elimination process, initially discarding methods presenting fatal flaws, then progressing with a financial assessment on an agreed upon method (Top-Down Longitudinal Stoping).

This mining method analysis has highlighted the need for further geotechnical input. The downstream consequence of a geotechnical model impacts the dilution, stable mining widths, pillar ratios, and affects the mining method. With no geotechnical input, industry benchmarked parameters (of similar mining methods) were assumed for this study.

3.1. IDENTIFICATION OF SUITABLE MINING METHODS

3.1.1. OREBODY CHARACTERISTICS

Using a Mining Method Selector Macro (Miller-Tait, L., Pakalnis, R. and Poulin, R., (1995)) and orebody characteristics, a high-level understanding of what mining methods are potentially feasible can be calculated. This tool was used to assess what mining methods should be approached and considered. One of the user interface pop-ups is shown in Figure 3-1.

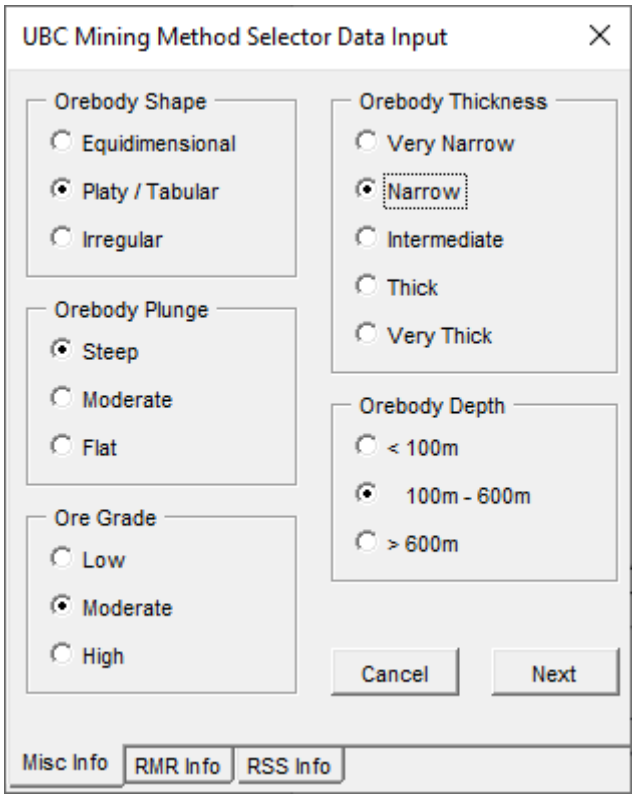


Figure 3-1 Mining Method Selector Macro

Table 3 below provides a rating score for each mining method given the input orebody characteristics. Given the steeply dipping narrow-sheeted nature of the mineralization stoping is the clear option.

Table 3 Mining Method Macro Results

	Final Results	
1	Sublevel Stoping	39
2	Shrinkage Stoping	36
3	Cut and Fill	36
4	Open Pit	30
5	Top Slicing	15
6	Square Set	10
7	Room and Pillar	-22
8	Sublevel Caving	-24
9	Block Caving	-29
10	Longwall	-30

3.1.1. HIGH LEVEL BREAK-EVEN GRADE

A high-level break-even grade (BEG) calculation was done based on processing cost and recovery assumptions supplied by EQ Resources, as shown in Figure 3-2.

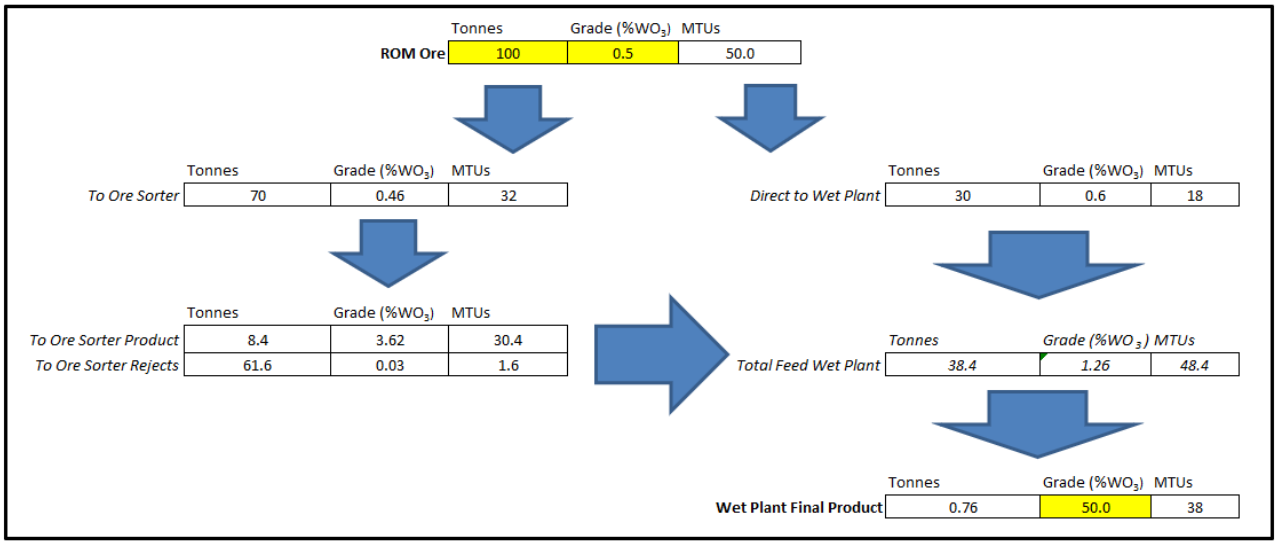


Figure 3-2 High level processing summary

Using this, and a revenue (concentrate) of AUD$18,200/t concentrate (@ 50%WO_3), the following table (Table 4) shows the relative mining cost 'ceiling' to break even. In other words, if all-in mining costs exceed this amounts (for a given grade), underground mining would be uneconomic.

Table 4 BEG calculations

At $18,200/t conc [APT (50% WO3]..

If grade to ROM is... Grade (%WO_3)	All-in Break Even Mining Cost ($/t ore) is...
0.20	$45.42
0.30	$73.26
0.40	$101.09
0.50	$128.93
0.60	$156.76
0.70	$184.60
0.80	$212.44
0.90	$240.27
1.00	$268.11
1.10	$295.94
1.20	$323.78
1.30	$351.61
1.40	$379.45
1.50	$407.29

Given the low tonnes per vertical meter (t/vm) stoping inventory and high lateral development demand to exploit these stopes, expectations around what realistic all-in mining costs would be for this type of deposit start at a figure of >$100-$120/t ore.

3.1.2. MINING METHODS SUMMARY

Table 5 summarizes the mining methods investigated.

Table 5 Mining Method Table Summary

Mining Method	Summary	Strengths	Considerations
Modified Avoca ✓	• Small scale mining method suitable for narrow and steeply dipping orebodies. • Retreat bottom-up mining sequence	• Utilises Waste Backfill (No Paste) • Suitable for Carbine orebody geometry • Light weight fleet	• Dilution and recovery control • Stope width limitation (max ~10m) • Waste backfill source and TKMs • Rib pillars • Sill pillar recovery
Sub Level Stoping (Longitudinal with Pillars) ✓	• Long-hole stoping method leaving pillars along strike • Retreat top-down mining sequence	• Utilises Waste Backfill (No Paste) • Familiar mining method	• Significantly less recovery (50:15 pillars?) • Combination of rib and sill pillars
Sub Level Stoping (Paste Backfill) ?	• Top down retreat (or primary/secondary) mining sequence • Opportunity for increased mining fronts and increased stope turnover	• Increased mining fronts and turnover • Top down underhand mining an option • Potentially increased ROI • Reduced waste material movements (utilize as rockfill into stopes)	• Potentially sensitive to cost • Pastefill source required • Enough metal tonnes to justify?
Sub Level Caving or Shrinkage ✗	• Top-down mining sequence • Positioned to target higher grade material at base of OP design	• Top-down progression. • Reduced upfront capital • Production unit costs are typically lower	• Requires sufficient void and strong slot strategy • Location to surface / cover sequence • Narrow orebody thickness

LONG HOLE STOPING METHOD

Long hole stoping was selected as a base case for the Mt Carbine Study. Long hole stoping is a highly selective and productive method of mining and can cater for varying ore thicknesses and dips. A retreat top-down mining sequence has its benefits allowing production to come online earlier and can be left open with a strategic placement of rib and sill pillars.

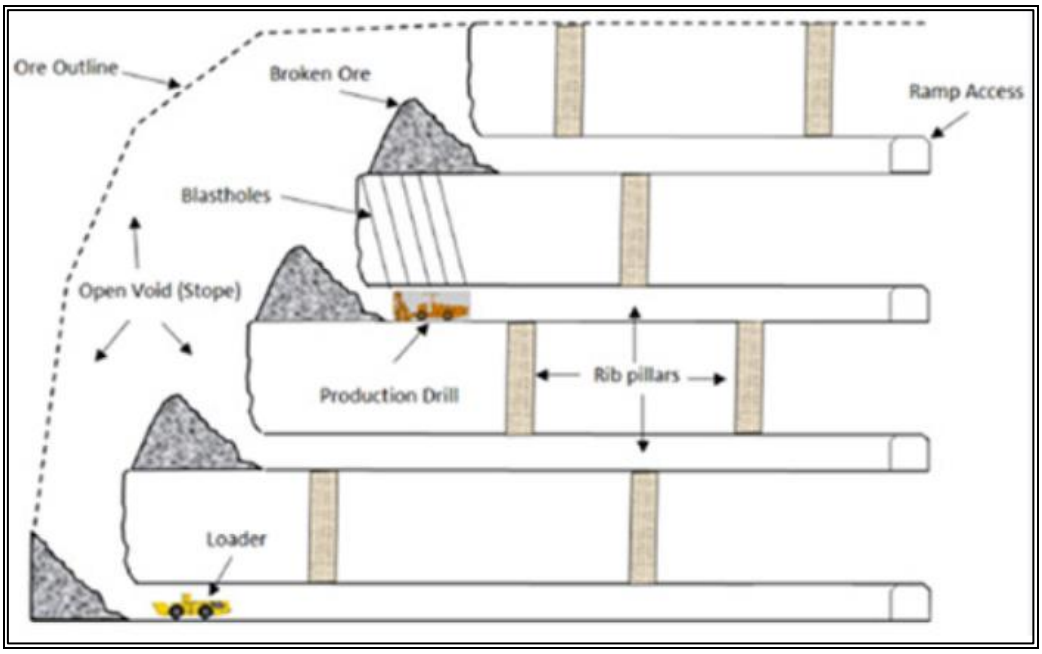


Figure 3-3 Longitudinal Stoping Mining Method

3.1.3. MINING METHODS DISCOUNTED

SUB LEVEL CAVE

A previous recommendation noted that a mass mining method could potentially be viable targeting the high tenor material at the base of the Open Pit design. A broad-brush level by level cost analysis was conducted on a Sub-Level-Cave (SLC) design to evaluate the viability. Figure 3-4 depicts six sub-level cave rings modelled and then interrogated against the resource model using the costs shown in Table 6.

Table 6 SLC Input parameters

Input Parameters		
Operating Cost ($/t ore)	$	20.00
Processing Cost ($/t ore)	$	8.3
APT (50% WO_3)	$	14,700

The findings are summarised in Table 7. Whilst the SLC has a cheaper operating cost than conventional stoping methods, the low metal tonnes per vertical meter and narrow orebody geometry mean a SLC footprint is not economic.

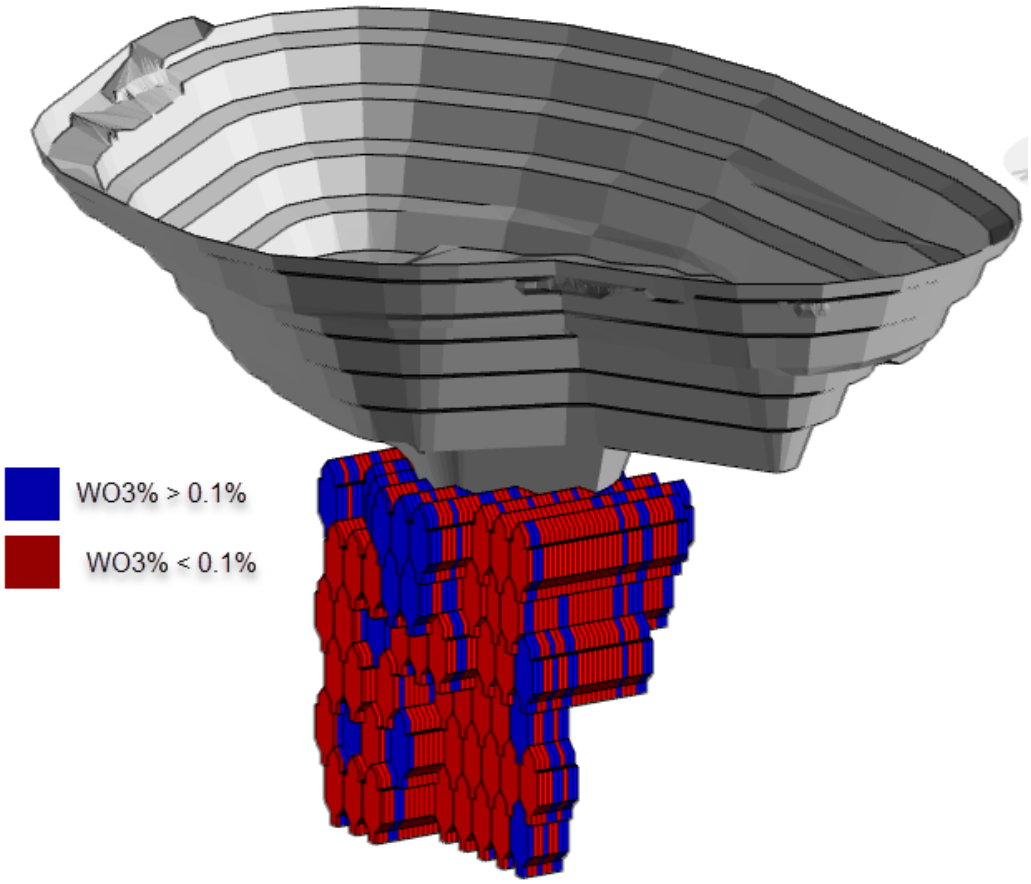


Figure 3-4 SLC Design

Table 7 SLC Level by Level Analysis

SLC	Row Labels	SLC Tonnes	Cumulative Tonnes	W.A.G - WO3%
	1	317,601	317,601	0.12
	2	506,175	823,776	0.12
	3	451,742	1,275,518	0.12
	4	358,651	1,634,169	0.14
	5	373,009	2,007,178	0.11
	6	294,202	2,301,380	0.08
	Grand Total	**2,301,380**		**0.12**

Row Labels	Pre-CAPEX Margin	Cumulative Margin Pre-CAPEX
1	-$9,851,221	-$9,851,221
2	-$5,293,722	-$15,144,943
3	-$1,619,108	-$16,764,050
4	$2,616,351	-$14,147,700
5	$777,935	-$13,369,765
6	-$1,403,576	-$14,773,341
Grand Total	**-$14,773,341**	

MASS MINING (CONVEYOR HAULAGE)

The original underground development was designed to house a conveyor system for broken stocks. Mt Carbine posed the question if this would be a feasible haulage solution going forward.

The following rules of thumb from *Tatman, C.R. (2001)*, indicate that trucking is a more economic haulage system for Mt Carbine underground:

- If an underground mine production exceeds 5000t/day, it is more economically served by a conveyor than trucks.
- A belt conveyor operation is more economical than truck haulage if the conveying exceeds 1 kilometre.
- The installed capital cost of an underground conveyor system is approximately equal to the cost of driving the heading to which it is placed.

3.1.4. OPTIONS TO EXPLORE IN FUTURE

This scoping study progressed with one mining method. However, there are other options to explore going forward.

REOPTIMISE OPEN PIT

Whilst a BFS has already been conducted, with new drilling, updated block model and change in price, there is potential for the open pit envelope to increase.

MULTI-LIFT STOPES

- Areas of mine amenable to double lift stopes working off unconsolidated rock fill
    - Would reduce the operating cost
- Further geotechnical input is required to determine the validity.

MODIFIED AVOCA (en-masse or opportunistic)

Avoca mining method (as depicted in Figure 3-5) is based on a longitudinal retreat sequence, with access for drilling, backfill and bogging occurring from the same end (back towards level access). It is a favourable method given the steeply dipping, narrow orebody geometry. It would result in a higher recovery of the resource, not requiring as much pillar support. A further study is required to see the impact of this bottom-up approach and answer questions like sourcing and costing the mullock for backfilling.

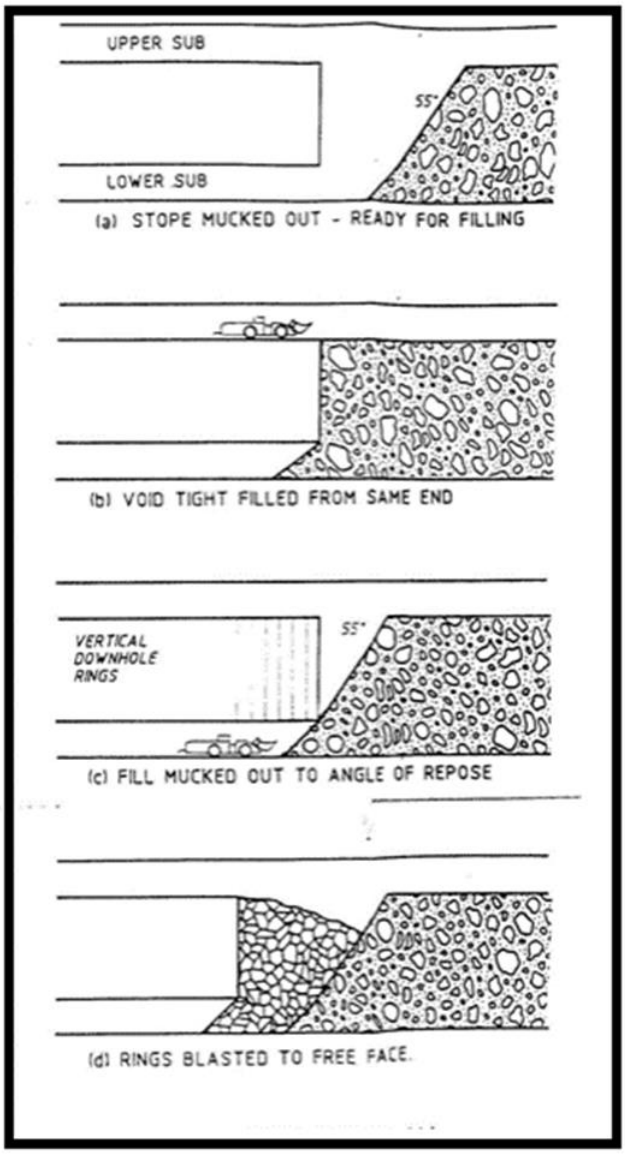


Figure 3-5 Avoca Mining Method

4. CONCEPTUAL DESIGN

At this stage of the study process, while no firm cost model existed for MCU (and in the interests of maintaining potentially economic mining inventory for as long as possible on the path to a complete design and supporting cost model), the inventory of stopes from the optimizer run were used, namely stopes where:

- Minimum mining width was greater than 1.8m and
- Maximum strike was <20m and
- Grade %WO_3>0.25

4.1. OPERATING DEVELOPMENT

Supporting ore drives wee digitized underneath the stoping inventory. From this, four distinct mining areas became apparent, as shown in Figure 4-1.

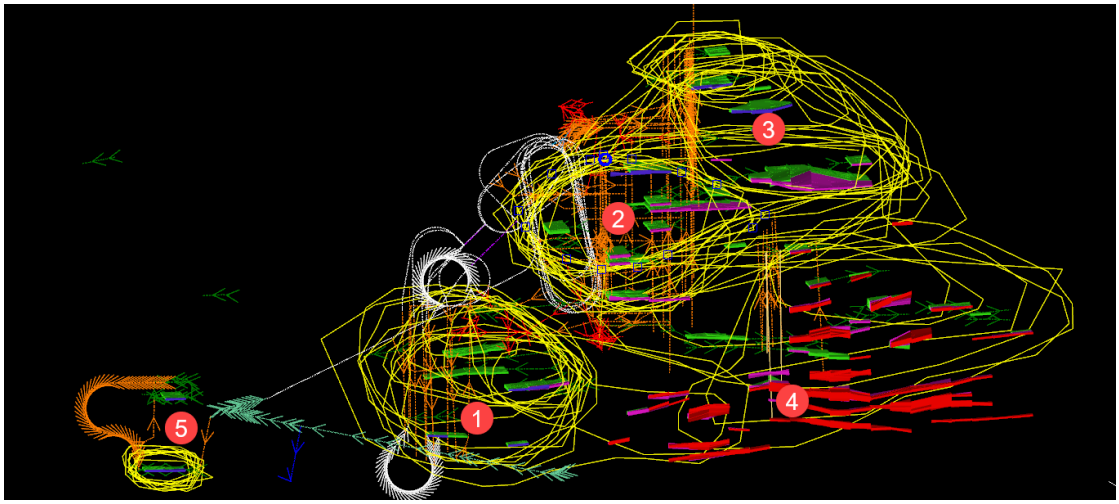


Figure 4-1 Four apparent mining districts begin to stand-out

A level spacing of 20m was chosen as an appropriate base case level spacing, primary consideration being hole long hole deviation in narrow vein stoping when holes are >15m.

Comments	LEVEL	z	DECLINE & ACCESS COMPLETE Alpha	Beta	Gamma	Delta	Omicron	<<< mining district
	1140	482.7						
	1160	462.7						
	1180	442.7						
	1200	422.7						
	1220	402.7						
Approx floor portal (380)	1240	382.7						
	1260	362.7	✓					
	1280	342.7	✓					
Approx decline face (322)	1300	322.7	✓				✓	
	1320	302.7	✓				✓	
	1340	282.7	✓	✓				
	1360	262.7	✓	✓	✓			
	1380	242.7	✓	✓	✓			
Approx pit bottom (220m)	1400	222.7	✓	✓	✓			
	1420	202.7	✓	✓	✓			
	1440	182.7	✓	✓	✓			
	1460	162.7	✓	✓	✓			
	1480	142.7	✓	✓	✓	✓		
	1500	122.7		✓	✓	✓		
	1520	102.7		✓	✓	✓		
	1540	82.7		✓	✓	✓		
	1560	62.7		✓	✓	✓		
	1580	42.7		✓	✓	✓		
	1600	22.7		✓	✓	✓		
	1620	2.7		✓	✓	✓		
	1640	-17.3		✓	✓	✓		
	1660	-37.3		✓	✓			
	1680	-57.3		✓	✓			
	1700	-77.3		✓	✓			
	1720	-97.3		✓	✓			
	1740	-117.3		✓	✓			
	1760	-137.3		✓	✓			
	1780	-157.3		✓	✓			
	1800	-177.3		✓	✓			
			1	2	3	4	5	
			Crown/end of life stopes					
			Pit					

Figure 4-2 Level name, elevation and extents of the four identified mining districts

Given the **low tonnes per vertical metre inventory brought forward from the stope optimizer process, and the high lateral development to support stoping,** the following design principles applied when laying out the concept design:

- The ability to open up multiple mining areas (N&S) simultaneously across multiple mining districts i.e., maximise flexibility and adaptability (if extra ore is delineated through further drilling)
- A ventilation network to support this

While all explicit lateral development required to sustain mining on a level was not explicitly designed, the major infrastructure was. These included main crosscuts, primary loading stockpile and return air connections. Some allowance for other required lateral (and vertical development) has been made in the cost model.

An example of a level layout is shown in Figure 4-3. This is typical of a level where, while a lot of resource is modelled, not a large proportion can sustain a minimum mining width (stoping) of 1.8m at a grade >0.25%WO_3.

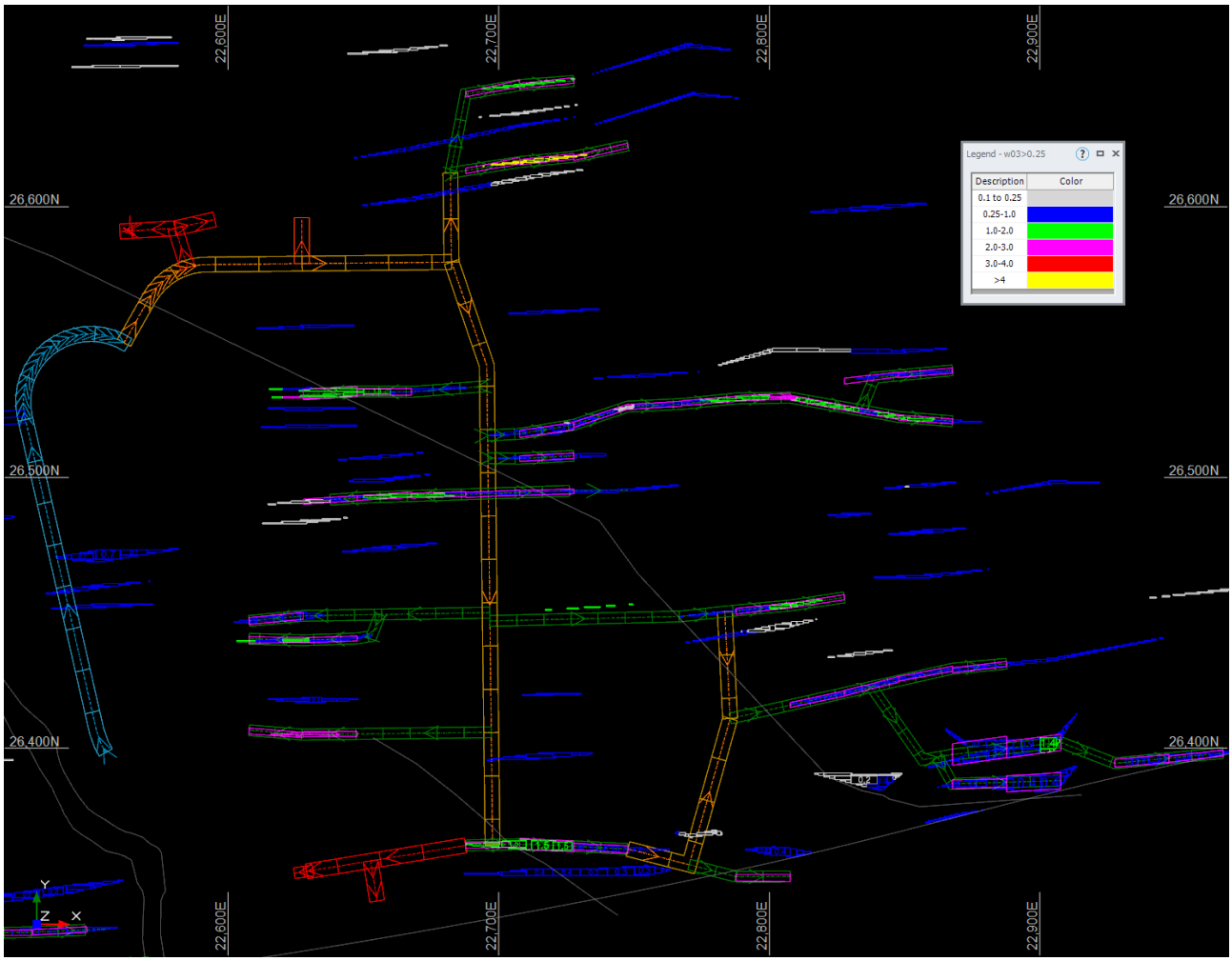


Figure 4-3 Layout of the 1560 level (block model slice included)

4.2. CAPITAL LAYOUT

Considerations for capital layout include (but not limited to):

- Faults
  - Where possible, avoid. If not, suitable stand-off or if must cross, cross perpendicular, as shown in Figure 4-4.

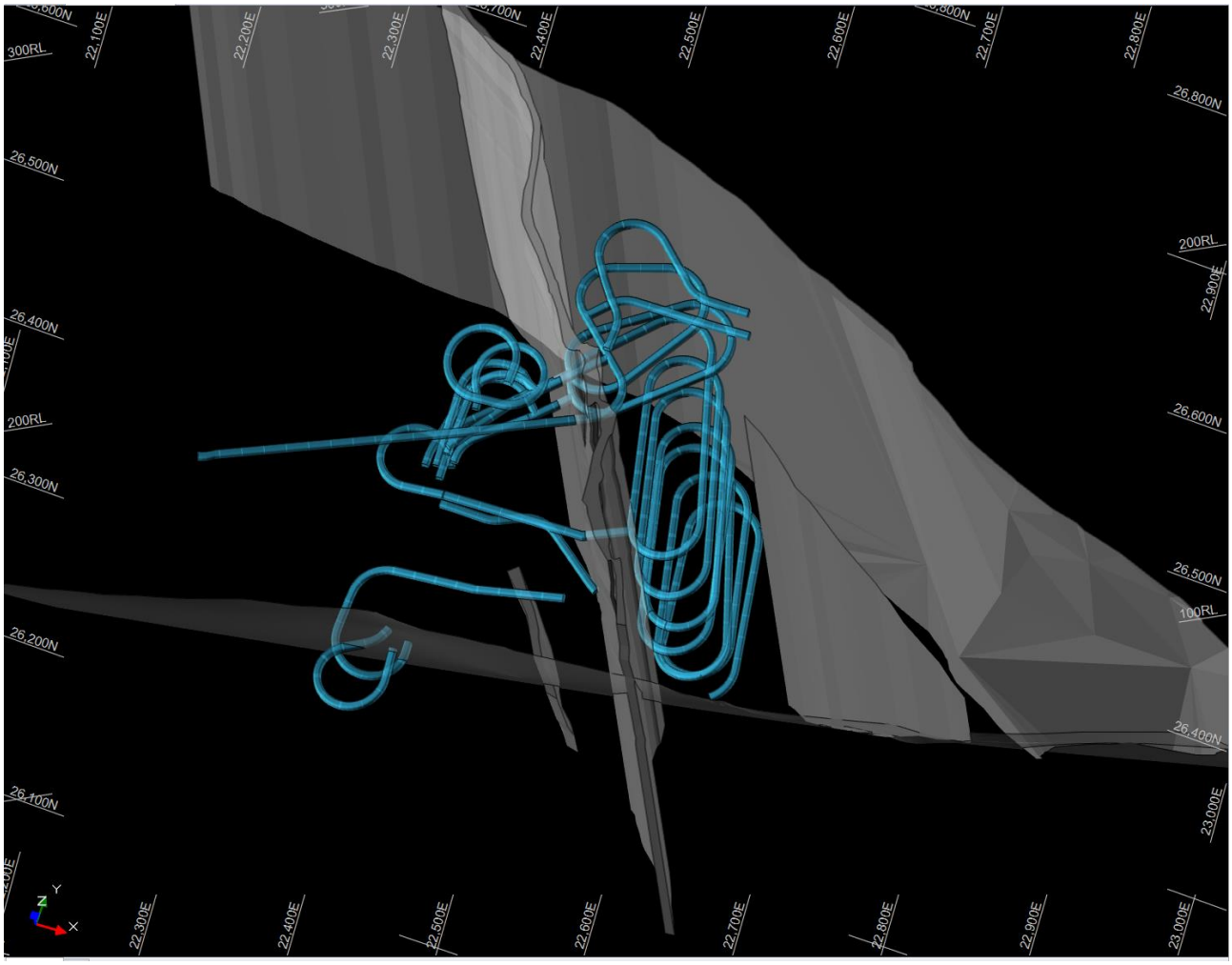


Figure 4-4 Positioning of decline relative to structural features

- Decline
  - Centralise where possible to access all payable stopes on a level across the four mining districts
- Return-air network
  - The return network is split into three main branches to facilitate multiple mining areas being maintained simultaneously (refer to Figure 4-5).
  - Where/when possible, due to the large lateral extent of potentially payable stopes on a level, return air connections were made at either end of the orebody extent, allowing for flexibility in mining especially in the southern areas where bogging distances (from fan location on level) would otherwise be >400m (see Figure 4-6).
- Fresh-air network
  - Some preliminary modelling of concept design identified the need for three surface fresh-air connections to allow continuation of the decline and service the lower levels of the mine

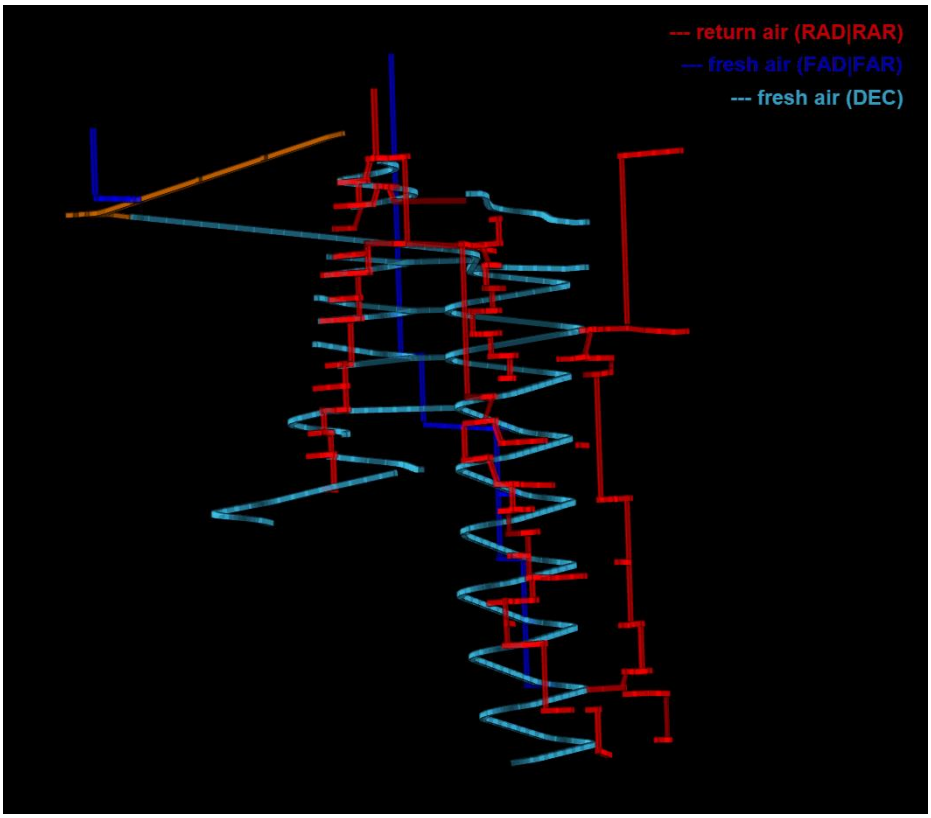


Figure 4-5 Isometric of the fresh and return air network

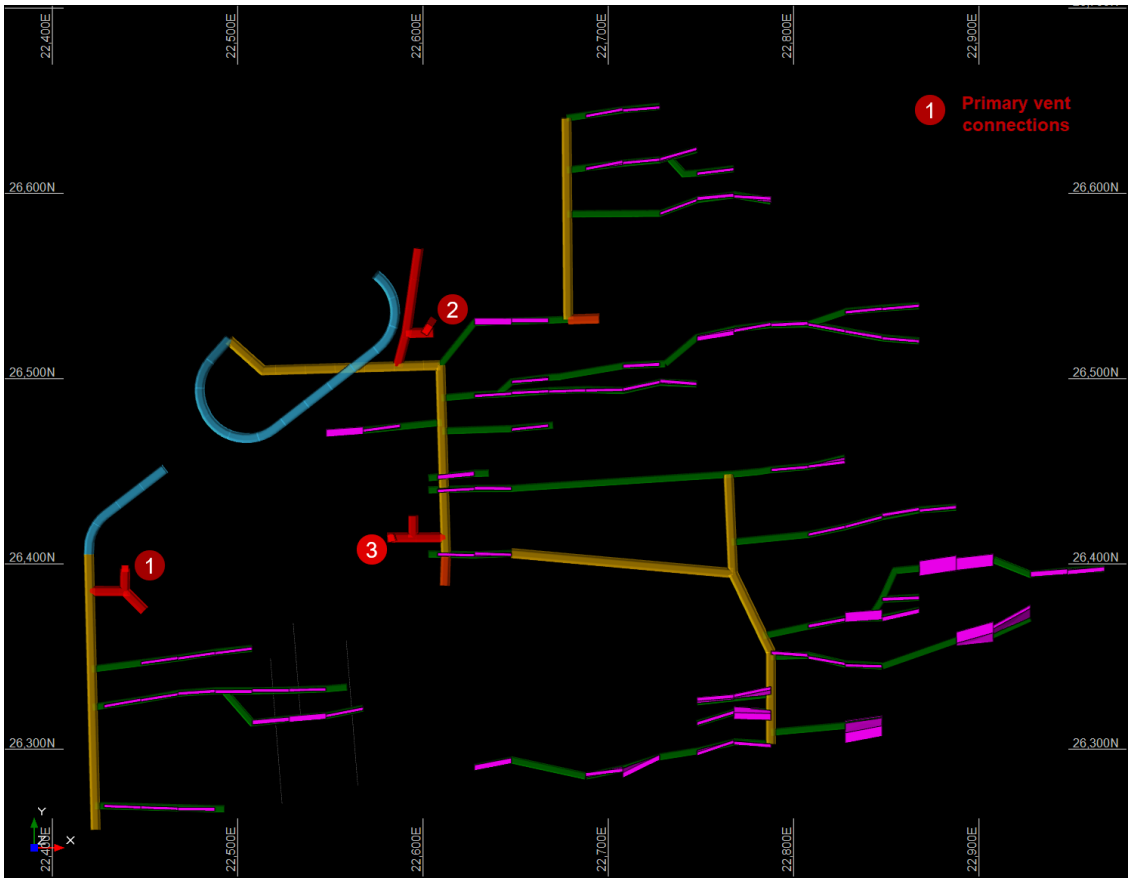


Figure 4-6 The 1440 level layout showing three primary return air connections

4.3. DEVELOPMENT SIZES AND PRELIMINARY EQUIPMENT SELECTION

For simplicity, the number of different size lateral development drives were limited to three. Considerations that determined the choice of excavation size included:

- For lateral development
  - *Decline (5.5mW x 5.5mH)*
    - Size suitable for a range of truck sizes
      - Consideration of existing as built and total TKM demand landed on 40t trucks (Sandvik TH545i or similar)
    - Large enough to support a decent amount of fresh-air intake without air speeds exceeding 6m/s
  - *Cross cuts, stockpiles, fresh and return air connections (5.5mW x 5.5mH)*
    - Allow for truck loading on the level
    - Vent drives to allow adequate volume of air and reduced air velocities
  - *Ore drives (4.0mW x 4.5mH)*
    - Given the large amount of ore development (albeit on narrow orebodies), ore drives were sized to allow for twin-boom jumbos (Sandvik DD321 or similar). Practically, this translates to at least 4m width (benchmarked with existing operations).
    - Bogging assumed to be using Sandvik LH517i or similar.
- Stoping
  - Based on stope width, Figure 4-7 shows the guidelines for stope drill and blasting used in the schedule

	STOPE_AVG_WIDTH		
	<3.5m	>3.5m and <5.0m	>5.0m
Pattern	Dice 5	3 hole ring pattern	Std. longhole pattern
Hole Diameter (mm)	76	76	76
Spacing (m)	Spacing is calculated by subtracting the hanging wall offset (0.3-0.5m) from the mining width	Spacing is calculated by subtracting the hanging wall offset (0.3-0.5m) from the mining width and dividing by 2	Nominal 2.2m spacing
Burden (m)	Spacing / 1.2	Spacing / 1.2	Nominal 1.8m burden
Drill Density (t/m)#	6	7.5	8
Charge Density (% of drilled metres)	95%	95%	75%

outside of slot

Figure 4-7 Stope drill and blast assumptions used in scoping study

  - An appropriate production hole rig would be Sandvik DL331 or Simba 1254
  - As for development, bogging assumed to be using Sandvik LH517i or similar.
- For vertical development
  - *FARs|RARs*
    - Raisbored vertical shafts (5m. diameter) - Redbore 90 or similar
    - Longholed RARs (4m x 4m) – used production rig
  - *Slots*
    - A SandvikDU411 (fitted with a V-30 to do stop slots, vertical rise slots)
      - Back-up production rig
      - Could also be a cable bolt (hole only) option with cables manually inserted and grouted

4.4. PRIMARY VENTILATION REQUIRMENTS

A basic Ventsim™ model was created (decline, return and fresh air connections) to understand mine operating pressures and therefore size an appropriate primary vent fan installation.

This modelling demonstrated the following:

- Early pressures are low <350Pa
- LOM pressures (decline at bottom) ➔ pressures are up to ~1.2kPa

Potential solutions considered:

1. Traditional surface fan mounted at top of RAR
2. Secondary fans mounted in a wall underground

Expectation of air demand for the concept design and schedule would be in the order of **around 250m³/s** (refer to build up of demand in "Physicals (by qtrs)" sheet in *Mt Carbine Scoping_Study_High_Level_Costs_Summary_220mpermo_max.xlsm).* An appropriate size fan to deliver this quantity of air would be 450-500kW fan.

For budgeting purposes, rule-of-thumb is around $1,500 per kW of installed power (all inclusive).

For this scoping study, to cut down on initial capital expenditure and considering Option 1 above would require a variable speed drive (additional cost) to operate at lower mine pressures (i.e., start-up to mid-mine life), Option 2 was chosen as nominated solution.

Example of appropriate installation to service the proposed design and schedule would be:

- Fan Model: AXN1400-794-100 (single stage)
- Fan Size: 110kW
- Poles: 4P|6P (allows for running at lower RPM at start up 990rpm, then increase to 1490rpm)
- No. of fans: 4 (wall mounted)

Figure 4-8 depicts this installation metrics running at 1490rpm. This configuration would be suitable for up to the **190m³/s** (at fan location), less with depth due to changing air density.

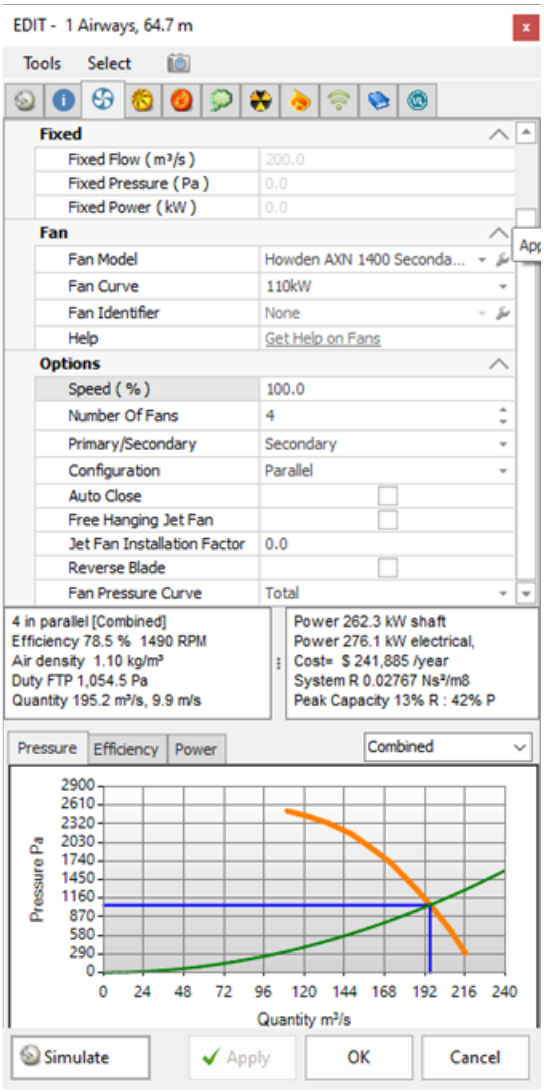


Figure 4-8 Example of primary installation to service early life of underground

Capital cost estimate used for start-up (and first few years) is priced on this configuration.

Unfortunately, early modelling predicts when a 5th fan is installed, this stalls. **At this point it is assumed this configuration is replace by a surface installation.** Given the large amount of open stope voids being left as the mine progresses and losses at level-to-level RAR installations, in practice this upgrade may need to happen earlier.

4.4.1. SECONDARY VENTILATION

Proposal at this stage of study is for the use of 90kW fans around the mine with a minimum 1200mm vent bag. These deliver in the range of 26-46m³/s, enough for the expected activity on any one level at a time[1].

[1] Schedule has limited to only one stope bogger operating on any one level at a time i.e., all stopes on a level are effectively 'in series'

5. FIRST PASS ECONOMIC ASSESSMENT

At this point of progression through the study process, an economic evaluation of the stopes and conceptual design was required. While keeping the inventory as full as possible was the driving philosophy, the objective of the following tasks was to ensure the inventory is also economically feasible.

5.1. FIRST PRINCIPLES BUILD-UP

Using the previous work supplied by EQ Resources, the build-up of unit rates for lateral development and stoping were updated (refer to *Mt Carbine Phase 1 2022_FINAL_USE.xlsm* for details). The result of this were:

- Unit rates for lateral development (exclusive of ownership, power and trucking costs) ($/m per profile)
- Trucking costs ($/tkm) with distances derived from stockpile to surface haulage modelling
- Stope D&B costs ($/t)
- Stope bogging ($/t based on bogging distance)

Note: it was important to apply direct mining costs to development and stoping (D&B, mucking, ground support, trucking and processing) so as not to burden each stope with other costs that should be applied at the whole mine level. **Hence, objective was to carry as much inventory forward (on the level) to the next stage of the study.**

5.2. MARGIN BY LEVEL AND OREDRIVE ASSESSMENT

Seeing that key economic parameters had been assessed and a conceptual development design has completed, a high-level evaluation of each level ore drive-by-ore drive could be achieved to provide a first pass look at whether development costs outweigh stope value. The first step along this path is for all designs to be attributed with the following financial data relevant to its shape and purpose:

- *OpCost*($) – Mining cost associated with operational based tasks (Ore drive Development and Stoping)
- *CapCost*($) – Mining cost associated with capital based tasks (Development of Declines/Stockpiles/Level Accesses/FAR's/RAR's etc.)
- *HaulageCost*($) – Level varied trucking cost for moving calculated ore and waste from level stockpile to surface.
- *ProcCost*($) – Processing cost of Mining Tonnes when the grade is above a Processing Cut-off Grade (PCOG) (for this exercise the PCOG was determined to be 0.0456% WO3)
- *Revenue*($) – value of metal contained in mining shape, if the interrogated grade is above Stope COG and Processing COG.
- *Margin*($) – Calculated Revenue minus applicable costs.

All calculations can be visualized in the supplied process map ("MCU_StopeAttributes.ddf") within the Interactive Cashflow Analysis | Apply Attributes node.

These attribute values, coupled with spatial attribution, provided the ability to use dynamic culminative charting of the financials per Level, Development Type (LDEV/VDEV/PROD), Ore drive and Stope. In Figure 5-1 provides an example of a typical level and the economic break-down has been shown.

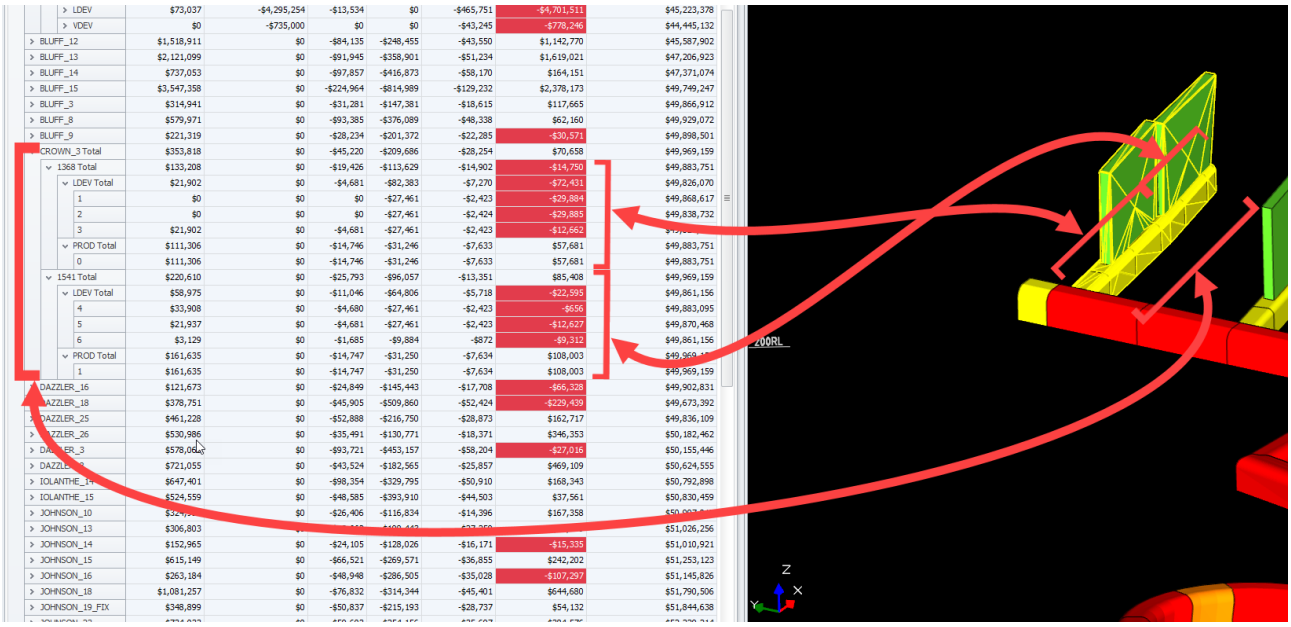


Figure 5-1 Example Ore drive Margin Breakdown per Stope/Cut

The breakdowns are then used to define which stopes have a negative total margin in which the relevant design is flagged as unviable to mine economically and subsequently removed from the inventory. This process also provides the opportunity to look at co-planar ore drives, ore drives-to-level accesses and total levels holistically, thus, providing progressive “trunk and branch” value. This can be seen in a simple example below in Figure 5-2, where the trunk development to the first stope has a negative margin until co-planar and branch ore drives/stopes provide a total positive margin.



Figure 5-2 Ore drive and Stope evaluation strategy

The branches and trunks are eventually scaled out to ensure the total level, inclusive of capital development, have a positive financial outcome and as such the level, as a whole, is kept in the inventory.

After completing the margin assessment on all levels, the inventory of stopes had been reduced to 1,435 (from the original 2,596 that came out of the stope optimizer run). This, plus the inclusion of development for the extraction of the stopes, shrunk the inventory from 6.4Mt @ 0.61%WO_3 to 5.8Mt @ 0.37%WO_3, total ore. Figure 5-3 shows the inventory taken through to sequencing (and scheduling).

The results from this analysis can be found in the supplied CAD file (Mt_Carbine_Scoping_MarginAnalysisbyLevel.duf)

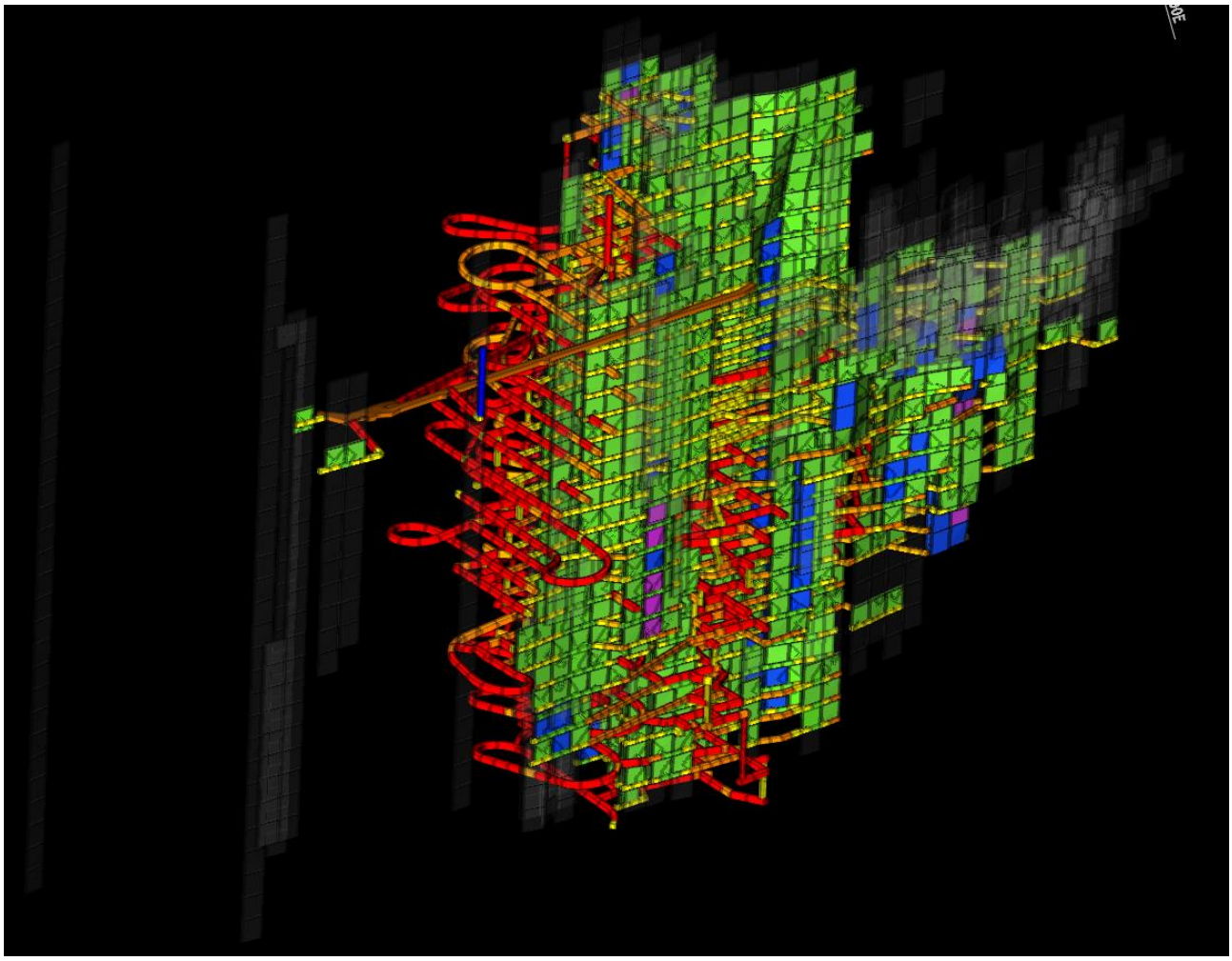


Figure 5-3 First pass economic assessment vs. Stope Optimiser output (shadowed) inventories

6. SCHEDULING, COST MODEL AND FINANCIAL ANALYSIS

Once the centreline mine design was complete, schedule tasks and task solids were created. The mine development and stoping was then sequenced, according to the top-down retreat sub-level stoping method described in above. Adequate stand-off distances (between stoping fronts) were maintained between adjacent working levels.

6.1. SCHEDULING PHILOSOPHY AND OBJECTIVES

Incorporating the stope mining recoveries detailed in 6.2.1 below, the starting mining inventory|physicals incorporated in the concept design is shown in Table 8.

Table 8 Mine Physicals for Concept Design

	Metric	TOTALS
MATERIAL MOVEMENT	**Total Ore Mrec Tonnes (t)**	**4,189,574**
	Total Ore WO3 (%)	**0.52**
	Total Ore WO3 (mtu)	**2,181,255**
	Stope Ore Mrec Tonnes (t)	2,328,951
	Stope Ore WO3 (%)	0.69
	Dev Ore Mrec Tonnes (t)	1,860,623
	Dev Ore WO3 (%)	0.31
	Waste Tonnes	2,701,538
MINING PHYSICALS	**Equivalent Metres (m) - Lat Dev**	**66,671**
	Capital Lat Dev (m)	19,639
	Operating Lat Dev (m)	47,032
	Equivalent Metres (m) - Vert Dev	**1,998**
	Truck tkm (tkm) - Ore	10,089,709
	Truck tkm (tkm) - Waste	7,469,320
	Truck_TKM - All	**17,559,030**
	Longhole Drill Metres (m)	**486,377**
	Fill Volume (m3)	**0**
	Cablebolt (m)	**144,216**

What stands out from the above table is the high proportion of development ore (as a percentage) of the overall ore profile. For this concept design, the figure is 56%.

Looking at the ore (dev + stope) inventory by level (Figure 6-1) we see a *low t/vm*. This may well be a function of drill density (especially at depth) but highlights the issue any underground mine at Mt Carbine faces (given the current resource) – not enough continuous, resource tonnage to sustain the capital development required to access it.

		IN-SITU								MINED (PLANNED)			
LEVEL	Elevation	In-situ Volume	In-situ Tonnes	wo3	In-situ Metal (mtu)	In-situ TONNES IND	In-situ TONNES INF	In-situ TONNES TARGET	*In-situ TONNES IND or INF (%)*	Mrec Tonnes (t)	Mrec wo3	Mrec Metal w03 (mtu)	*Planned Recovered t/vm*
1260	362.7	44,702	122,484	0.55	67,692	35,074	28,306	58,515	*52%*	96,512	0.45	43,176	*4,826*
1280	342.7	46,640	127,794	0.56	71,639	25,758	43,824	58,212	*54%*	113,644	0.50	57,180	*5,682*
1300	322.7	56,368	154,448	0.52	80,984	23,979	52,162	78,308	*49%*	148,648	0.48	70,928	*7,432*
1320	302.7	55,984	153,395	0.54	83,383	25,886	52,189	75,320	*51%*	150,149	0.50	75,001	*7,507*
1340	282.7	61,232	167,776	0.55	91,564	25,753	60,430	81,593	*51%*	167,586	0.50	82,991	*8,379*
1360	262.7	73,918	202,536	0.54	108,650	43,165	70,312	89,059	*56%*	175,669	0.48	84,813	*8,783*
1380	242.7	87,426	239,546	0.54	129,258	58,184	79,199	102,164	*57%*	215,124	0.49	106,055	*10,756*
1400	222.7	86,336	236,562	0.55	129,844	50,159	87,614	98,789	*58%*	221,085	0.51	111,885	*11,054*
1420	202.7	110,710	303,346	0.58	175,276	88,581	94,396	120,370	*60%*	267,093	0.53	141,793	*13,355*
1440	182.7	89,911	246,356	0.57	139,636	52,569	83,458	110,329	*55%*	240,446	0.52	125,584	*12,022*
1460	162.7	73,872	202,408	0.57	115,602	43,169	68,647	90,593	*55%*	172,798	0.52	89,006	*8,640*
1480	142.7	72,079	197,496	0.58	114,781	40,432	63,478	93,585	*53%*	196,516	0.54	105,868	*9,826*
1500	122.7	69,129	189,413	0.62	116,612	6,106	104,544	78,763	*58%*	190,116	0.57	108,319	*9,506*
1520	102.7	67,540	185,060	0.62	115,475	56	106,495	78,510	*58%*	182,611	0.58	105,338	*9,131*
1540	82.7	65,260	178,813	0.62	110,579	0	102,284	76,529	*57%*	180,423	0.57	103,515	*9,021*
1560	62.7	63,957	175,243	0.61	106,546	0	99,346	75,897	*57%*	160,471	0.55	88,395	*8,024*
1580	42.7	60,991	167,114	0.59	98,925	0	92,537	74,577	*55%*	166,072	0.55	91,706	*8,304*
1600	22.7	54,861	150,319	0.59	88,485	0	80,922	69,397	*54%*	151,258	0.54	81,529	*7,563*
1620	2.7	54,000	147,959	0.58	85,845	0	77,171	70,788	*52%*	148,276	0.54	80,464	*7,414*
1640	-17.3	36,134	99,008	0.61	60,452	0	45,884	53,124	*46%*	100,186	0.57	56,879	*5,009*
1660	-37.3	40,327	110,495	0.56	62,418	0	51,095	59,400	*46%*	102,164	0.50	50,726	*5,108*
1680	-57.3	40,812	111,824	0.55	62,020	0	51,522	60,303	*46%*	113,864	0.52	58,619	*5,693*
1700	-77.3	35,449	97,131	0.54	52,276	0	47,689	49,442	*49%*	98,892	0.50	49,509	*4,945*
1720	-97.3	33,062	90,589	0.54	48,712	0	41,354	49,235	*46%*	91,843	0.49	45,399	*4,592*
1740	-117.3	35,383	96,949	0.53	51,772	0	43,950	52,999	*45%*	98,763	0.49	48,077	*4,938*
1760	-137.3	33,432	91,604	0.55	50,702	0	43,169	48,435	*47%*	85,758	0.49	41,674	*4,288*
1780	-157.3	32,671	89,518	0.53	47,481	0	41,485	48,033	*46%*	91,526	0.49	44,980	*4,576*
1800	-177.3	21,820	59,786	0.56	33,731	0	28,513	31,273	*48%*	60,678	0.52	31,770	*3,034*

Figure 6-1 Mine ore inventory from concept design (in-situ vs mined)

Looking at the weighted average t/vm from the table above, we get a figure of ~8,300. From the work of Tatman (2001), we can derive a guidance as to what the target annual production rate should be from the formula:

Annual production rate (APR) = Rate Factor x Rate Multiplier

Where:

- Rate Factor = metric tonnes per vertical metre
- Rate Multiplier = guidance given by Tatman (2001) as to what this should be, as a function of deposit thickness (see Figure 6-2).

Deposit thickness (m)	Low Risk	Moderate Risk	High Risk
< 5	<20	20 to 50	>50
5 to 10	<50	50 to 70	>70
> 10	<30	30 to 70	>70

Figure 6-2 Guidance for Rate Multiplier (taken from Tatman, 2001)

For this mining inventory, the calculated APR is in the range of 170-420kt per annum.

The overall objective(s) for the scheduling of the concept design was as follows:

 # Ramp up to (or as close as possible to) the processing plant capacity by the time the open pit feed has been exhausted (start of 2026).

 # Underground operation should be independent of pit (and schedule) i.e., to avoid complications, ensure no interactions

6.2. KEY SCHEDULE INPUTS

Timing for start of project was arbitrary and (for the sake of the exercise), it was assumed this started with rehabilitation of the existing as-built section of decline beginning Aug-2022, with 2022 being defined as Yr0 in supplied cost model.

More detail on schedule inputs can be found by investigating the associated Deswik.CAD and Deswik.Schedule file listed in Section 10.2 below. For brevity, the key input schedule assumptions which have a material effect on schedule outcome are as follows:

6.2.1. MINING RECOVERY ASSUMPTIONS

As mentioned in 3.1.2 above, the top-down (no fill) longhole stoping mining method was chosen. The downside to this method is that pillars need to be left to maintain local and overall stability. Given the lack of geotechnical information available (to determine rock mass qualities), an estimation of the extent of these local pillars was made, based on previous experience in narrow vein longhole stoping operations.

The range of the recoveries used for this study are shown below in Table 9. An isometric of the design showing these recoveries is shown in Figure 6-3. Level by level, lode by lode breakdown of mining stope recovery assumptions in detailed in Appendix A.

Table 9 Range of stope mining recoveries used in study

Legend - PLANNED_MINING_RECOVERY

Description	Color
Crown pillar region [<0.5]	
Modified recovery (due to pit proximity)	
Sill pillars (5m vert per 100m vert) [0.67]	
Pit affected (maintain min. ratio) [0.70 to 0.92]	
Rib pillars (5m lateral per 60m lateral) [0.92]	
Standard Recovery (5% loss) [0.95]	

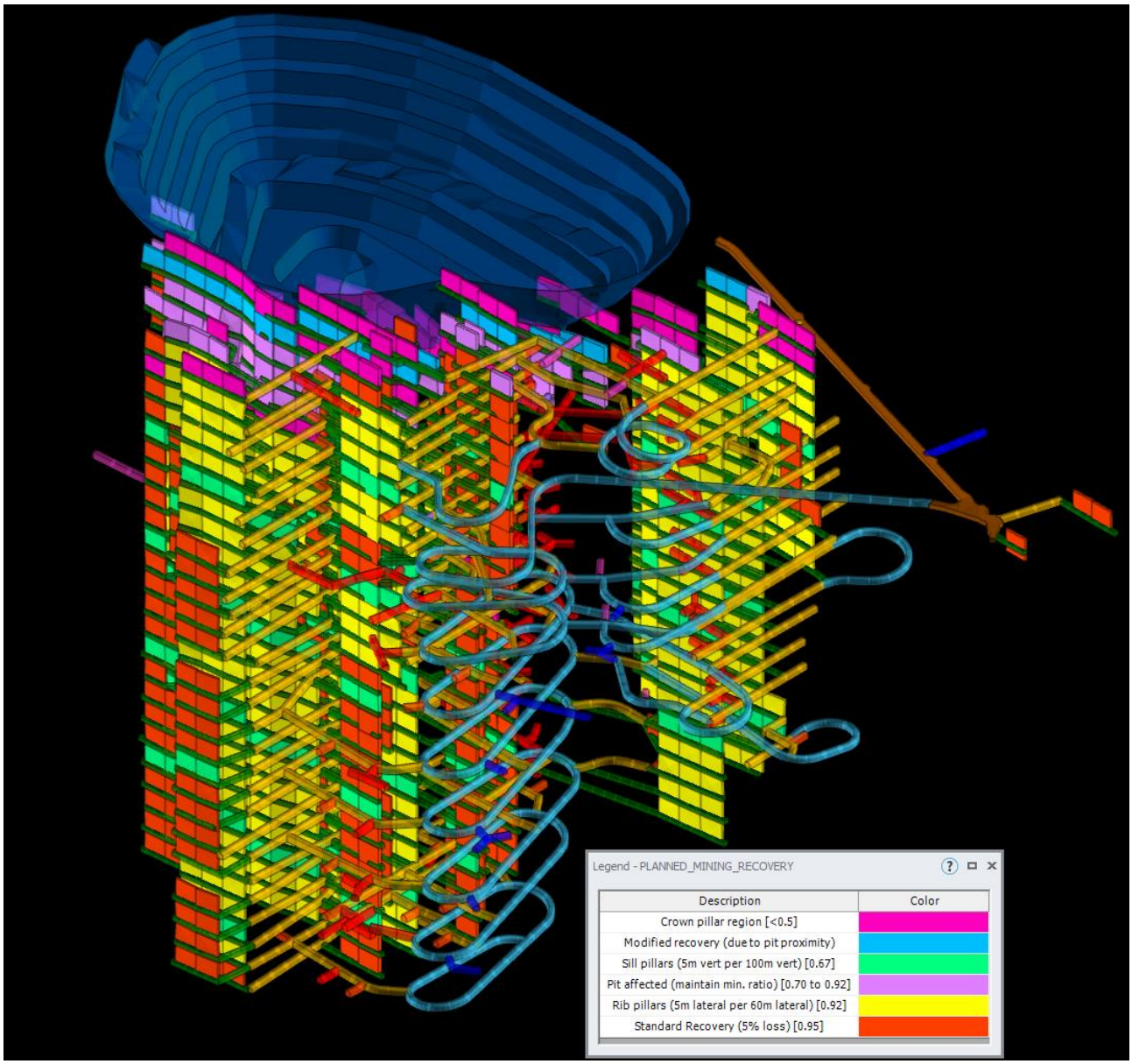


Figure 6-3 Overview of conceptual mine showing planned stope recoveries (view from NW)

6.2.2. TASK RATES AND EQUIPMENT RATES

Summary of tasks rates used in the schedule are shown below in Figure 6-4 with the key task rates highlighted.

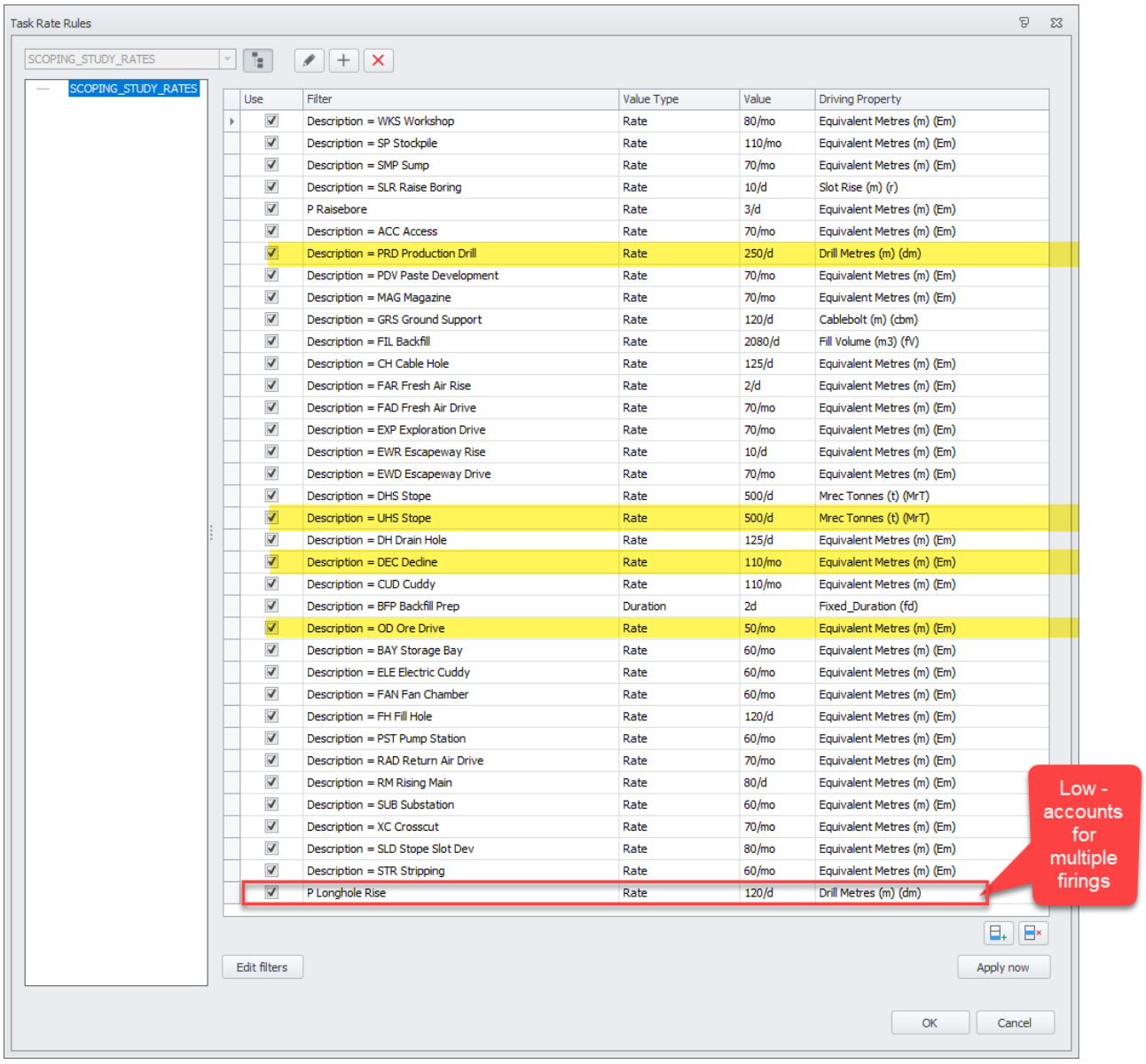


Figure 6-4 Task rates used in schedule

Summary of the resource assignment for final pass of levelling is shown in Figure 6-5. Key takeaway from this is individual jumbo capacity is 220m/mo. This takes into account the wide range of levels being worked at any one time (and hence a greater tramming allowance needs to be accounted for).

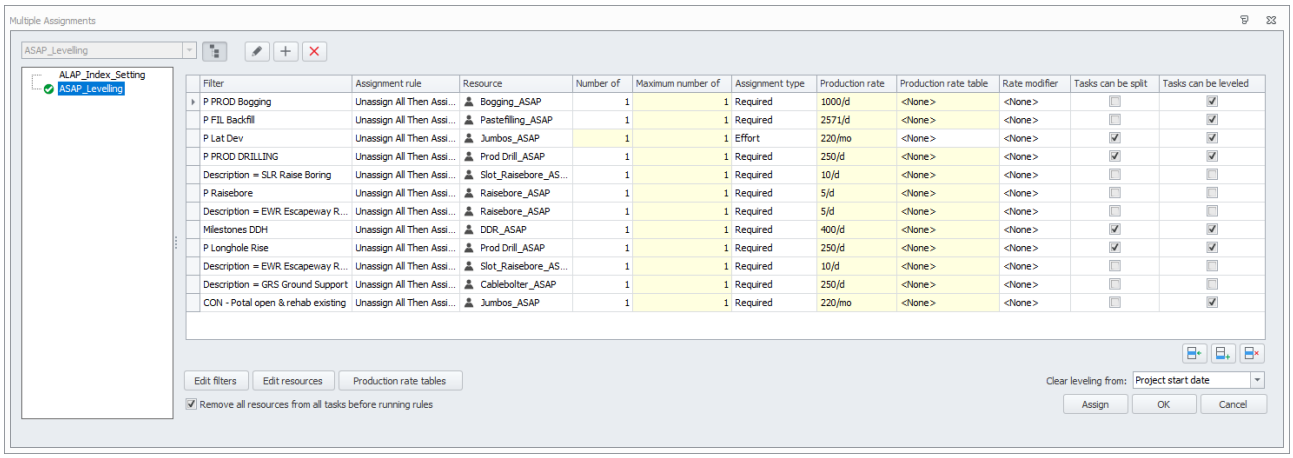


Figure 6-5 Resource assignment used

6.2.3. ADDITIONAL ALLOWANCES

As well as straight line linear metres, allowances were made in the schedule for the following:

- Jumbo stripping (for fillets, jumbo boxes, fan stripping)
- Cables
    - Intersection cables (lateral development)
    - Stope cables (brow and, where appropriate, HW & crown cables)

6.3. RESOURCE LEVELLING OF SCHEDULE

Resource levelling for this project involved two passes of levelling:

1. ALAP index setting
    - Production is set to ASAP, everything else is set to ASAP
    - An appropriate ramp up of stoping activity is set
2. ASAP levelling
    - Using the order of tasks from the ALAP levelling, a second pass of resource levelling is completed, this time all activities now ASAP and equipment numbers are limited (jumbos, stope boggers)
    - Again, an appropriate ramp up of stoping activity is set as well as limits on capital development (m/mo) to ensure the decline doesn't get to far ahead.

Main take-outs from the levelled scheduled are:

- Given the narrow vein, high intensity lateral development requirement, a maximum of four (4) jumbos were scheduled (see
    - This 'uncovers' a certain number of stopes per month / per year

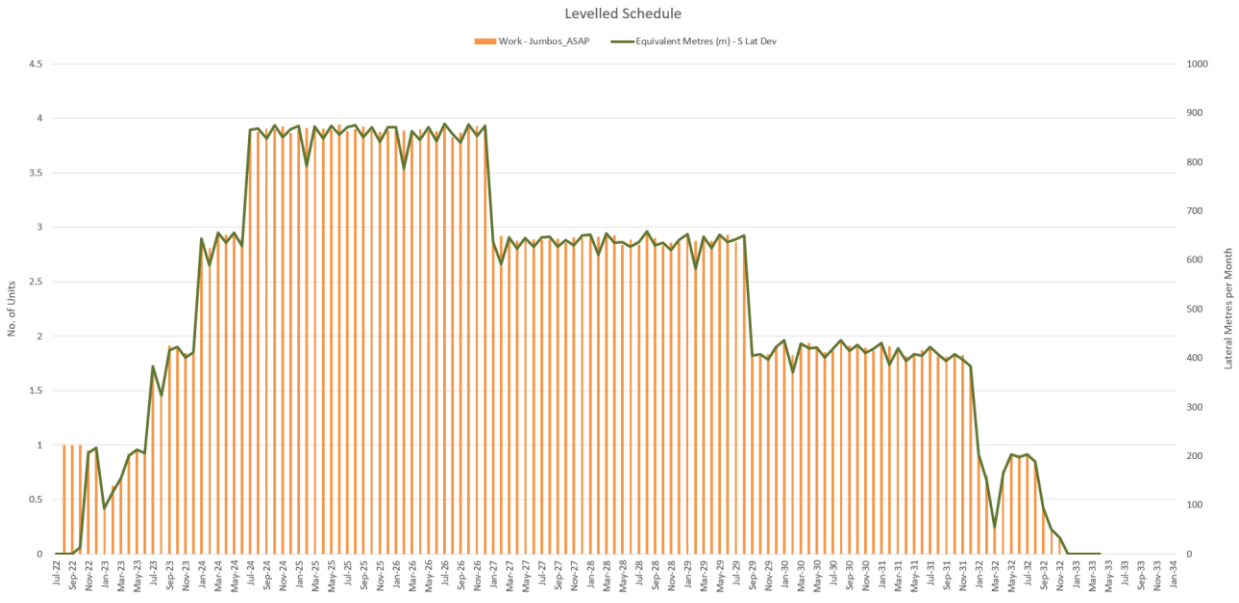


Figure 6-6 Levelled jumbos (# of) and corresponding lateral metres per month

- Apply a workable ramp up to the mining of those stopes, the following ore profile falls short of 'filling the process plant' (~60kt/mo). Figure 6-7 shows the ore profile achieved.

- Overall mining rate for the mining inventory presented is ~50vm/year. For reference, McCarthy (2011) suggests the upper end of what is suggested is sustainable is 60vm/yr. Other published guidelines De La Vergne (2008) suggest the following:
    - For a steeply dipping orebody, annual production should not exceed 30 to 40m of mine depth

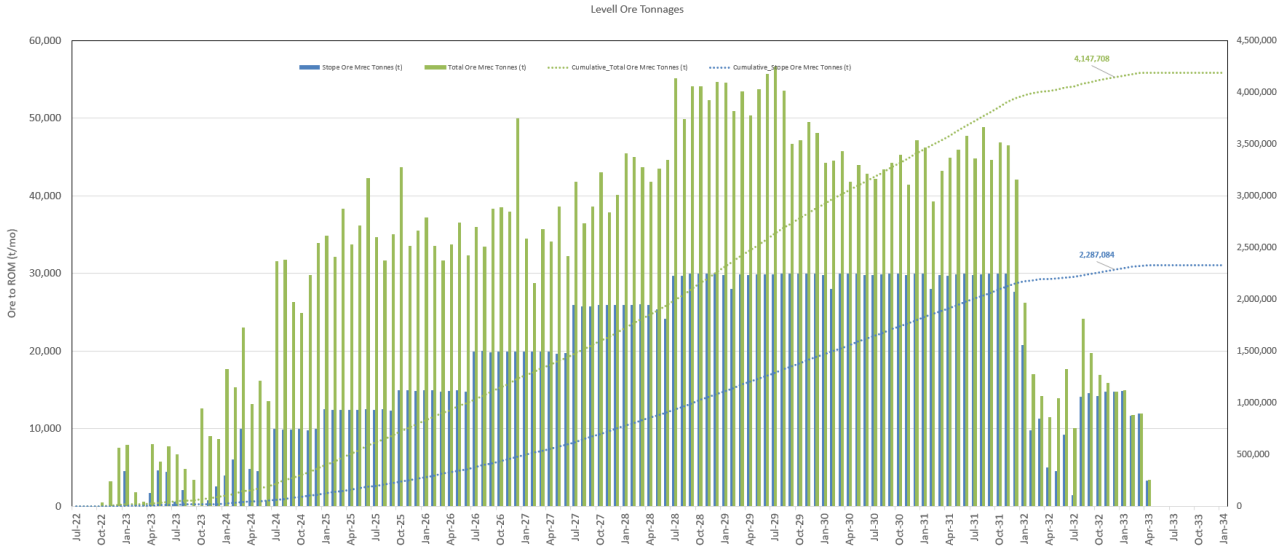


Figure 6-7 Levelled ore profile

6.4. COST MODEL

A simplified cost model was constructed for the presentation of the scoping study economics (refer to *Mt Carbine-Scoping_Study_High_Level_Costs_Summary.xlsm)* The process involved:

- Dumping of mine physicals and primary equipment demand
    - High level diamond drilling program for resource conversion
- Applying built up unit rates for lateral development and stoping
- Applying stope bogging and trucking cost separately
- Accounting for the costs of secondary and ancillary equipment (fixed monthly cost +/- variable cost on output)
- Determination of labour profile to service mining (and corresponding equipment) schedule (shift personnel, supervisory & technical services and maintenance)
    - On-costs (flights and accommodation) included as line item
- Ventilation and power demand
- Capital infrastructure establishment cost

The following section describes the build-up of the above-mentioned costs (see “Costs” sheet in *Mt Carbine-Scoping_Study_High_Level_Costs_Summary_220mpermo_max.xlsm*):

6.4.1. DIRECT MINING COSTS – CAPITAL

1. Lateral development - derived from mine physicals (m) x unit rate (built up from first principles)
2. Vertical development - derived from mine physicals (m) x unit rate (estimate from benchmarking)
3. Cable bolting - derived from mine physicals (cable metres) x unit rate (estimate from benchmarking)

4. Trucking - derived from mine physicals (tkm) x unit rate (built up from first principles)

6.4.2. DIRECT MINING COSTS – OPERATING

As outline in 6.4.1. In addition:

1. other secondary mining fleet have been costed in at a $/mo (estimate from benchmarking)
2. other ancillary equipment to support the proposed mining profile costed in at a $/mo (estimate from benchmarking)
3. minor plant to service the mine costs at a $/mo (estimate from benchmarking)

Cost allocation of these have been 'split' between operating and capital based on relative lateral metres of each over time.

6.4.3. MINING "FIXED" COSTS

Labour

Frontline labour (for development and stoping activities) has been accounted for in the unit rate build-up. All other labour required is detailed in the "Physicals (by qtrs.)" sheet in *Mt Carbine-Scoping_Study_High_Level_Costs_Summary_220mpermo_max.xlsm.* Additional labour cost build-up is shown in the "Labour Buildup" sheet.

Allowances for messing and flights have also been included.

Fuel

Unit rates include fuel cost (lateral development, stoping, trucking).

Additional build-up for fuel demand for other equipment has been included (L) x nominal diesel price.

Power

Estimate for power demand was done (refer to "Physicals (by qtrs.)" sheet) (kWh) x nominal power price.

6.4.4. DIAMOND DRILLING

A first pass assessment to diamond drilling requirements were added to the mining schedule (ddm) x nominal rate ($/ddm). Allowance has been made in "Costs" sheet for this to be reviewed (and added to if required) to bring it up to an appropriate level.

6.4.5. PROCESSING COST

A simplified material flow model was created with consultation with EQ Resources personnel (refer to "Processing|BEG" sheet in *Mt Carbine-Scoping_Study_High_Level_Costs_Summary_220mpermo_max.xlsm*).

Mass yields and upgrade factors supplied by EQ Resources.

Unit costs referenced from BFS documentation and verified by EQ Resources personnel.

6.4.6. CAPITAL COST ESTIMATE

A high-level estimate was done for major items for commencement of underground operations (refer to "Capex" sheet). At the time of population of this sheet, the author was unaware of what facilities provisions had been made for the open cut operation and, to avoid duplication, left items off this list *which may need to be introduced* at subsequent stages of study.

Given EQ Resources supplied budget prices from an OEM for frontline mining equipment (jumbos, loaders, trucks), it was assumed these were the only equipment purchased.

An amortisation schedule was also produced and added back into the cashflow (refer to *"Amortisation"* sheet).

6.4.7. NOTABLE EXCLUSIONS

Refer to "Exclusions" sheet and empty items in the "Capex" sheet. EQ Resources should review and adjust where necessary.

7. FINANCIAL EVALUATION

The figures and tables presented in this section come from the supplied cost model (Mt *Carbine-Scoping_Study_High_Level_Costs_Summary_220mpermo_max.xlsm*).

7.1.1. CUMULATIVE NET CASHFLOW AND NPV

Figure 7-1 shows the cashflow summary for concept design and schedule. At the given price (equiv. APT $18,200/t concentrate [50%WO_3]) and a 6% discount rate, the project has a $79M cumulative net cashflow for a $29.4M NPV. Given the level of accuracy in both the cost estimate and predominantly based on inferred material, these figures would have a degree of accuracy of +/-30% (estimated).

Excluding Yr 0 (in this case arbitrarily labelled 2022), the mining inventory designed is consumed over a period of 10.25 years, with the final quarter consisting of mining remnant stopes adjacent to the (then finished) open pit.

Positive cashflow is not achieved until Yr 5 and on a cumulative basis, not until Yr 8.

Mt Carbine UG Scoping Study - CASHFLOW ANALYSIS																
		2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033			
		Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	TOTAL		
Ore Mined (to ROM)	t	11,098	76,419	276,846	431,124	438,841	441,234	583,872	619,949	526,379	540,473	201,472	41,866	4,189,574		
Grade	%WO_3	0.17	0.31	0.42	0.49	0.47	0.52	0.51	0.57	0.60	0.58	0.45	0.63	0.52		
Contained Metal	mtu	1,856	23,645	116,684	209,822	208,075	228,816	297,372	353,058	314,222	310,976	90,359	26,371	2,181,255		
Final Concentrate Feed (t)	t	28	362	1,785	3,209	3,182	3,500	4,548	5,400	4,806	4,756	1,382	403	33,361		
Final Concentrate Feed (%WO3)	%WO_3	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00		
Final Concentrate Feed (mtu)	mtu	1,419	18,082	89,231	160,455	159,119	174,980	227,407	269,990	240,292	237,810	69,099	20,166	1,668,050		
Reliased Price - APT (50% WO_3)	$AUD/t	18,200	18,200	18,200	18,200	18,200	18,200	18,200	18,200	18,200	18,200	18,200	18,200	18,200		
Revenue	$AUD	516,655	6,581,744	32,479,976	58,405,623	57,919,266	63,692,778	82,775,994	98,276,498	87,466,262	86,562,664	25,152,150	7,340,471	607,170,081		
Mine Operating Cost (incl. UG overheads)	$AUD	2,945,964	9,448,007	23,877,760	34,982,389	37,374,439	33,861,173	39,164,941	41,764,306	35,320,273	37,200,889	19,244,205	5,056,996	320,241,344		
Process Cost	$AUD	91,788	632,043	2,289,739	3,565,738	3,629,570	3,649,360	4,829,085	5,127,478	4,353,576	4,470,147	1,666,336	346,266	34,651,126		
Other Site Overheads	$/t ROM feed	0	0	0	0	0	0	0	0	0	0	0	0	0		
Total Opex	$AUD	3,037,752	10,080,050	26,167,499	38,548,128	41,004,009	37,510,533	43,994,026	46,891,785	39,673,850	41,671,035	20,910,541	5,403,262	354,892,469	Weighted Averages (OPEX)	
Operating Cost ($/t - ore)	$/t	274	132	95	89	93	85	75	76	75	77	104	129	85	85	$/t
Operating Cost ($/mtu - produced)	$/mtu	2,140	557	293	240	258	214	193	174	165	175	303	268	213	299	$/mtu produced
Fixed Plant Capex	$AUD	7,866,500	4,556,430	7,173,736	2,548,648	1,039,504	2,126,592	443,539	134,000	0	0	0	0	25,888,949		
Dev Capital Cost	$AUD	2,609,526	15,592,158	26,136,867	23,438,662	21,332,933	19,382,653	11,889,477	4,143,030	5,069,560	2,386,309	30,000	0	132,011,175		
Total Capex	$AUD	10,476,026	20,148,588	33,310,603	25,987,310	22,372,438	21,509,245	12,333,016	4,277,030	5,069,560	2,386,309	30,000	0	157,900,124	Weighted Averages (ALL-IN)	
															122	$/t
Total Expenditure	$AUD	13,513,778	30,228,638	59,478,102	64,535,438	63,376,446	59,019,778	56,327,042	51,168,814	44,743,409	44,057,344	20,940,541	5,403,262	512,792,593	307	$/mtu produced
Op Cash Flow	$AUD	2,521,097	3,498,306	6,312,477	19,857,495	16,915,258	26,182,245	38,781,967	51,384,714	47,792,413	44,891,628	4,241,608	1,937,208	252,277,612		
Amortisation	$AUD	8,914	332,158	3,442,149	8,863,801	11,334,826	15,500,567	22,778,765	28,423,330	27,443,882	28,895,401	8,419,238	2,457,093	157,900,124		
Royalties	$AUD	12,916	164,544	811,999	1,460,141	1,447,982	1,592,319	2,069,400	2,456,912	2,186,657	2,164,067	628,804	183,512	15,179,252		
Net Profit Before Tax	$AUD	2,542,927	3,995,007	2,058,329	9,533,554	4,132,450	9,089,359	13,933,802	20,504,471	18,161,874	13,832,161	4,806,433	703,396	79,198,236		
Tax	$AUD	0	0	617,499	2,860,066	1,239,735	2,726,808	4,180,141	6,151,341	5,448,562	4,149,648	0	0	27,373,800		
Net Profit After Tax	$AUD	2,542,927	3,995,007	1,440,830	6,673,488	2,892,715	6,362,551	9,753,662	14,353,130	12,713,312	9,682,512	4,806,433	703,396	51,824,436		
Operating Cash Flow(+ Amort.)	$AUD	2,534,013	3,662,849	4,882,979	15,537,289	14,227,541	21,863,118	32,532,427	42,776,460	40,157,194	38,577,913	3,612,805	1,753,697	209,724,560		
Net Cash Flow Inc. Tax	$AUD	-13,010,040	-23,811,438	-28,427,624	-10,450,021	-8,144,896	353,873	20,199,411	38,499,430	35,087,634	36,191,605	3,582,805	1,753,697	51,824,436		
Net Cash Flow Exc. Tax	$AUD	-13,010,040	-23,811,438	-27,810,125	-7,589,955	-6,905,161	3,080,681	24,379,552	44,650,771	40,536,196	40,341,253	3,582,805	1,753,697	79,198,236		
Cum. Net Cash Flow Inc. Tax	$AUD	-13,010,040	-36,821,477	-65,249,101	-75,699,122	-83,844,019	-83,490,145	-63,290,734	-24,791,304	10,296,330	46,487,935	50,070,739	51,824,436	51,824,436		
Cum. Net Cash Flow Exc. Tax	$AUD	-13,010,040	-36,821,477	-64,631,602	-72,221,558	-79,126,719	-76,046,038	-51,666,486	-7,015,715	33,520,482	73,861,735	77,444,539	79,198,236	79,198,236		

CUMULATIVE NET CASHFLOW $AUD M (exc tax)	$79
NPV TOTAL $AUD M (exc tax)	$29.4
IRR (exc tax)	12%
CUMULATIVE NET CASHFLOW $AUD M (inc tax)	$52
NPV TOTAL $AUD M (inc tax)	$10
IRR (inc tax)	8%

Figure 7-1 Cashflow summary for UG design and schedule

7.1.2. SENSITIVITY ANALYSIS

A sensitivity analysis on metal (mtu's) (same result as modifying price), operating costs and capital cost, with the results shown in Figure 7-2

Mt Carbine UG Scoping Study
NPV Sensitivity Analysis

Sensitivity Analysis of Net Present Value

Sensitivity	()										
Factor	-50%	-40%	-30%	-20%	-10%	0%	10%	20%	30%	40%	50%
Metal (mtu's) | Price	$ (178)	$ (137)	$ (95)	$ (54)	$ (12.2)	$ 29	$ 71	$ 112	$ 154	$ 195	$ 237
Operating Cost	$ 145	$ 121	$ 98	$ 75	$ 52	$ 29	$ 6	$ (17)	$ (40)	$ (63)	$ (86)
Capital Cost	$ 95	$ 82	$ 69	$ 56	$ 42	$ 29	$ 16	$ 3	$ (10)	$ (23)	$ (36)

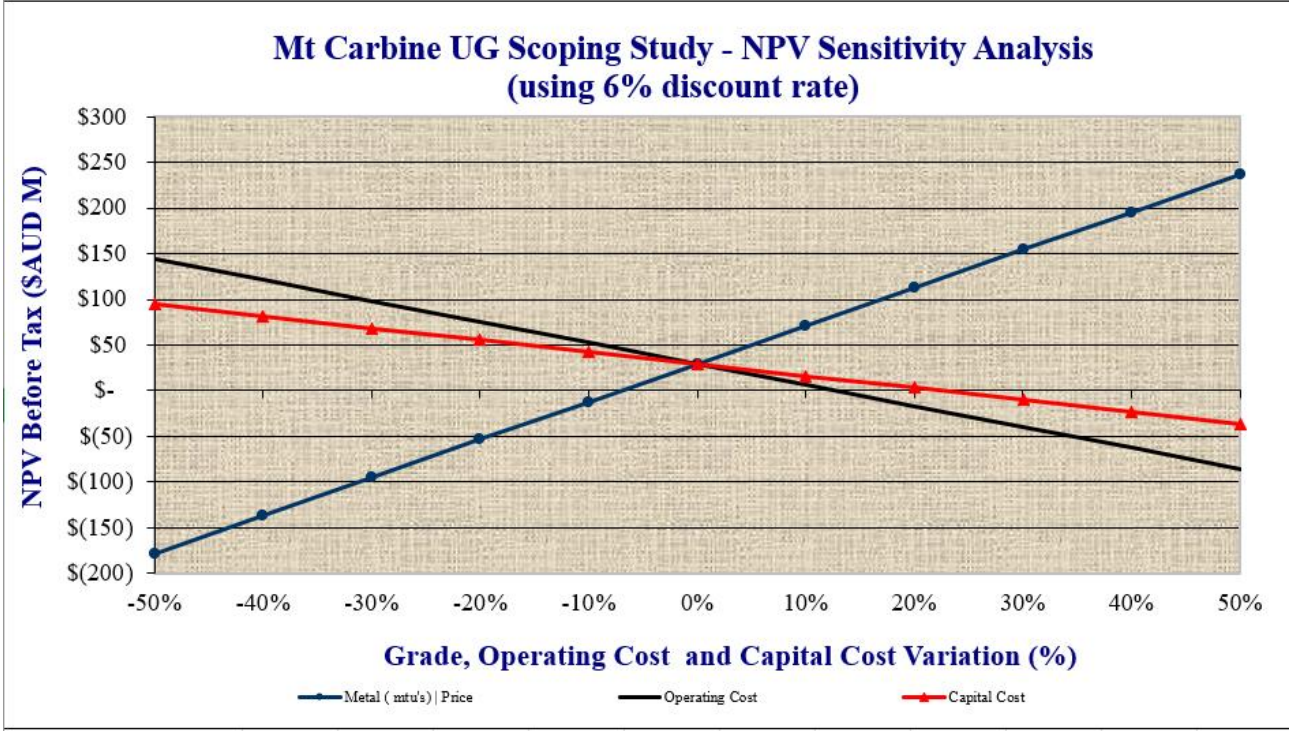


Figure 7-2 MCU UG scoping study sensitivity analysis

All calculations have been performed on the financial summary (refer to "Cashflow Analysis" sheet) with no change in mining inventory (tonnes, metres etc). It can be seen from Figure 7-2 that the project is very sensitive to metal (grade) (or price) fluctuations. For example, a +/-10% change in grade (achieved by adding/deleting 10% more mtu's to ore to ROM contained metal) results in a +/-200% increase in NPV.

This relative change is much smaller when it comes to changes in operating or capital costs, as can be seen in the graph/table above.

8. S.W.O.T ANALYSIS

Figure 8-1 SWOT analysis depicts a brief SWOT analysis resulting from the inputs/outputs/findings of this scoping study. It is a recommended starting point for EQ Resources to progress forward in their stated aim of increased mine life for Mt Carbine.

INTERNAL FACTORS			
	STRENGTHS (+)	IMPORTANCE	JUSTIFICATION | COMMENT
1	Processing methodology and costs	Significant	Gives confidence to revenue side of the equation
2	Work and models completed as part of the scoping study can be re-used as part of future studies	Medium	Future savings when examing variations on the underground layouts and their economics
3	Flexible mining design and sequencing to allow multiple mining fronts	High	Needed to achieve production rates modelled
4			
5			
6			
7			
8			
9			
10			

INTERNAL FACTORS			
	WEAKNESSES (–)	IMPORTANCE	JUSTIFICATION | COMMENT
1	Resource status (correlates to drill density of resource)	High	Based on model presented, only ~12% of the UG mining invenotry presented has an 'Indicated' resource status
2	Resource quantity (tonnes)	Significant	Low conversion of potenial resource to (initally) mining inventory, then possibley reserve
3	Grade distribution (as presented in block model)	Significant	Potentially extending levels lower than ore physically exists
4	Rock mass classification modelling | lack of geotechincal input	High	Geotech modelling required which will could impact assumed factors like dilution, pillar sizes, stope dimensions, ground support requirements
5	Year on year, large number of operating levels are open in schedule	High	Leads to greater ventilation demand (and more cost) and decreased productivities
6	Uniform block model density	Low	Appears unrealistic, but not significant
7			
8			
9			
10			

EXTERNAL FACTORS			
	OPPORTUNITIES (+)	IMPORTANCE	JUSTIFICATION | COMMENT
1	Capital development layout would be able to remain realtively unchanged for any incremental ore that is realised during additonal drilling	High	Ability to realise more tonnes on each level from the existing capital development, thereby improving mine economics
2	Incorporate alternate mining methods |techniques (multiple lifts, modified avova)	Medium	Save on lateral development, waste haulage to surface
3	Produce a smaller scale underground option from design|schedule presented here	Medium	One that better matches EQ Resoruces monthly cashflow constraints
4	Pit inventory increases	High	Assuming pit economics were done at a lower price than was used for this study, it would be advisable to re-look at the pit optimisation to understand if a bigger shell could be mined economically
5			
6			
7			
8			
9			
10			

EXTERNAL FACTORS			
	THREATS (–)	IMPORTANCE	JUSTIFICATION | COMMENT
1	Change in realisable concentrate price	Significant	Ecomimcs of underground mining inventory sensitive to price/in-situ metal changes
2	Assumed ground support regime applied to lateral develiopment (and stoping) is inadequate.	Medium	Additional support elements over and above those built-in add cost to the overall minng cost
3	Cost escalation in ground support elements	High	Anecdotal evidence that ground support elements have risen 20% in the last year. This will have -ve impact to overall profitability of the underground
4	Cost escalation in primary ventialtion upgrade cost	Medium	-ve impact to mine profitability
5			
6			
7			
8			
9			
10			

Figure 8-1 SWOT analysis

9. CONCLUSIONS AND RECOMMENDATIONS

9.1. CONCLUSIONS

Prima facie, the under-pit resource appears extensive. However, a lot of the modelled ore is discontinuous (refer to Figure 4-3) and at grade that doesn't support underground extraction. As a result, a large portion of the stated resource (at this stage) appears uneconomic from both and open pit or underground mining perspective (albeit the pit optimisation was done at a lower MTU price). This is illustrated in the waterfall diagrams shown in Figure 9-1 and Figure 9-2 (refer to APPENDIX B: for details on calculations).

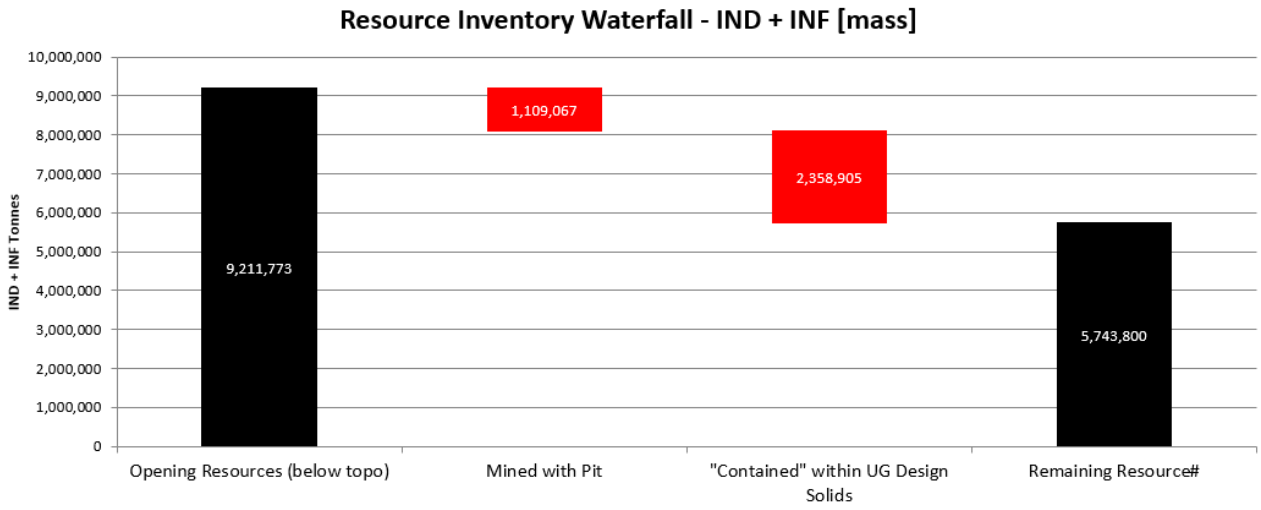


Figure 9-1 Resource inventory depletion (tonnes)

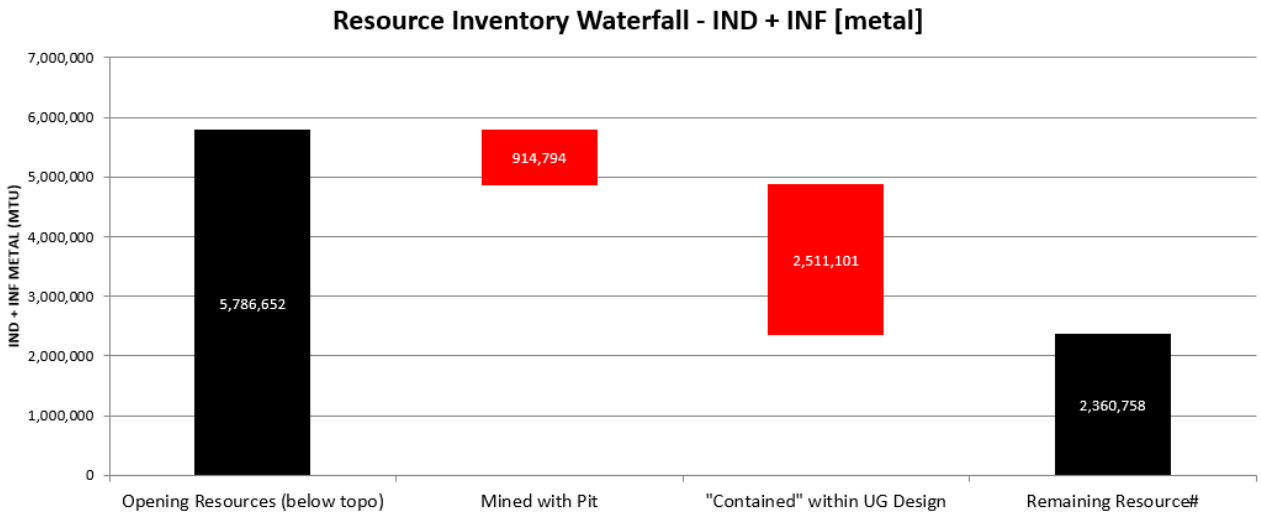


Figure 9-2 Resource inventory depletion (metal)

The upside is that there is high chance that a re-optimisation of the open pit would result in some of the "Remaining Resource" being consumed (as well as the obvious depletion from the "Contained within UG Design").

Grade distribution (modelled) is remarkably consistent vertically so while we don't see horizontal extents on the level, the resource model grade is consistent with depth and is obviously a function of the resource estimation technique employed. This can be seen in Figure 9-3.

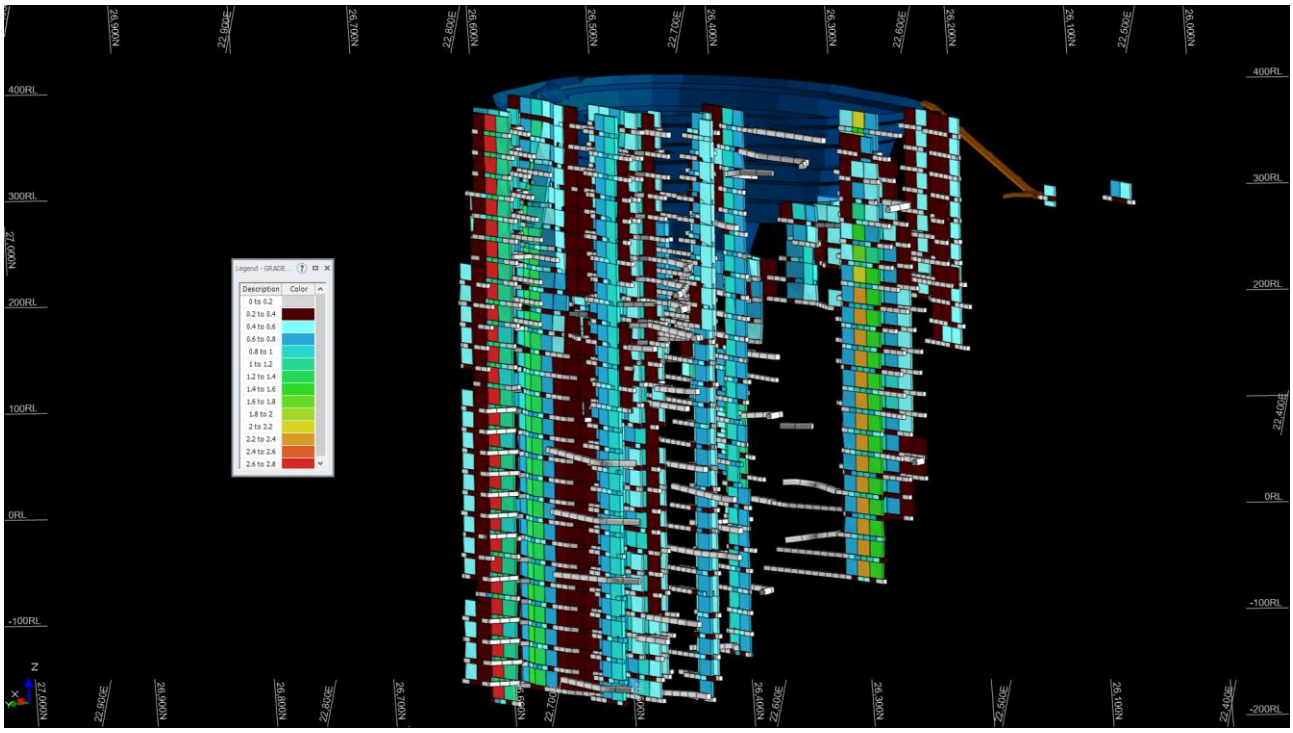


Figure 9-3 Mined grade distribution of economic underground stoping inventory highlighting remarkable consistency in grade with depth

With relatively sparse stoping tonnes currently delineated on each level and each level spread out over a large footprint, producing a robust, economically viable design and schedule was challenging. However, at the supplied pricing, an economic (albeit modest) mine plan and schedule was able to be constructed utilising the most cost-effective underground mining method possible (for narrow view deposits). Consideration however must be given to the sensitivity to the project to changes in grade/price, as presented in Section 7.1.2.

9.2. RECOMMENDATIONS

The following recommendations are made on the basis of the findings from this study:

1. Re-align the price regimes upon which the open pit and underground assessment (mining inventories) have been made
    - After discussion with EQ Resources, it was declared that the pit was design around a price of AUD$14,700/t conc (or at least lower than the AUD$18,200/t conc. assumption used in this study). Re-running the optimisation (with sensitivities), preferably after resource model update has occurred, on the resource model would at least:
        - Firm up current design and/or
        - Provide an extension option for a potential cut back design and schedule to be worked up and incorporated into site business planning processes
        - Incorporate one (or both if necessary) into an execution ready pit design and schedule

2. Following the work above, once the open pit inventory changes are clear (if any), suggest a smaller, scaled back underground option could be investigated. Obvious starting strategy would include (cognizant of minimising cash out and upfront capex to establish even the smallest scale underground options):
    - Re-access and re-establish existing u/g development to an appropriate standard
    - Establish drill platforms to drill-out easily accessible ore on the 1260 and 1280 levels
    - Determine economics of one or two levels and commence mining, basically justifying "the next level" based on the drilling done above
    - Additionally, access to underground workings could also be accessed from the penultimate bench of the open pit following the completion of open pit mining
        - Following the rationale from above and positive economics, the mine could then be developed up (to meet up with the incremental mining from the existing decline) and/or down, where the resource model indicates the best grades are
3. Depending in the results from the above two work items, produce a consolidated site cashflow model better suited to an operating mine
4. Geotech modelling to support open pit (then underground)
    - Basics (log core, Geotech modelling, rock characteristics) >>> pit slope recommendations (and the stoping recommendations)
        - Produce a geotechnical block model for use by open pit/ug planning resources
    - If any of the underground scenarios get beyond stoping study level, incorporate 3D modelling of sequence

10.REFERENCES AND SUPPORTING DOCUMENTATION

10.1. REFERENCES

EQ Resources

Mt Carbine Bankable Feasibility Study (2021). Accessed from https://www.eqresources.com.au/site/invest-in-us/banking-feasibility-study

Mining and As-built Data

Wireframes – faults, high grade zones
Drillhole database
Block model (Mt_Carbine_20210918.bmf)
Spry model
Optimised pit shells and designs
As-built topography
Previous u/g conveyor decline design

Cost Data and Financial Models

2021 Budget Schedule UG v2.xlsx
EQR Monthly Dec 27.xlsm
Mt Carbine Phase 1 2021.xlsx
Correspondence and previous budget equipment pricing

External

Miller-Tait, L., Pakalnis, R. and Poulin, R., (1995), UBC Mining Method Selection,4th Int'l. Symp. on Mine Planning & Equipment Selection, Calgary, 31 Oct-3 Nov, 1995, pp. 163-168.

Tatman, C.R. (2001) Production Rate Selection for Steeply Dipping Tabular Deposits, Mining Engineering, October 2001, pp. 62–64.

McCarthy, P. (2011) Production rate optimisation – avoiding the temptation of tonnage, Strategic versus Tactical Approaches in Mining 2011

De La Vergne, J (2008) Hard Rock Miner's Handbook Edition 5_3, available from https://www.stantec.com/content/dam/stantec/files/PDFAssets/2014/Hard%20Rock%20Miner%27s%20Handbook%20Edition%205_3.pdf

10.2. SUPPORTING DOCUMENTATION

Scoping study deliverables made available to EQ Resources include:

Name of File	What is it?	Relevance
Mt Carbine SO.duf	Deswik.CAD	Stope Optimizer Scenarios
Mt Carbine Phase 1 2022_FINAL_USE.xlsm	Excel file	First principles build-up of lateral development, stoping and trucking costs
MCU_StopeAttributes.ddf	Deswik.CAD Process Map	Provides the workings used for the First pass economic assessment and dashboard launcher
DashboardStartingPoint.DeswikCADDashboardDesign FinLevelOD.DeswikCADDashboardDesign Stopes.DeswikCADDashboardDesign Tonnes.DeswikCADDashboardDesign	Deswik.CAD Dashboard configuration files	Dashboards configured to analyse first pass economic assessment
Mt_Carbine_Scoping_MarginAnalysisbyLevel.duf	Deswik.CAD file	Results from first pass economic assessment
Mt_Carbine_Scoping_Jumbo_220mpermo.duf Mt_Carbine_Scoping_Jumbo_220mpermo.dsf	Deswik.CAD and Deswik.Schedule file	3D viewing of mine design, animation of schedule and schedule data
Levelling_Charts_Output_Mt_Carbine_Scoping_Jumbo_220mpermo.xlsm	Excel	Dump sheet used when resource levelling >>> understand resources and capacity constraints used for resource levelling
Mt Carbine-Scoping_Study_High_Level_Costs_Summary_220mpermo_max.xlsm	Excel	Financial model
Resource_to_Mining_Inventory.xlsx	Excel	Waterfall pointing to resource 'depletion'

All files can be found on the EQ Resources Deswik portal account

https://clientportal.deswik.com/Downloads/ShowFolder?path=Sites%2FEQ%20Resources%20-%20Mt%20Carbine%20Tungsten%20Mine%2FUG%20Study%2FFinal_Deliverables

APPENDIX A: DETAILED STUDY INPUTS

LEVEL	BLUFF_1	BLUFF_3	BLUFF_7	BLUFF_8	BLUFF_9	BLUFF_12	BLUFF_13	BLUFF_14	BLUFF_15	BLUFF_16	CROWN_3	DAZZLER_3	DAZZLER_7	DAZZLER_8	DAZZLER_18	DAZZLER_23	DAZZLER_25	DAZZLER_26	IOLANTHE_9	IOLANTHE_11	IOLANTHE_14	IOLANTHE_15	JOHNSON_10	JOHNSON_12	JOHNSON_13	JOHNSON_14	JOHNSON_15	JOHNSON_18	JOHNSON_19_FIX	JOHNSON_20_FIX	JOHNSON_21	JOHNSON_23	JOHNSON_24	JOHNSON_25	JOHNSON_26_FIX	JOHNSON_27	JOHNSON_28	JOHNSON_29	JOHNSON_31	TALIS_12	TALIS_13	TALIS_14	TALIS_16	TALIS_18	TALIS_21	TALIS_22	TALIS_26	TALIS_32	TALIS_37	TALIS_38	TALIS_40	TALIS_41	TALIS_45
1260				0.50			0.50						0.50	0.25			0.85	0.85			0.50																																
1280				0.50			0.50						0.55	0.55			0.85	0.95			0.92																0.70					0.60		0.95	0.50	0.95	0.60			0.95	0.95	0.92			0.92
1300				0.92			0.92						0.70	0.70			0.95	0.95			0.92	0.95							PIT							0.92		0.92	0.95	0.50		-	0.95	0.95	0.70			0.92	0.95	0.92			0.92
1320				0.92			0.92						0.50	0.50			0.95	0.95			0.92															0.92		0.92	0.85		0.95	0.95	0.95	0.80		0.95	0.92	0.95	0.92			0.92
1340				0.92			0.67						0.95	0.95			0.95	0.95		PIT	0.92				PIT												0.92		0.92	0.95	0.95	0.95	0.95	0.95	0.80	0.95	-	0.92	0.95	0.92	0.95	0.95	0.92
1360			0.65	0.67	0.65		0.92			0.95				0.95			0.67	0.67	0.95	<0.5	0.67							PIT				PIT		PIT		0.92		0.92	0.95	-	0.67	0.67	0.50	0.50	0.95	0.67	-	0.67		0.95	0.67
1380	0.95		0.75	0.92	0.75	0.50	0.92			0.95		0.50		0.95	0.70		0.95	0.95	0.95		0.92		PIT					PIT	0.20	0.85		0.55	PIT	0.20		0.67		0.92		0.67	0.95	-	0.95	0.95	0.92	0.95		0.92	0.95	0.92		0.95	0.92
1400	0.95			0.92	0.85	0.70	0.92	PIT	PIT	0.95	0.95	0.55	0.67	0.95			0.95	0.95			0.92		0.55		0.70	PIT		0.70				0.70	0.40	0.55	PIT	0.92		0.67		0.92	0.95	-	0.95	0.95	0.92	0.95		0.92		0.92	0.67	0.92
1420		0.65		0.92	0.67	0.85	0.92	0.50	0.45	0.95	0.95	0.70		0.95	0.95		0.95	0.95			0.92		0.70		0.95	0.50	0.70	0.85				0.85	-	0.70	0.40	0.92		0.92		0.92	0.95	-	0.95	0.95	0.92	0.67		0.95		0.92	0.95	0.92
1440		0.65		0.92		0.85	0.67	0.75	0.75		0.95	0.85		0.95	0.95		0.95	0.95					0.70		-	0.70	0.85					0.92	-	0.85	0.85	0.92		0.92		0.92	0.67	0.95	0.95	0.95	0.92	0.95		0.95		0.92	0.95	0.92
1460				0.92	0.95	0.85	0.92		0.95		0.95	-		0.95	0.50		0.50	0.50					0.50		0.95	0.50	0.50		0.95			0.50	0.50	0.50	0.50	0.92		0.92		0.67	0.95	-	0.67		0.67	0.95		0.67				0.67
1480							0.92		0.95		0.95	0.92		0.50	0.95		0.95	0.95					0.95			0.92	0.95				0.92	0.95	-	0.95	0.95	0.67		0.92		0.92	0.95	0.95	0.95		0.92	0.95		0.92				0.92
1500							0.92				-	0.92		0.95	0.95		0.95	0.95						0.95		0.92				0.95	0.92	0.95	0.92	0.95	0.95	0.92		0.67		0.92	0.95	0.95	0.95		0.92	0.95		0.92				0.92
1520							0.67				0.95	0.92		0.95	0.67		0.95	0.95								0.92					0.92	0.67	0.92	0.95		0.92		0.92		0.92	0.95	0.95	0.95		0.92	0.67		0.92				0.92
1540							0.92				0.95	0.92		0.50	0.95		0.95	0.95								0.95					0.92	0.95	0.92	0.95		0.92		0.92		0.92	0.67	0.95	0.95		0.92	0.95		0.95				0.92
1560							0.92				0.95	0.67		0.95	0.95		0.67	0.67								0.95					0.67	0.95	0.92	0.67		0.92		0.92		0.67	0.95	-	-		0.67	0.95		0.67				0.67
1580							0.92				0.95	0.92		0.95	0.95		0.95	0.95													0.92		0.92	0.95		0.92		0.92		0.92	0.95	0.95	0.95		0.92	0.95		0.95				0.92
1600											0.67	0.92		0.95	0.95		0.95	0.95													0.92		0.95		0.92		0.92	0.67	0.92	0.95	0.95	0.95		0.92	0.95		0.95				0.92
1620											0.95	0.92		0.95	0.67	0.95	0.95	0.95													0.95			0.95		0.92	0.95	0.92	0.95	0.95	0.95	0.95		0.92	0.67		0.95				0.92
1640											0.95	-		0.95	0.95	0.95	0.95	0.95													0.95					0.92		0.92	0.67	0.95	-		0.92	0.95		0.95				0.92
1660											0.95	0.92		0.67	0.95	0.95	0.67	0.67																		0.92		0.67	0.95	0.67	-		0.67	0.95		0.67				0.67
1680											0.95	0.92		0.95	0.95	0.95	0.95	0.95																		0.92		0.92	0.95	0.95	0.95		0.92	0.95		0.95				0.92
1700											-	0.92		0.95	0.95	0.95	0.95	0.95																		0.92		0.92	0.95	0.95	0.95		0.92	0.95		0.95				0.92
1720											0.95			0.95	-	-	0.67	0.95																		0.92		0.92	0.95	0.95	0.95		0.92	0.67		0.95				0.92
1740											0.95			0.95	0.95	0.95	0.95	0.67																		0.92		0.92	0.67	0.67	0.95		0.92	0.95		0.95				0.92
1760											0.95			0.95	0.95	0.95	0.95	0.95																		0.67		0.92	0.95	0.95	0.95		0.67	0.95		0.67				0.67
1780											0.95				0.95	0.95	0.95	0.95																						0.95	0.95		0.92	0.95		0.95				0.92
1800																		0.95																										0.92	0.95		0.95				0.95
	end of life stope																																																			

Legend - PLANNED_MINING_RECOVERY

Description	Color
Crown pillar region [<0.5]	
Modified recovery (due to pit proximity)	
Sill pillars (5m vert per 100m vert) [0.67]	
Pit affected (maintain min. ratio) [0.70 to 0.92]	
Rib pillars (5m lateral per 60m lateral) [0.92]	
Standard Recovery (5% loss) [0.95]	

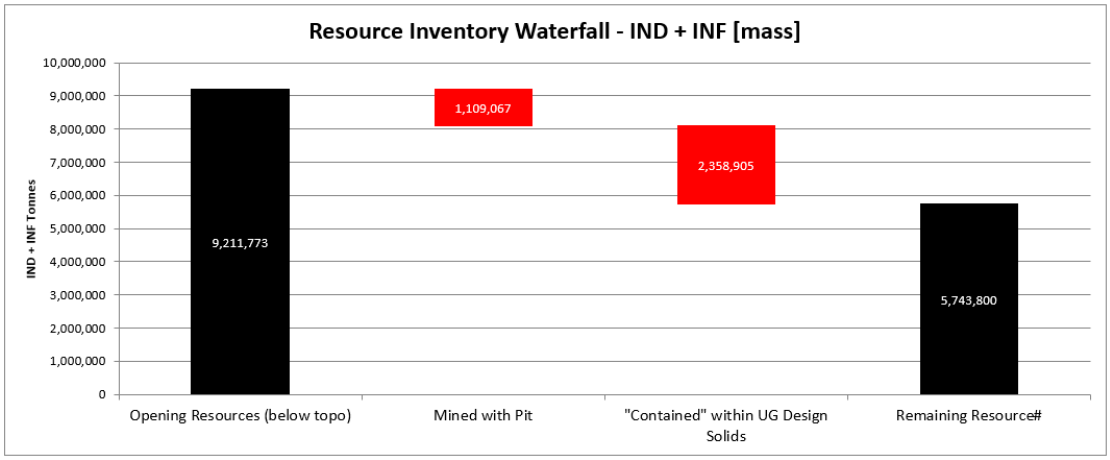
APPENDIX B: DETAILED STUDY OUTPUTS

Resource Waterfall Data

TONNES (IND & INF)

	Start	Rem	Pos Invisible	Positive Dec Visible	Positive Inc. Visible	Negative Invisible	Negative Dec. Visible	Negative Inc. Visible
Opening Resources (below topo)	9,211,773							
Mined with Pit						8,102,706	1,109,067	
"Contained" within UG Design Solids						5,743,800	2,358,905	
Remaining Resource#		5,743,800						

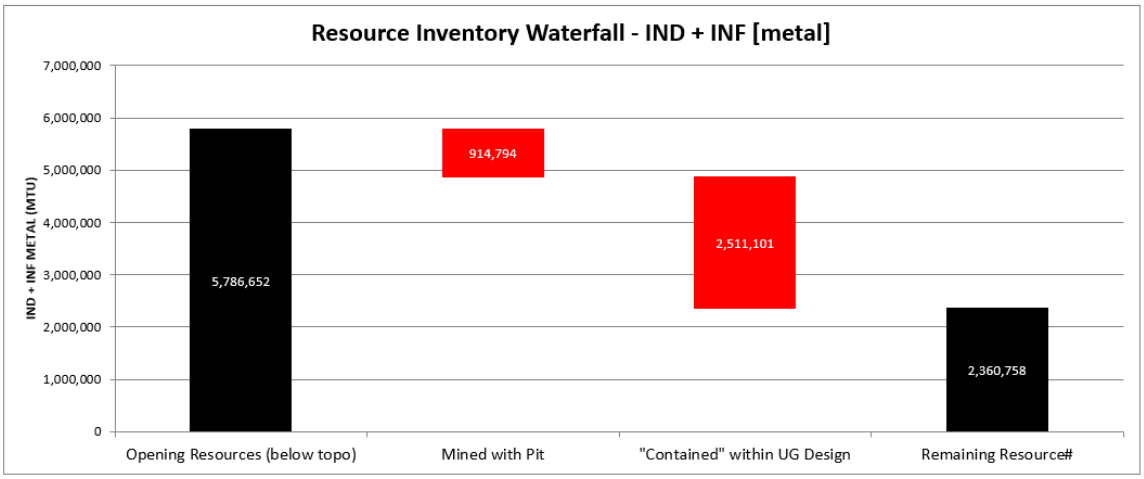
outside pit deign and outside ug excavations



METAL (IND & INF)

	Start	Rem	Pos Invisible	Positive Dec Visible	Positive Inc. Visible	Negative Invisible	Negative Dec. Visible	Negative Inc. Visible
Opening Resources (below topo)	5,786,652							
Mined with Pit						4,871,858	914,794	
"Contained" within UG Design						2,360,758	2,511,101	
Remaining Resource#		2,360,758						

outside pit deign and outside ug excavations



GRADES (IND & INF)

	Start	Rem	Pos Invisible	Positive Dec Visible	Positive Inc. Visible	Negative Invisible	Negative Dec. Visible	Negative Inc. Visible
Opening Resources (below topo)	0.63							
Mined with Pit						0.60	0.82	
"Contained" within UG Design						0.41	1.06	
Remaining Resource#		0.41						

outside pit deign and outside ug excavations

Appendix O:
Mt Carbine Study Underground Development – Update December 2023 (EQR 2023)

RESOURCES



MT CARBINE STUDY UNDERGROUND DEVELOPMENT

UPDATE

DECEMBER 2023

Document History

REVISION	DATE	AUTHOR	CHANGE DESCRIPTION	APPROVED BY
A	06/12/23	TB & WS	Internal Review DRAFT	
B	09/12/23	TB & WS	Issued for Approval	
C	09/12/23	TB & WS	Issued for Use	

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1. Executive Summary

A detailed scoping study done by Deswik included information normally in a Feasibility Study but was declared a scoping study due to the resources only being inferred. The aim of this project is to convert these resources into Reserves and so allow the completion of a BFS study that would allow management to make a decision to progress the underground. The scoping study is summarized here.

Category	Details	Comment
Mine Life	5 years	Two years of drill out, Development Drive, Trial Mining, Commissioning, Ramp up to full mining.
Resource Used	2Mt @ 0.52%	Approximately 40% of resource
Development Costs	Stage 1 - $12M Stage II - $22M	Drill & Test Commission & Run
Pricing	$320 / APT	Current Pricing
Workforce	35 direct personnel	Managed by existing EQR Management
Equipment Required	UG Fleet	Ore to be treated by existing mining Facility
Mining Rate	1100tpd	Ramps up over 6 months
Free Cashflow		
NPV & IRR		
Capital Required		

This study is to be completed on a smaller start up project for the first 5 years of underground development using the costings and existing work completed by Deswik. It is the intention to complete 5 years of resources and conduct some trial mining to assess if this project works.

Scope of 5-year project.

Category	Details	Comment
Mine Life	Initial 5 years Complete a full FS	Targeting of an economic 5-year mine life can be achieved within a reasonable cost and timeframe.
Resources Needed	2Mt @ + 0.5% Approximately 50% of the ore as outlined in the Scoping Study.	2Mt of ore is considered sufficient to mine at a economic rate for 5 years being exactly what the open cut achieves in terms of ore production. At the average vein width of 2.25m it is 324k m2 of vein in long section. This is 1 vein at 1km (strike) and 300m (vertical) or 3 veins at 360m (strike) and 300m vertical. Already we have identified 11 veins north of the pit that would fit the size criteria and these are in the inferred resource category.

Production Rate	400,000tpa of ore. (178K m3)	2km of development per year
Zone	Two Potential Areas 1) Iron Duke Zone 2) Western High Grade zone.	Iron Duke Zone has the advantage of being already inferred resource; 11 veins have the grade criteria, is on boundaries of the pit. And has been demonstrated to have the vertical and horizontal dimensions.
Mining Rate	1000 tpd	Ramp up to 1200tpd operation. Nominally 100tpd operation.
Workforce	35	35
Equipment Required	Underground Gear	Jumbo's, Scooptram's, UG trucks, Compressor, Service Vehicle, Rockbolter, Drill Rigs, Scaler, Long Hole Rig,
Utilities Required	1.5MW	Transformer (1000W) for 1.5Mw power, Pressured Water, Pumps, Crib hut, Amenities, piping etc
BFS Costs	Optimal Mining	800,000 for study only
Capital Cost	$12m Stage 1 BFS , $22m Stage II kick off to cashflow	

Subsequently, the study will assess the cost and operational benefits the of commencement of an Underground Operation as both a standalone operation and conjunction with mining at the open pit. The study incorporates utilization of the existing ore sorting plant, processing plant and current infrastructure development

The strategy for the feasibility study will better minimise the capital expenditure of the upgrade where possible and maximise the use of all existing on-site mining, processing and supporting infrastructure.

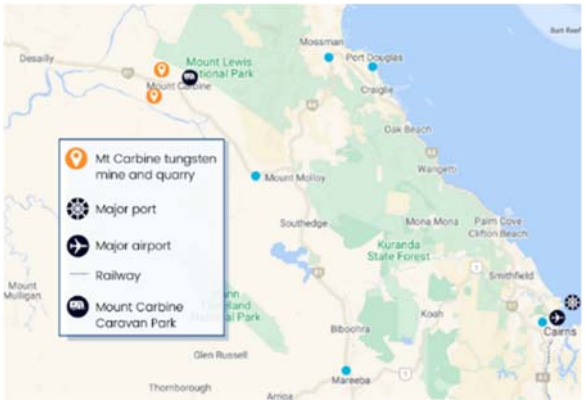
1. Mt Carbine Underground Project

a. Overview

Mt Carbine is an operating tungsten mine and rock quarry located 130 km north of the city of Cairns in Far North Queensland, Australia.

The mine is at the northern end of the Atherton Tableland approximately two hours (130 km) by sealed highway from the port and major centre of Cairns and 45 minutes from Port Douglas. There is a small historic hotel and caravan park adjacent to the mine site and a small town. The mine location is shown in Figure 1.

Figure 1: Mine Location



EQ Resources Limited (EQR) acquired a 100% interest in Mt Carbine Quarries Pty Ltd, an entity that owns mining leases ML4867 and ML4919 along with the associated Quarry in June 2019.

EQR has been operating the mine and quarry concurrently, with the mine currently processing tailings and low grade ore stockpiles located on the site that are remnant from previous operations on the site.

The mine is well supported by existing services and infrastructure.

1.1. History of Project

The Mt Carbine tungsten deposit was discovered around 1883, with production first commencing in 1895.

A summary of the history of the Mt Carbine deposit is included in Table 1.

Table 1: History of Mt Carbine Asset Ownership and Activity

1.1 Company	Year	Year	Key Points
Individual Small miners	1883	1905	Underground vein operations
Irvinebank Co-op Company	1906	1918	Co-op Organized UG mining - site processing
Electric Ore Reduction Corp. Ltd.	1918	1920	Name change
Idle after 1919 decrease in Wolfram Prices			Low Tungsten Prices
North Broken Hill Ltd.	1967	1968	Drilled first 3 holes into Mt Carbine
R.B. Mining Pty. Ltd.	1968	1976	Designed and construct mine - Continue drilling
Qld Wolfram Pty. Ltd. & R.B. Mining Pty. Ltd.	1976	1986	10 years of Operational OC - 22Mt extracted
Poseidon Minerals Ltd. + Normandy Minerals Ltd.	1984	1993	JV. Designed UG & installed 420m of decline
Mt Carbine Quarries Pty. Ltd.	1993	2010	Purchase Licenses to run quarry

1.1 Company	Year	Year	Key Points
Icon Resources	2010	2011	Sublease the project for evaluation
Carbine Tungsten	2011	2015	Name change
Speciality Metals International	2015	2020	Name change
EQ Resources	**2020**	**Present**	**New resource and BFS**

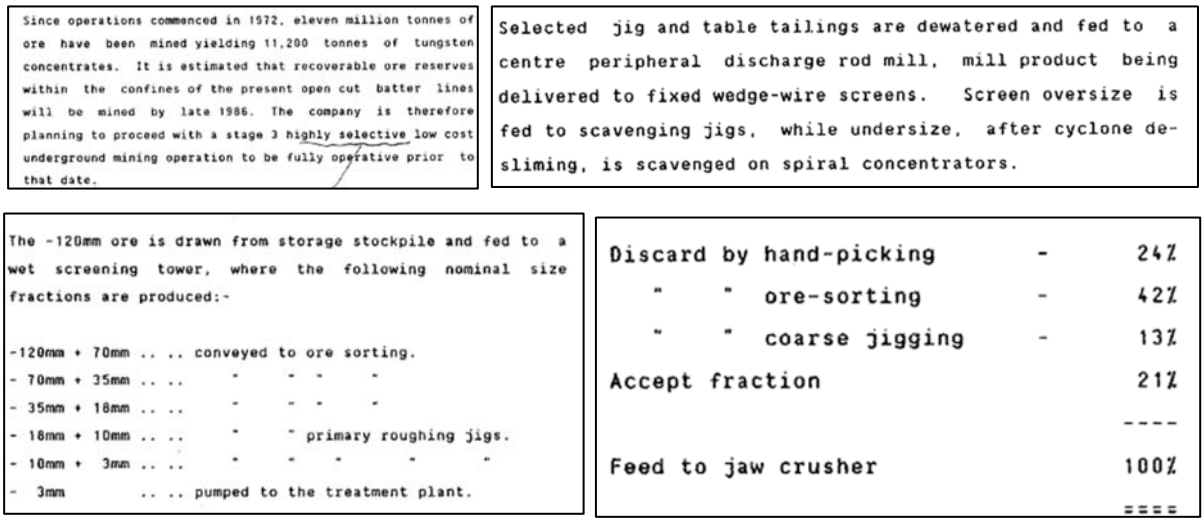
1.2. Historical Underground Investigations.

1.2.1. RB Mining Model

At the end of open pit mining in 1986 Posiden Minerals Joint Ventured into the project to conduct underground mining. The mine was designed for a block cave operation at 7.2Mt @ 0.2% WO3 and a decline was started. The decline was 8 x 4m in size and was 1:6 grade being steeper than normal 1:7 due to extraction being by conveyor belt. The tunnel was installed for a total length of 430m (down to elevation 305m from 375m) before tungsten prices fell and the plan was stopped.

The reports detail that the decline was dry and in very good ground conditions with only rock bolting done over a 2m fault zone and at the portal entrance. Once EQR opens the entrance it i to complete a full Geotech evaluation of the decline by an qualified expert and under new legislation all access's are required to be fully meshed and rock bolted. As part of our costing going forward, a refurbishment of the 430m decline is required and costed out at $800,000.

A Feasibility was completed by RB Mining on 5th October, 1984 for a Sub Level Caving mine with the following details



Since operations commenced in 1972, eleven million tonnes of ore have been mined yielding 11,200 tonnes of tungsten concentrates. It is estimated that recoverable ore reserves within the confines of the present open cut batter lines will be mined by late 1986. The company is therefore planning to proceed with a stage 3 highly selective low cost underground mining operation to be fully operative prior to that date.

Selected jig and table tailings are dewatered and fed to a centre peripheral discharge rod mill, mill product being delivered to fixed wedge-wire screens. Screen oversize is fed to scavenging jigs, while undersize, after cyclone de-sliming, is scavenged on spiral concentrators.

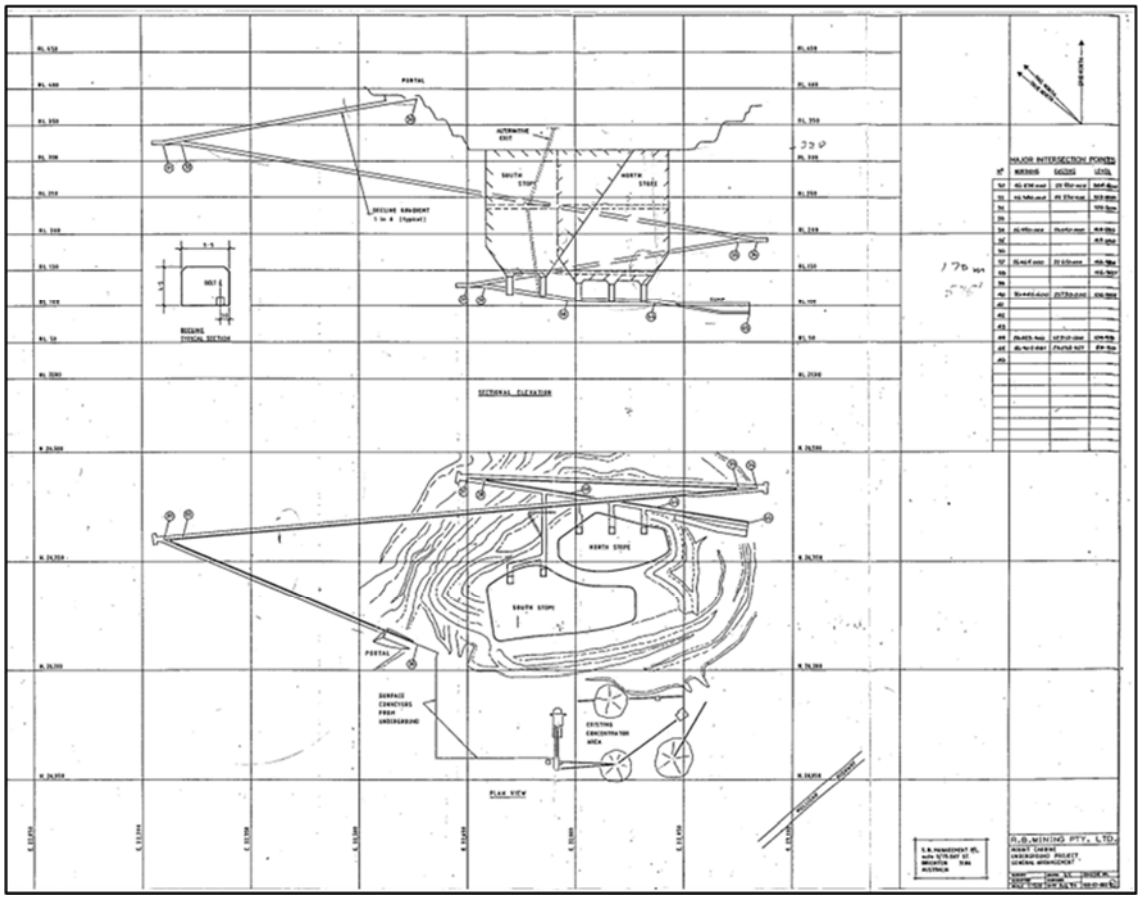
The -120mm ore is drawn from storage stockpile and fed to a wet screening tower, where the following nominal size fractions are produced:-

-120mm + 70mm .. .. conveyed to ore sorting.
- 70mm + 35mm .. .. " " " "
- 35mm + 18mm .. .. " " " "
- 18mm + 10mm .. .. " " primary roughing jigs.
- 10mm + 3mm .. .. " " " " "
- 3mm .. .. pumped to the treatment plant.

Discard by hand-picking	-	24%
" " ore-sorting	-	42%
" " coarse jigging	-	13%
Accept fraction		21%

Feed to jaw crusher		100%
		====

Figure _ Processing method used by RB Mining during the first open cut operation.



The -3mm fraction from the wet screening tower is similarly treated in a separate jig - spiral circuit. This material is not rod-milled.

The total scavenger and -3mm jig concentrate is returned to the primary concentrator for up-grading, while the spiral concentrate is upgraded on a single shaking table.

The total crude concentrate, which assays between 40 - 50% WO3, is treated in a concentrate cleaning section which includes:

1. Screening and rolls-crushing of coarse fractions, followed by dewatering and high - solids conditioning.

2. Table flotation, to remove sulphides.

3. Drying, screen sizing, and primary magnetic separation using magnetic disc separators.

4. Closed - circuit tabling of non-magnetic fractions, to remove apatite and other gangue fractions.

5. Drying of table concentrate, and removal of residual magnetic fraction on induced roll magnetic separators.

5.3 STOPE OUTLINE

The stope outline was determined by the following factors in order of importance.

1. Structure of the vein system.

   The vein system was basically zonal as infillings of a previous shear stress system which was itself very close to vertical.

   Any stopes encompassing zones at depth had to be vertical unless constrained by a fault, in this case the cut off fault on the South Wall.

   Since the zones are lineal east-west the stope had to be east-west.

2. Grade of ore

   (a) Quartz content

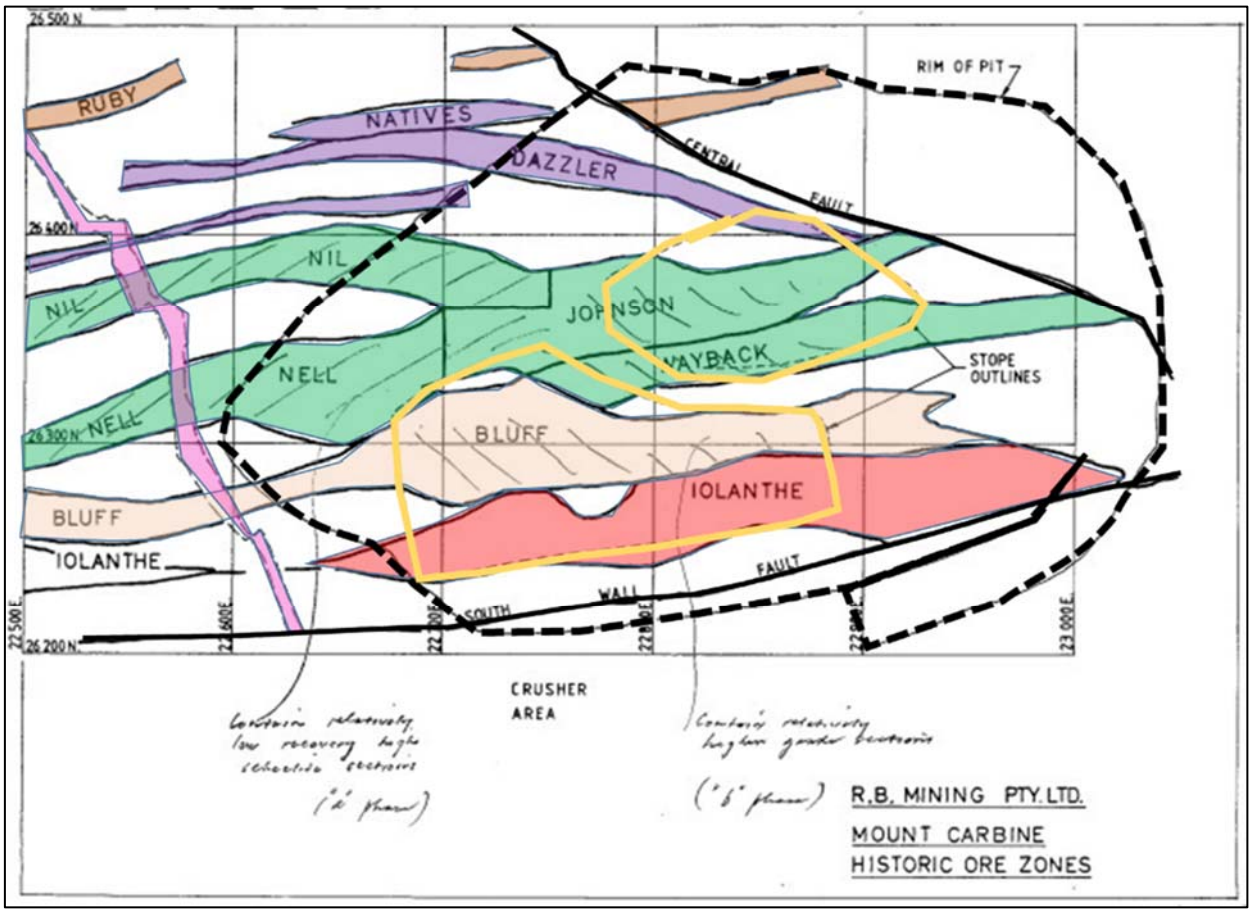
   (b) Tungsten content of quartz

   (c) WO3 in the rock.

3. A tonnage of ore sufficient for at least 7 years operations.

4. Mining costs and the necessity for the cost per tonne to be less than open cut costs per tonne.

Figure _ 1984 Design of Sub Level Caving model for mining 7.2Mt @ 0.18% WO3



6. Heating of induced roll non-magnetics and treatment on a high tension electrostatic separator for removal of cassiterite and sulphides from the scheelite concentrate.

7. Acid leaching of selected scheelite table circuit fractions for removal of apatite.

8. Roasting of wolframite concentrates, for elimination of residual sulphur levels.

The resulting high-grade (70 - 75% WO3) wolframite and scheelite concentrates, (Table 3.2) which are currently being produced at a rate of approximately 800 tonne/year of WO3, are analysed in an on-site laboratory prior to being packaged in either 23 litre or 200 litre drums for shipment.

Total concentrator tailings, including the -3mm circuit tail and desliming cyclone overflows, are pumped to a large tailings dam, one kilometre away. The settled water gravitates to return water pumps for re-use in the plant.

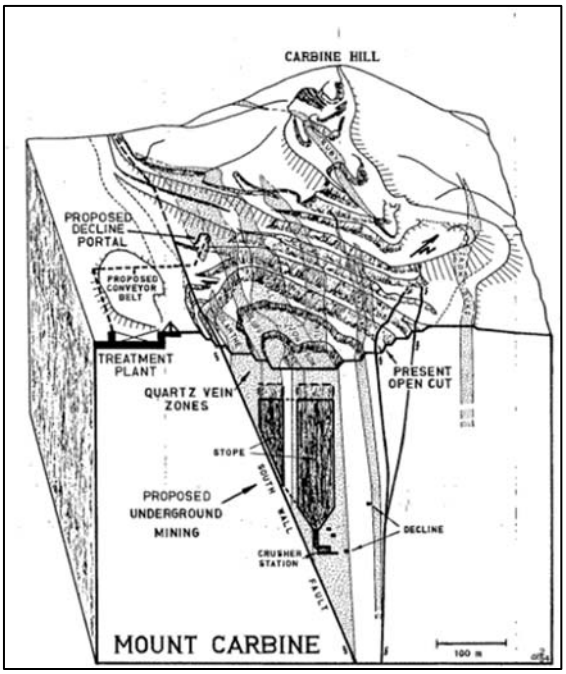


Figure _ Vein zones defined by RB Mining and plans for Underground Sub Level Caving Operation.

1.2.2. Icon Resources Model

In July, 2020 Icon Resources completed an internal Underground Scoping study with the following results.

The figure below shows the planned historical block cave operation.

M1 have made assumptions on mining rates, level spacing and stope sizes

- Overall mining rate up to 750,000 tonne per annum
- Individual stopes mined at a maximum of 15,625 t per month
- Maximum of four stopes in production at once.
- Level spacing based on 50m levels floor to floor, stope lengths along strike maximum of 25m.
- One development jumbo operating at 240 metres per months with a maximum of 120 metres per month per single heading.
- Dilution based on 0.25m on both footwall and hanging wall of the stope.
- Mining recovery set at 85% to account for rib and sill pillars where required.
- Waste development rock to be used as fill.
- Contractor used in the open pit will be used in the underground operation.

ACTIVITY	COST/ORE TONNE
Mining Over heads[1]	$6.6
Development	$6.6
Drill, charge, load, haul	$13.65
Processing	$15.85
Total	$42.66
Processing Recovery	75%
WO3 price	$23,700
Cut Off Grade	**0.24%**

Table 3: Cut Off Grade Calculation

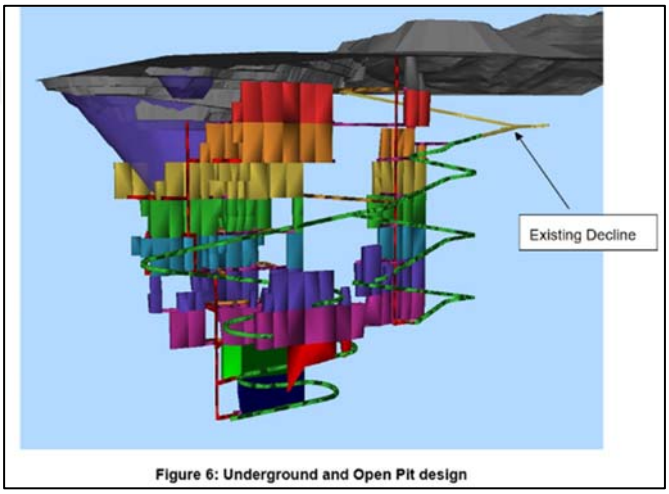


Figure 6: Underground and Open Pit design

CUT OFF (WO3%)	TONNES	GRADE (WO3%)
0.15	7,100,128	0.23
0.24	2,991,379	0.31

Table 4: Sensitivity on Grade for Mining Inventory

	TONNES	GRADE (%WO3)
Development Ore (T)	196,256	0.28
Stope Ore (T)	4,685,925	0.25
Total	**4,882,181**	**0.25**

Table 5: Final Mining Inventory

MTU (WO3) IN CONCENTRATE	1,555,221
Revenue ($250MTU)	388,805,254
Mining Costs ($AU)	(151,113,668)
Processing Costs ($AU)	(106,172,479)
Freight Cost ($AU)	(1,832,939)
Other Costs ($AU)	(21,423,186)
Capital ($AU)	(68,900,000)
Projected Cash Flow ($AU)	**39,362,981**

Table 11: Project Cash Flow Summary

ACTIVITY	METRES
Decline	3515
RAR Access	645
Access Development	3,780
Vertical Development	859
Ore Drives	4,703
Drilling	230,000

Table 6: Underground Physicals

Table _ Parameters used in Deswik Modelling

m MT CARBINE	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	YR 8	TOTAL -
DECLINE	675	688	684	434	441	360	233	-	3,515
Vent Drives	241	13	114	11	109	126	31	-	645
Total m's	915	701	798	445	551	487	264	-	4,160
Tonnes	68,588	56,106	61,820	35,556	41,962	36,514	20,620	-	321,166
	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-
Ventilation Rises	-	-	-	-	-	-	-	-	-
Vertical Rises	283	82	100	50	143	154	48	-	859
Tonnes(raise)	9,437	2,739	3,337	1,669	4,760	5,123	1,605	-	28,670
	-	-	-	-	-	-	-	-	-
Access Waste									-
Access	658	1,001	547	590	481	504	-	-	3,780
Access Tonnes	39,154	59,552	32,547	35,104	28,615	30,005	-	-	224,977
	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-
Total 2 Boom Jumo Development m	1,573	1,701	1,345	1,035	1,031	990	264	-	7,940
2 Boom Mt Carbine Horizontal Waste Tonnes	107,741	115,659	94,367	70,659	70,577	66,519	20,620	-	546,142
Total Mt Carbine waste Vert & Horz	117,179	118,398	97,704	72,328	75,337	71,642	22,225	-	574,813
	-				-			-	-
Ore Drives									-
									-
Total 1 Boom Metres	1,297	1,175	807	404	407	448	165	-	4,703
Development Ore Tonnes	39,382	53,665	36,116	24,973	20,813	12,514	8,793	-	196,256
Grade	0.36	0.29	0.24	0.27	0.26	0.24	0.24	-	0
									-
Stoping									-
									-
									-
Mt Carbine Stope Production	149,629	698,335	713,884	725,027	729,187	737,488	741,207	193,170	4,685,925
Grade WO3%	0.26	0.24	0.26	0.27	0.24	0.24	0.25	0.25	0.25
	-								-
									-
Total Ore	189,011	750,000	750,000	750,000	750,000	750,000	750,000	193,170	4,882,181
WO3 %	0.28	0.24	0.26	0.27	0.24	0.24	0.25	0.25	0
	-	-	-	-	-	-	-	-	-
Mined WO3 (T)	523	1,794	1,963	2,029	1,790	1,807	1,902	483	12,291

Table _ Underground Schedule for Deswik Model.

Table 8 shows that the underground operation would be cash flow positive with the assumptions used in the study. The underground would operate over an eight year period, producing 9,218 t of WO3 with a operating discounted cash flow of AU$15.06M.

The underground operation has estimated to require approximately AU$14.5M of capital over the life of the operation, including all capital and exploration development. This mine plan has been set up to maximise the mine life, this was undertaken with the underlying assumption that further mineralisation will be found by utilising the installed development, thus improving the overall NPV of the project.

The underground project shows high sensitivity to the WO3 price as well as a changing in operating costs, with very little sensitivity to a change in discount rate. The high sensitivity to the change in operating costs will be due to the large amount of operating development required to develop the underground operation.

Using the financial model supplied by Icon Resources (Mount Carbine Model 14jun09.xls), M1 combined the open pit and the underground tonnages to produce a combined production schedule and financial model for the Mount Carbine project.

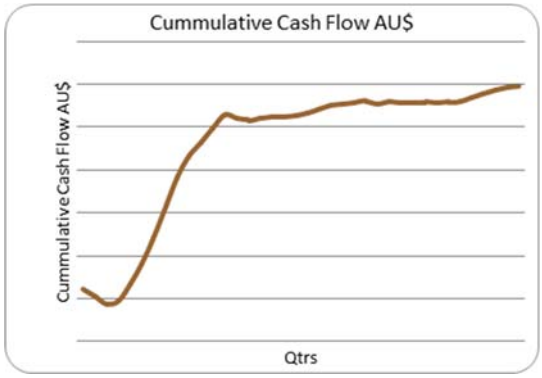
The model assumed that the underground mine will begin operation within the last year of the open pit. Utilising the existing decline for the underground mine, decouples the pit and underground operations, thus allowing the underground to begin at a time that suits the overall project requirements. M1 have also assumed that one contractor will be used across all mining phases of the operation.

The financial model has been altered to reflect updated prices used in the earlier models.

The combined model shows that at the current level of knowledge and drilling that the Mount Carbine project could produce an operating life of approximately 10 years producing a pre-tax NPV at 8% of AU$21.8M and an IRR of 28%. Table 11 shows a summary of the combined project.

The figures used in Table 11 have been based on an AU$250 per MTU WO3 price and all costs based on unit rates detailed in M1 Mount Carbine Model Sept09.xls.

The combined model shows (Figure 8) that the cash deficit peaks around quarter 2 at approximately AU$62M with break even occurring at quarter 9.



Mining One have been commissioned by Icon Resources to conduct a mining study for the Mount Carbine project. The accuracy of the study was to a scoping study level being ± 30%.

The study showed that based on the assumptions and block model supplied, mining of the Mount Carbine orebody using both underground and open pit methods should produce a positive NPV. Using an 8% discount rate and AU$250 per MTU the NPV of the project is AU$21.9M over a life of approximately 10 years this value does not included reprocessing of the old tailing and waste dumps on site.

The project should be cash positive after 2 years with a maximum cash deficit of AU$62M. M1 have shown by the scoping study that the potential of the Mount Carbine project warrants further studies, to firm up the assumptions used and gain further information on the ore body.

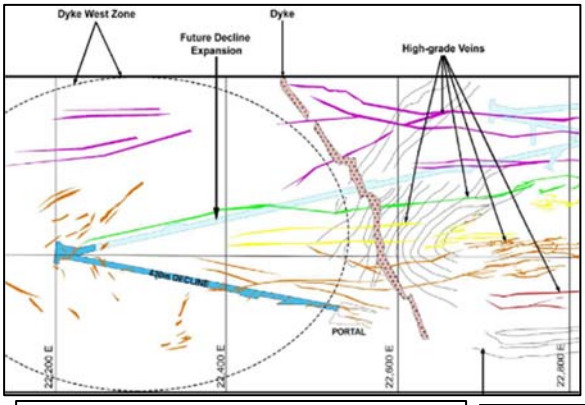
Mining One believe that the Mount Carbine project shows potential for both an underground operation and open pit, however the information used in the study is limited and would require further validation in the next level of study, M1 recommend the following:

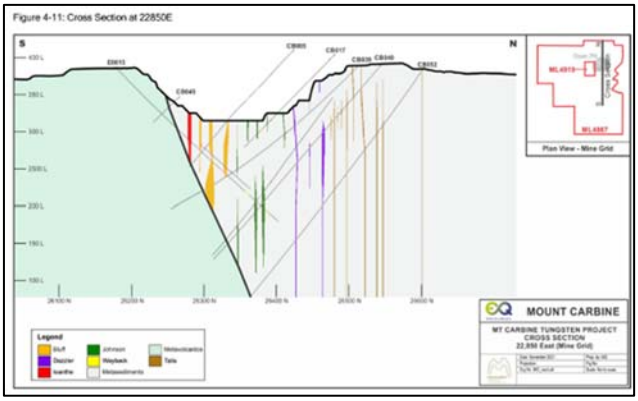
- The next level of study will require more detailed cost estimates. M1 can develop these estimates using zero based cost models.
- Infill drilling to increase the confidence in the ore body and block model.
- Conduct a geotechnical study to determine stable open pit wall angles and underground maximum stope dimensions; this may require geotechnical drilling and logging to complete.
- Produce open pit design and determine the suitability of using uncut or cut WO3 grades in the future design processes.
- Conduct detailed study on the optimum processing plant size, based on the size of the orebody.

1.2.3. Deswik Model

This work was done in February 2022 and was a desktop review and study to investigate mining using narrow vein mining techniques and on the basis of the 2021 Resources completed by Measured Group in May, 2021.

The model incorporated the following





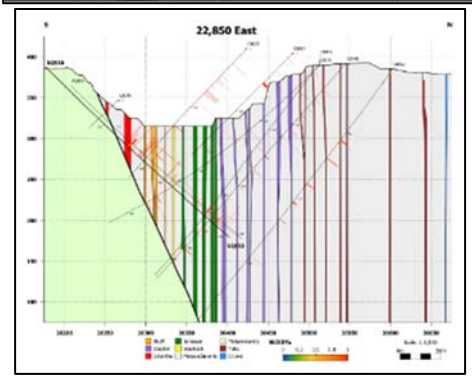


Table 1 Mt Carbine resource – September 2021

Orebody	Resource Classification	Tonnes (Mt)	Grade (WO_3 %)	WO_3 (mtu)
Low-Grade Stockpile	Indicated	12	0.075	900,000
In Situ	Indicated	2.40	0.74	1,776,000
	Inferred	6.81	0.59	4,017,900
	Total	*9.21*	*0.63*	*5,793,900*
All	**Total**	**21.21**		**6,693,900**

Figure __ showing the location of the sheeted vein system relative to the pit. Resource Model Reviewed.

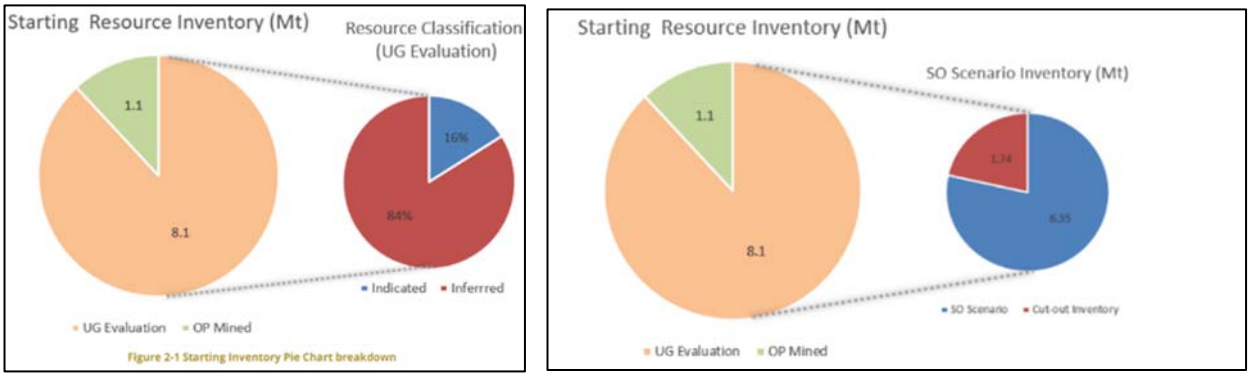


Figure _ Resources used in the Deswik Model and proportion of Invetory

Total of 2,596 stopes for 6.3Mt @ 0.6% as starting inventory of which only 16% has been drilled as indicated Resources. Break Even Grade was determined above 0.25% Cutoff to give 4.2Mt @ 0.52% in stope blocks that are in 4 zones within the deposit. The zones were separated due to lack of drilling.

Deswik.SO Parameters	
Block Model	Mt_Carbine_20210918.gmdlb
Cut-Off	WO_3: 0.25%
Stope Dimensions	Height: 20m, Strike: 20m
Stope Width	Min: 1.8, Max: 20m
Stope Pillars	Min: 4 m
Dip (Default)	90 deg

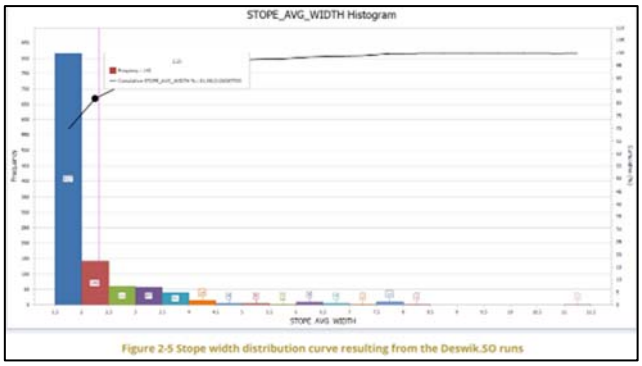


Table __ Block model parameters used to define stopes & stope average width histogram

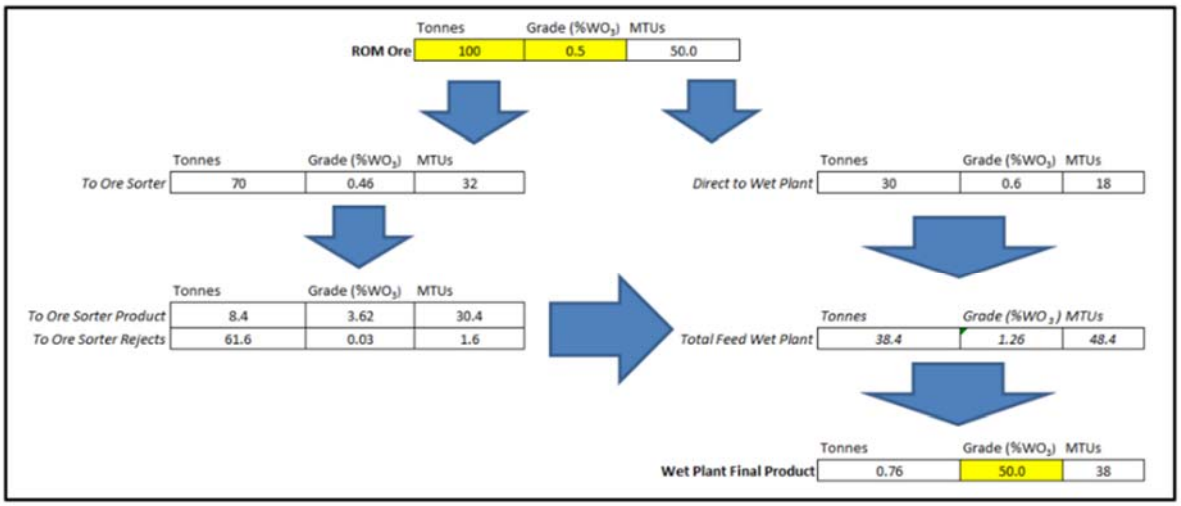


Figure 3-2 High level processing summary

Figure _ High Level Processing Summary taken from Deswik Report 2022.

A high level break even cost was established based on extensive cost information supplied by the company during its 18months of mining activity. Note this activity reflects a lower recovery of 76% than what was achieved at 79%. It is anticipated that recovery will exceed 80% when fresh pit ore was mined. (weathering of the stockpiles has reduced the scheelite down to dust level and higher losses into slimes)

Table 4 BEG calculations

At $18,200/t conc [APT (50% WO3]..

If grade to ROM is... Grade (%WO_3)	All-in Break Even Mining Cost ($/t ore) is...
0.20	$45.42
0.30	$73.26
0.40	$101.09
0.50	$128.93
0.60	$156.76
0.70	$184.60
0.80	$212.44
0.90	$240.27
1.00	$268.11
1.10	$295.94
1.20	$323.78
1.30	$351.61
1.40	$379.45
1.50	$407.29

Table 8 Mine Physicals for Concept Design

	Metric	TOTALS
MATERIAL MOVEMENT	**Total Ore Mrec Tonnes (t)**	**4,189,574**
	Total Ore WO3 (%)	**0.52**
	Total Ore WO3 (mtu)	**2,181,255**
	Stope Ore Mrec Tonnes (t)	2,328,951
	Stope Ore WO3 (%)	0.69
	Dev Ore Mrec Tonnes (t)	1,860,623
	Dev Ore WO3 (%)	0.31
	Waste Tonnes	2,701,538
MINING PHYSICALS	**Equivalent Metres (m) - Lat Dev**	**66,671**
	Capital Lat Dev (m)	19,639
	Operating Lat Dev (m)	47,032
	Equivalent Metres (m) - Vert Dev	**1,998**
	Truck tkm (tkm) - Ore	10,089,709
	Truck tkm (tkm) - Waste	7,469,320
	Truck_TKM - All	**17,559,030**
	Longhole Drill Metres (m)	**486,377**
	Fill Volume (m3)	**0**
	Cablebolt (m)	**144,216**

Table _ Cutoffs showing breakeven cost S and financial summary of Deswik Scoping Study

At this stage of the study process, while no firm cost model existed for MCU (and in the interests of maintaining potentially economic mining inventory for as long as possible on the path to a complete design and supporting cost model), the inventory of stopes from the optimizer run were used, namely stopes where:
- Minimum mining width was greater than 1.8m and Maximum strike was 0.25 and Grade %WO3>0.25.

After completing the margin assessment on all levels, the inventory of stopes had been reduced to 1,435 (from the original 2,596 that came out of the stope optimizer run). This, plus the inclusion of development for the extraction of the stopes, shrunk the inventory from 6.4Mt @ 0.61%WO3 to 5.8Mt @ 0.37%WO3 , total ore. Figure 5-3 shows the inventory taken through to sequencing (and scheduling).

Looking at the ore (dev + stope) inventory by level (Figure 6-1) we see a low t/vm. This may well be a function of drill density (especially at depth) but highlights the issue any underground mine at Mt Carbine faces (given the current resource) – not enough continuous, resource tonnage to sustain the capital development required to access it.

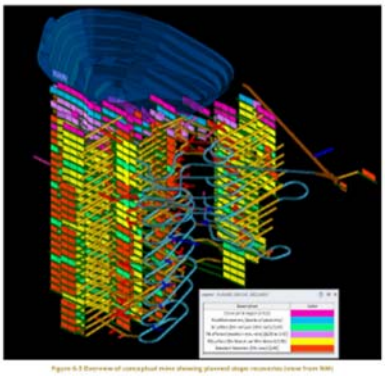
		IN-SITU								MINED (PLANNED)			
LEVEL	Elevation	In-situ Volume	In-situ Tonnes	wo3	In-situ Metal (mtu)	In-situ TONNES IND	In-situ TONNES INF	In-situ TONNES TARGET	*In-situ TONNES IND or INF (%)*	Mrec Tonnes (t)	Mrec wo3	Mrec Metal w03 (mtu)	*Planned Recovered t/vm*
1260	362.7	44,702	122,484	0.55	67,692	35,074	28,306	58,515	*52%*	96,512	0.45	43,176	*4,826*
1280	342.7	46,640	127,794	0.56	71,639	25,758	43,824	58,212	*54%*	113,644	0.50	57,180	*5,682*
1300	322.7	56,368	154,448	0.52	80,984	23,979	52,162	78,308	*49%*	148,648	0.48	70,928	*7,432*
1320	302.7	55,984	153,395	0.54	83,383	25,886	52,189	75,320	*51%*	150,149	0.50	75,001	*7,507*
1340	282.7	61,232	167,776	0.55	91,564	25,753	60,430	81,593	*51%*	167,586	0.50	82,991	*8,379*
1360	262.7	73,918	202,536	0.54	108,650	43,165	70,312	89,059	*56%*	175,669	0.48	84,813	*8,783*
1380	242.7	87,426	239,546	0.54	129,258	58,184	79,199	102,164	*57%*	215,124	0.49	106,055	*10,756*
1400	222.7	86,336	236,562	0.55	129,844	50,159	87,614	98,789	*58%*	221,085	0.51	111,885	*11,054*
1420	202.7	110,710	303,346	0.58	175,276	88,581	94,396	120,370	*60%*	267,093	0.53	141,793	*13,355*
1440	182.7	89,911	246,356	0.57	139,636	52,569	83,458	110,329	*55%*	240,446	0.52	125,584	*12,022*
1460	162.7	73,872	202,408	0.57	115,602	43,169	68,647	90,593	*55%*	172,798	0.52	89,006	*8,640*
1480	142.7	72,079	197,496	0.58	114,781	40,432	63,478	93,585	*53%*	196,516	0.54	105,868	*9,826*
1500	122.7	69,129	189,413	0.62	116,612	6,106	104,544	78,763	*58%*	190,116	0.57	108,319	*9,506*
1520	102.7	67,540	185,060	0.62	115,475	56	106,495	78,510	*58%*	182,611	0.58	105,338	*9,131*
1540	82.7	65,260	178,813	0.62	110,579	0	102,284	76,529	*57%*	180,423	0.57	103,515	*9,021*
1560	62.7	63,957	175,243	0.61	106,546	0	99,346	75,897	*57%*	160,471	0.55	88,395	*8,024*
1580	42.7	60,991	167,114	0.59	98,925	0	92,537	74,577	*55%*	166,072	0.55	91,706	*8,304*
1600	22.7	54,861	150,319	0.59	88,485	0	80,922	69,397	*54%*	151,258	0.54	81,529	*7,563*
1620	2.7	54,000	147,959	0.58	85,845	0	77,171	70,788	*52%*	148,276	0.54	80,464	*7,414*
1640	-17.3	36,134	99,008	0.61	60,452	0	45,884	53,124	*46%*	100,186	0.57	56,879	*5,009*
1660	-37.3	40,327	110,495	0.56	62,418	0	51,095	59,400	*46%*	102,164	0.50	50,726	*5,108*
1680	-57.3	40,812	111,824	0.55	62,020	0	51,522	60,303	*46%*	113,864	0.52	58,619	*5,693*
1700	-77.3	35,449	97,131	0.54	52,276	0	47,689	49,442	*49%*	98,892	0.50	49,509	*4,945*
1720	-97.3	33,062	90,589	0.54	48,712	0	41,354	49,235	*46%*	91,843	0.49	45,399	*4,592*
1740	-117.3	35,383	96,949	0.53	51,772	0	43,950	52,999	*45%*	98,763	0.49	48,077	*4,938*
1760	-137.3	33,432	91,604	0.55	50,702	0	43,169	48,435	*47%*	85,758	0.49	41,674	*4,288*
1780	-157.3	32,671	89,518	0.53	47,481	0	41,485	48,033	*46%*	91,526	0.49	44,980	*4,576*
1800	-177.3	21,820	59,786	0.56	33,731	0	28,513	31,273	*48%*	60,678	0.52	31,770	*3,034*

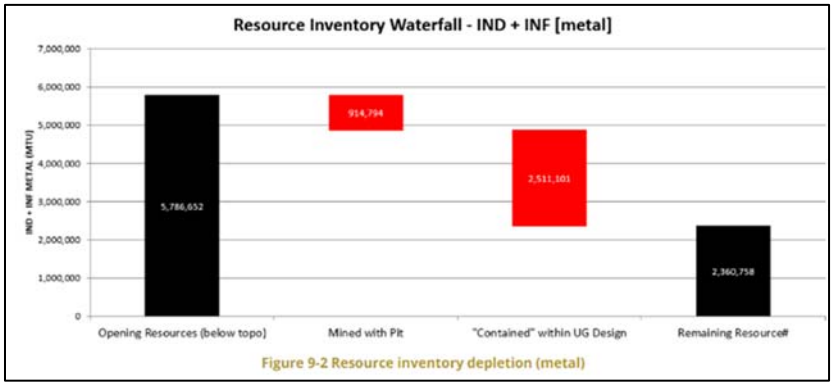
Table _ Mine Inventory per level showing tonnes and grade pulled from Resource Model.

Figure 7-1 shows the cashflow summary for concept design and schedule. At the given price (equiv. APT $18,200/t concentrate [50%WO3]) and a 6% discount rate, the project has a $79M cumulative net cashflow for a $29.4M NPV.

Given the level of accuracy in both the cost estimate and predominantly based on inferred material, these figures would have a degree of accuracy of +/-30% (estimated). Excluding Yr 0 (in this case arbitrarily labelled 2022), the mining inventory designed is consumed over a period of 10.25 years, with the final quarter consisting of mining remnant stopes adjacent to the (then finished) open pit.

Positive cashflow is not achieved until Yr 5 and on a cumulative basis, not until Yr 8 Prima facie, the under-pit resource appears extensive. However, a lot of the modelled ore is discontinuous (refer to Figure 4-3) and at grade that doesn't support underground extraction. As a result, a large portion of the stated resource (at this stage) appears uneconomic from both and open pit or underground mining perspective (albeit the pit optimisation was done at a lower MTU price). This is illustrated in the waterfall diagrams shown in Figure 9-1 and Figure 9-2 (refer to APPENDIX B: for details on calculations).





Figures _ Scoping Documents showing Deswik design and waterfall diagram for resources.

1. Grade distribution (modelled) is remarkably consistent vertically so while we don't see horizontal extents on the level, the resource model grade is consistent with depth and is obviously a function of the resource estimation technique employed. This can be seen in Figure 9-3.

The following recommendations are made on the basis of the findings from this study:

- Re-align the price regimes upon which the open pit and underground assessment (mining inventories) have been made ➢
- After discussion with EQ Resources, it was declared that the pit was design around a price of AUD$14,700/t conc (or at least lower than the AUD$18,200/t conc. assumption used in this study).
- Re-running the optimisation (with sensitivities), preferably after resource model update has occurred, on the resource model would at least:
- • Firm up current design and/or
- • Provide an extension option for a potential cut back design and schedule to be worked up and incorporated into site business planning processes
- • Incorporate one (or both if necessary) into an execution ready pit design and schedule

2. Following the work above, once the open pit inventory changes are clear (if any), suggest a smaller, scaled back underground option could be investigated. Obvious starting strategy would include (cognizant of minimising cash out and upfront capex to establish even the smallest scale underground options):

- Re-access and re-establish existing u/g development to an appropriate standard
- Establish drill platforms to drill-out easily accessible ore on the 1260 and 1280 levels
- Determine economics of one or two levels and commence mining, basically justifying "the next level" based on the drilling done above
- Additionally, access to underground workings could also be accessed from the penultimate bench of the open pit following the completion of open pit mining
- Following the rationale from above and positive economics, the mine could then be developed up (to meet up with the incremental mining from the existing decline) and/or down, where the resource model indicates the best grades are

3. Depending in the results from the above two work items, produce a consolidated site cashflow model better suited to an operating mine

4. Geotech modelling to support open pit (then underground)

- Basics (log core, Geotech modelling, rock characteristics) >>> pit slope recommendations (and the stoping recommendations)
- Produce a geotechnical block model for use by open pit/ug planning resources
- If any of the underground scenarios get beyond stoping study level, incorporate 3D modelling of sequence

1.3. Purpose of Upgrade Study

This study is to put in place a practical path forward to complete the investigations for an Underground Mine at Mt Carbine. The early scoping study done by Deswik by an experience underground mining engineer shows that the project has potential for a long life underground operation utilizing the higher grade narrow vein style mineralization.

The review is to put in place a meaningful mine life of 5 years initial that has drilled out indicated resources and sufficient test work completed to allow a BFS to be completed on the project.

The scope is to outline an 18 month work period for completion of

a. Resource drill out of 2.2Mt above 0.5% WO3
b. Completion of 700 of decline extension to understand ground conditions and access the main veins to be mined
c. Trial mining of 2 stopes to understand the parameters of mining for a Modified Avoca method.
d. Completion of a BFS on the Underground
e. Be ready for a mining start.

2. Geology & Geotech

2.1. Geology Relevant to Underground

Significant advances have been made on the Deposit Geology since mining began as follows

1. Continuity established. Veins pinch and swell but remain strong over distances of 3-500m. In several cases veins are close enough to form an aggregate ans of be mined at larger width above target 0.5% WO3
2. Grade is erratic and patchy but over a distance of 10s of meters we see that the averages of high gade are consistent. It is recommended that grade is indicated at 25m centers but established accurately at 10m centers. For the underground mining it is considered that the process of initiall 25m spacing will establish potential stopes and that grade control drilling by insertion of 4 additional holes will provide grade certainty (Measured)



.

Figure _ 2nd December, 2023 showing vein continuity. The planned new portal is at far end of pit and will be driven 300m into the hill (towards the right on this west facing picture)



Figure _ 2nd December photo of east end of Open Cut displaying continuous mineralized veins over 30m vertical.

2.2. Underground Geotech

The Ground Control Management Plan contains a summary of the background geology. The background information included in the May 2023 inspection report is repeated here so that this report can be read as a standalone report. A very good summary of prior geotechnical investigations is provided in Chapter 4 of The Mt Carbine Bankable Feasibility Study (2021). For the purposes of this review greatest reliance has been place on the two early reports: 1. Piteau & Associates' (1982) "Report on Slope Stability Analysis and Design of Open Pits". This report is based on 6 months of field work by a geologist and subsequent design analysis and recommendations from two world-recognised slope stability experts. It is an outstanding report.

The excellent condition of the existing pit void attests to the appropriateness of the Piteau recommendations and this review reaffirms their validity. 2. Golder Associates (1984) "Report to R.B. Mining Pty Ltd on Mt. Carbine Review of Rock Mechanics". This report pays particular attention to the proposed underground Mt Carbine, Inspection, 1/11/23, v0.1 3 gts-mcm-231101-inspcn-v0.1.docx last saved on 06/11/23 at 10:14 GeoTek Solutions Pty Ltd mining proposal and the transition from open pit to underground mining. It includes the results of seven post-Piteau diamond drill holes that were drilled during May – June 1984. Like the Piteau report, the Golder report was prepared by a world class rock mechanics expert.

The original data for both the Piteau and Golder reports appears to have been lost. Consequently, reliance has been placed on the tables and plots presented in those reports and the only way to delve into the data more deeply is to digitise plans, logs and plots and even then, the digitised information would be very high-level. As an example, the appended modified Piteau Figure 14 was developed by merging scanned and, current design data. A further report, HCOVG (2020) "Brief review and structural assessment/scoping of Iron Duke-Peteresens-MtCarbine EPM14872", focusses on the detailed structural geology and the sequence of geological events in and around Mount Carbine.

It is less directly relevant to the geotechnical issues. More recently, drilling by EQ Resources has produced core in which the orientation of the veins has been measured. The orientation data is contained within EQ Resources' database for drillholes EQ001 to EQ026. These data were compared with the results presented in the Piteau and Golder reports and found to be in strong agreement. Mine north is 50.6° east of MGA94z55

north i.e. the mine grid has been rotated approximately 51° anticlockwise from MGA94z55 north. The means to make this correction has been embedded in the spreadsheet “Grid Conversion to local.xlsx”.

In this report the local grid system will be referenced, unless otherwise stated, e.g. when referring to compass directions such as “north” this will mean north relative to local grid north.

3. Resources & Reserves

The terms and definitions outlined in the JORC Code have been adopted for the reporting of Mineral Resources. The JORC Code is published by the Joint Ore Reserves Committee of the Australasian Institute of Mining and Metallurgy, Australian Institute of Geoscientists and Minerals Council of Australia, and has been developed with the input of the Committee for Mineral Reserves International Reporting Standards.

The Competent Person responsible for the estimation and reporting of Mineral Resources for the Mt Carbine Tungsten Project, is Mr Christopher Grove, a Competent Person who is a Member of The Australasian Institute of Mining and Metallurgy. Mr Grove is a Principal Resource Geologist and a full-time employee of Measured Group Pty Ltd and has sufficient experience that is relevant to the style of mineralisation and type of deposit under consideration and to the activity being undertaken to qualify as a Competent Person as defined in the 2012 Edition of the JORC Code.

Mr Grove consents to the inclusion in this report on the matters based on his information in the form and context in which it appears. As per the requirement of the JORC Code, Table 1, Sections 1-3, has been completed for both the insitu and LGS orebodies and are provided in APPENDIX B: and APPENDIX C: respectively. The Mineral Resource estimate was finalised on 21 September 2021, which utilised geological data from 20,426 metres of diamond core drilling from 79 drill holes for the insitu orebody and bulk sampling from the Low-Grade Stockpile (Table 10-1). Grade vs tonnage classification is shown in Figure 10-1 and Table 10-2.

Diamond Drilling	Total holes	Total metres
Pre-2021 Drilling	63 Holes	16,355.55 m
2021 Drilling	16 Holes	4,068.30 m
2022 Drilling	10 Holes	2,121.9 m
Total	89 Holes	22,545.75 m

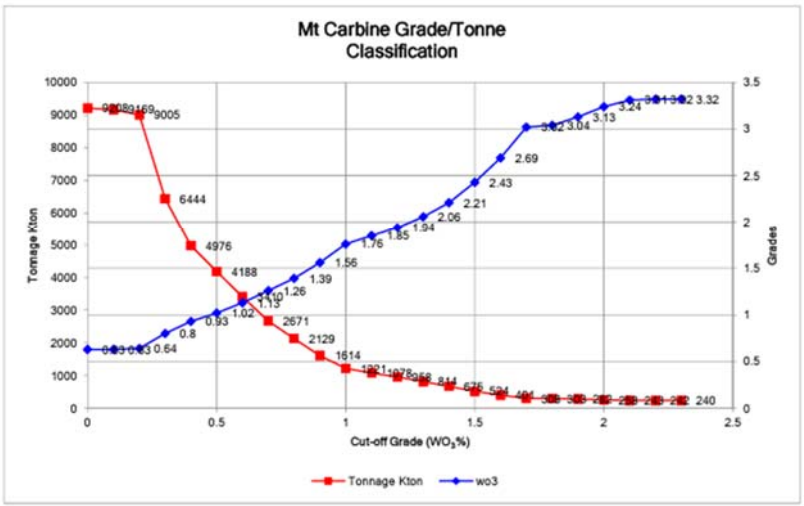
Table ____ History of Drilling Campaigns

Orebody	Resource Classification	Tonnes (Mt)	Grade (WO_3 %)	WO_3 (mtu)
Low-Grade Stockpile	Indicated	12	0.075	900,000
In Situ	Indicated	2.40	0.74	1,776,000
	Inferred	6.81	0.59	4,017,900
	Total	*9.21*	*0.63*	*5,793,900*
All	**Total**	**21.21**		**6,693,900**

1. Total estimates are rounded to reflect confidence and resource categorisation.
2. Classification of Mineral Resources incorporates the terms and definitions from the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (JORC Code, 2012) published by the Joint Ore Reserve Committee (JORC)
3. No uppercut was applied to individual assays for this resource, a lower cut of 0.15% WO3 was applied, which is the grade where the mineralisation forms distinct veins.
4. Drilling used in this methodology was all diamond drilling with ½ core sent according to geological intervals to ALS for XRF15b analysis.
5. Resource estimation was completed using Kriging Methodology.
6. Indicated spacing is approximately 30 m x 30 m; Inferred is approximately 60 m x 60 m.
7. The deposit is a sheeted vein system with subparallel zones of quartz tungsten mineralisation that extend for >1.2 km in length and remain open. At depth, the South Wall Fault cuts the Iolanthe to Johnson veins but the Iron Duke zones remain open to depth.

Table 10-1: Mt Carbine Resource Estimate, as at September 2021

Figure 10-1: Mt Carbine Insitu Mineral Resource Estimate Grade - Tonnage Curve



Cut-off (%)	WO3%	Tonnage Kton
0	0.63	9208
0.1	0.63	9169
0.2	0.64	9005
0.3	0.8	6444
0.4	0.93	4976
0.5	1.02	4188
0.6	1.13	3410
0.7	1.26	2671
0.8	1.39	2129
0.9	1.56	1614
1	1.76	1221
1.1	1.85	1078
1.2	1.94	958
1.3	2.06	814
1.4	2.21	675
1.5	2.43	524
1.6	2.69	401
1.7	3.02	308
1.8	3.04	303
1.9	3.13	282
2	3.24	258
2.1	3.31	243
2.2	3.32	242
2.3	3.32	240

Figure _ Tonnage Grade curve for Current Open Cut Table _ Grade tonnage for different cut-offs (Open Cut)

3.1. QA/QC SAMPLES

From the total 4,068 m of drilling completed in 2021, 1,404 samples were sent to ALS laboratory in Brisbane. Standards and blanks were included in all batches sent for assay.

The total number of standards and blanks inserted into this assaying programme was 146 samples comprising just over 10.2% of the samples submitted, comprising the following: − 79 tungsten sample standards were analysed on a 1 in 20 basis; and − 67 blank samples were tested inserted on a 1 in 20 basis. 7.2.1

3.1.1. STANDARDS

During the 2021 drilling campaign, a total of 13 standards were assayed to assess the reliability of the laboratory. Standards were inserted at random into sample batches using one standard (MC-3), which represented a bulk sample taken from the LGS, with an average grade of 0.225% WO3.

The errors were within a 3% margin for all QA/QC standard results with the likely variation being that stated variation within the standard itself. The checks showed there was little drift or error in the results determined by the laboratory. The standards assay results were well within the allowed ±10% range of the expected values. Table 7-1 shows the Certified Reference Material (CRM) used in the current exploration program. Table 7-1: CRM Used in the 2021 Exploration Programme

3.2. Reasonable prospects for eventual economic extraction

EQR has completed and is completing various studies on the Mt Carbine orebodies to assess the viability and economics of maintaining the current operations and developing future mining domains in the deeper orebodies. The results of work completed for Mt Carbine is assisting EQR in refining the current plan for the ongoing studies for the Mt Carbine Open cut and Underground project. EQR has multiple paths to continue to mine and develop future mining domains in the various orebodies at Mt Carbine. Measured Group is satisfied that there has been sufficient study, economic analysis, and the opportunity to apply technological developments in mining methods to meet the reasonable prospects for the eventual economic extraction (“RPEEE”) test. Currently, there is a reasonable basis to assume the Mineral Resource estimated for Mt Carbine orebodies will be mined in future.

3.3. Model Validation

Validation of the block model was made by: − Checking that drill holes used for the estimation plotted in expected positions; − checking that flagged domains intersections lay within, and corresponded with, domain wireframes; − ensuring whether statistical analyses indicated that grade cutting was required; − checking that the volumes of the wireframes of domains matched the volumes of blocks of domains in the block model; and − checking plots of the grades in the block model against plots of drill holes. Historical estimates were examined and the comparisons were similar yet inconclusive due to the 'discreet' style of geological interpretation in this estimate compared to the larger, all-encompassing lower grade style previously.

3.4. Drilling for Underground Resources

The company has remodeled resources twice since the Deswik Analysis with the current model based on broader shapes for larger tonnage Open Cut investigations. The current resources released on 13th February, 2023 is :-

Orebody	Resource Classification	Tonnes (Mt)	Grade (%WO_3)	WO_3 (mtu)
Low-Grade Stockpile	Indicated	10.126	0.075	759,450
In-Situ	Indicated*	2.75	0.07	178,517
	Inferred*	0.83	0.06	53,789
	Subtotal	***13.71***	***0.07***	***991,756***
	Indicated**	18.06	0.30	5,405,901
	Inferred**	10.68	0.30	3,217,311
	Subtotal	***28.74***	***0.30***	***8,623,212***
All	**Total**	**42.45**		**9,614,968**

Notes:

1. Total Estimates are rounded to reflect confidence and resource categorisation
2. Classification of Mineral Resources incorporates the terms and definitions from the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (JORC Code, 2012) published by the Joint Ore Reserve Committee (JORC)
3. No uppercut was applied to individual assays for this resource; lower cuts of 0.05% & 0.08% WO3 were applied to the resource and reported as Low Grade Insitu and In Situ respectively. These cuts are where mineralisation forms distinct vein zones. Material from 0.05-0.08% WO3 is to be allocated to the LGS until required for blending purposes.
4. Drilling used in this methodology was all diamond drilling with 1/2 core sent acoording to geological intervals to ALS for XRF-15b analysis
5. Resource estiamtation was completed using the Kriging Variable Orientation Estimation Methodology
6. Indicated spacing is approximatley 30 x30m inferred is approximatley 60 x 60m.
7. The deposit is sheeted vein system with subparrallel zones of quartz tungsten mineralisation that extends for >1.2km in length and remains open to the west and north. At depth the South Wall Fault cuts the Iolanthe to Johnson's veins but the Iron Duke zones remain open to depth.

Table _ February, 2023 Mineral Resource Estimate for Mt Carbine

Table 2: Mt Carbine Low Grade Stockpile Ore Reserve Estimate 1st May 2023

RESERVE CATEGORY	ROM TONNES (Mt)	WO_3 %
LGS - Proved	-	-
LGS - Probable	9.77	0.075%
LGS - Total	**9.77**	**0.075%**

Table 3: Mt Carbine Open Pit Ore Reserve Estimate 1st May 2023

RESERVE CATEGORY	ROM TONNES (Mt)	WO_3 %
Open Pit - Proved	-	-
Open Pit - Probable	5.93	0.28%
Open Pit - Total	**5.93**	**0.28%**

Table _ Open Cut Reserves for the 6 year mine life model currently being implemented .

Cost Item	Units	Unit Cost
Drill & Blast	$/t	$1.26
Waste Mining	$/t	$3.27
Ore Mining	$/t	$3.30
Crushing\Screening	$/feed t	$2.00
Ore Sorting	$/feed t	$1.49
Gravity Plant	$/feed t	$12.45
Rehabilitation	$/total t	$0.26
Contractor Overheads	$/total t	$1.34
State Royalty	% of revenue	2.70%

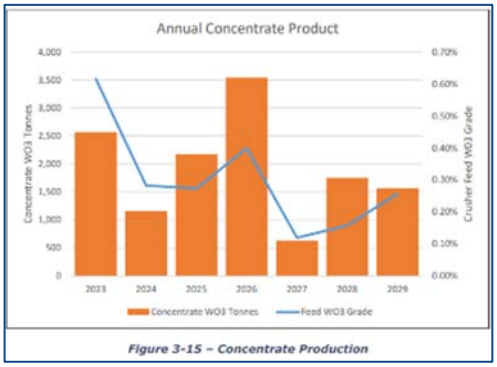


Figure 3-15 – Concentrate Production

Table _ Costings used in BFS for Open Cut. *Figure _ Concentrate Production on Current Mine plan*

Revenue assumptions are based on the forecast for ammonium paratungstate (APT) price of US$340 per mtu (metric tonne unit, 1mtu=10kg) with a AUD:USD exchange rate of 0.73 applied. This equates to US$12,240/concentrate tonne produced on site based on the concentrate being 50% WO3 grade and 72% of the WO3 in the APT is payable ($340 * 100mtu/tonne * 50% * 72%).

The final assumed realised price for each tonne of 50% WO3 concentrate is AU$16,767 for the pit optimisation work. This Open Cut Resources defines how much remaining ore exists and gives us parameters of costs for our modelling. (i.e. Plant & Administration costs will largely remain unchanged with an underground model and real costs of labour etc can be used from the existing modelling.

3.5. Potential Underground Resources.

Once the reserves for open cut mining have been taken out of the reserves we find we have

22.81Mt @ 0.3% WO3 left in resources from which to draw the required ore tonnes needed to sustain an underground operation. If we look at the grade verses tonnage curves and use the 0.25% WO3 as our cutoff we have a total of

12.78Mt @ 0.48% WO3 at 0.25% WO3 lower cutoff.

Cut-off (WO_3)	Tonnes	Grade (WO_3)	WO_3
(% WO_3)	(Mt)	(% WO_3)	(mtu)
0	35.83	0.25	8,957,737
0.05*	32.33	0.27	8,855,518
0.08**	28.74	0.30	8,623,212
0.1	26.53	0.32	8,423,949
0.15	21.32	0.36	7,774,790
0.2	16.61	0.42	6,952,182
0.25	12.72	0.48	6,079,893
0.5	3.37	0.85	2,878,938
0.75	1.30	1.25	1,634,882
* Cut-off used to define Low Grade Stockpile (0.05-0.08% interval)			
** Cut-off used to define ROM Stockpile (>0.08% WO_3)			

Table __ Grade cutoff variation table for February Resource Model showing tonnes and grades at each cut.

The model entertained in this upgrade scoping study is using the cutoff chosen by the Deswik Modeling Crew at 0.25% WO3 but instead of being scattered across the orebody additional drilling has shown there is two potential high grade zones identified as high priority areas..

- Iron Duke System (Johnson, Dazzler, Talis, Crowne vein systems) north of the current pit or
- Western Extensions where the down dip plunge of the ore body was located.

Each of these areas has the potential to bring together more than 2Mt of high grade ore (>0.5% WO3) with the Iron Duke zone have more drilling than the western extensions. The target is to get the ore in as tight a zone as possible to keep development costs to a minimum. The Icon concept was chasing the Iron Duke System and significantly less development than what as done up as a model by Deswik which undertook a large entire resource scope, Shown here in the yellow boxes in the figure below.

Appendix 1 shows the intercepts of high grade in Mt Carbine Deposit and also indicates the Metal Value (Grade x Meters) with cutoff for stope blocks being 0.5% over a minimum of 2m ie Metal value above 1.

NON JORC REVIEW OF POTENTIAL										
	Vein	Intv.	East	North	Length	Vertial	m	Tonnes	Grade	Metal Factor
Main Area	Iolanthe	16	22475	22990	515	80	4.17	464,100	0.73	2.63
	Bluff	39	22475	22975	500	150	3.26	658,722	0.99	3.16
	Waybak	23	22475	22975	500	215	2.93	849,708	0.85	2.17
	Johnson	30	22652	22975	323	250	3.58	779,805	0.82	2.98
							3.49	**2,752,335**	**0.78**	**3.14**
Under Drilled	Dazzler	46	22536	22974	437	250	2.46	724,970	0.74	1.68
	North 1	52	22501	22900	399	250	2.14	576,700	0.63	1.27
	North 2	24	22561	22752	191	250	2.41	310,711	0.84	1.82
							3.05	**4,364,716**	**0.75**	**1.56**

Table _ Summary of individual veins showing widths and average grade for planning purposes.

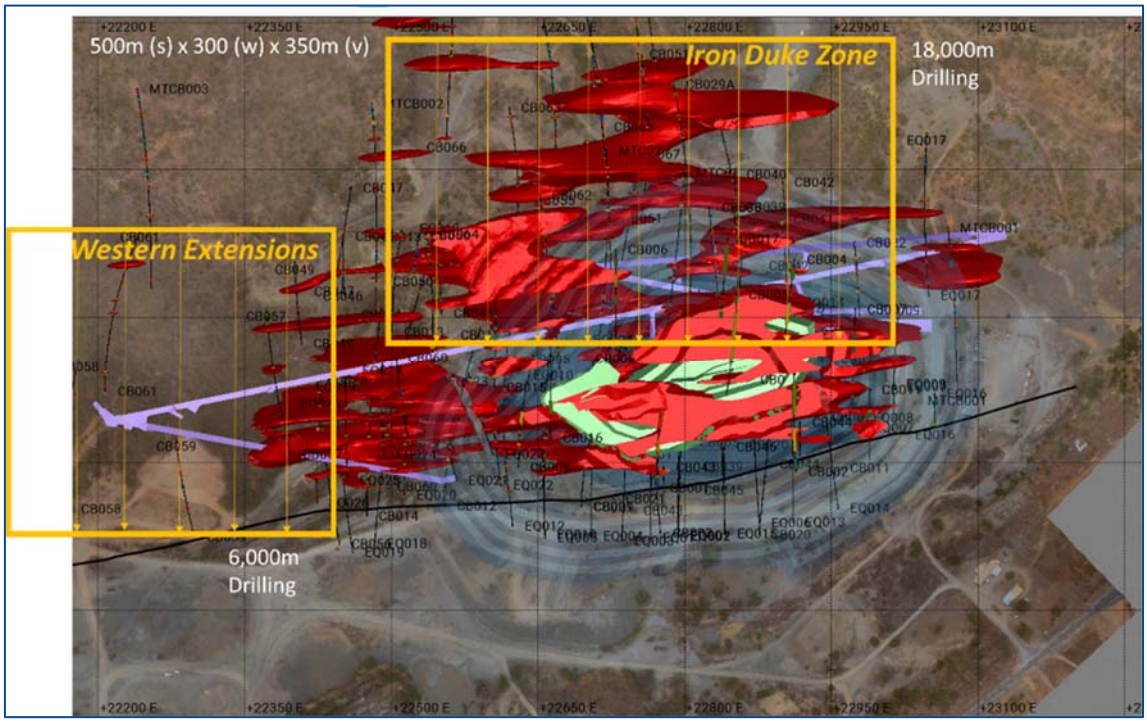


Figure _ Location of the two drill zones to be investigated for underground potential.

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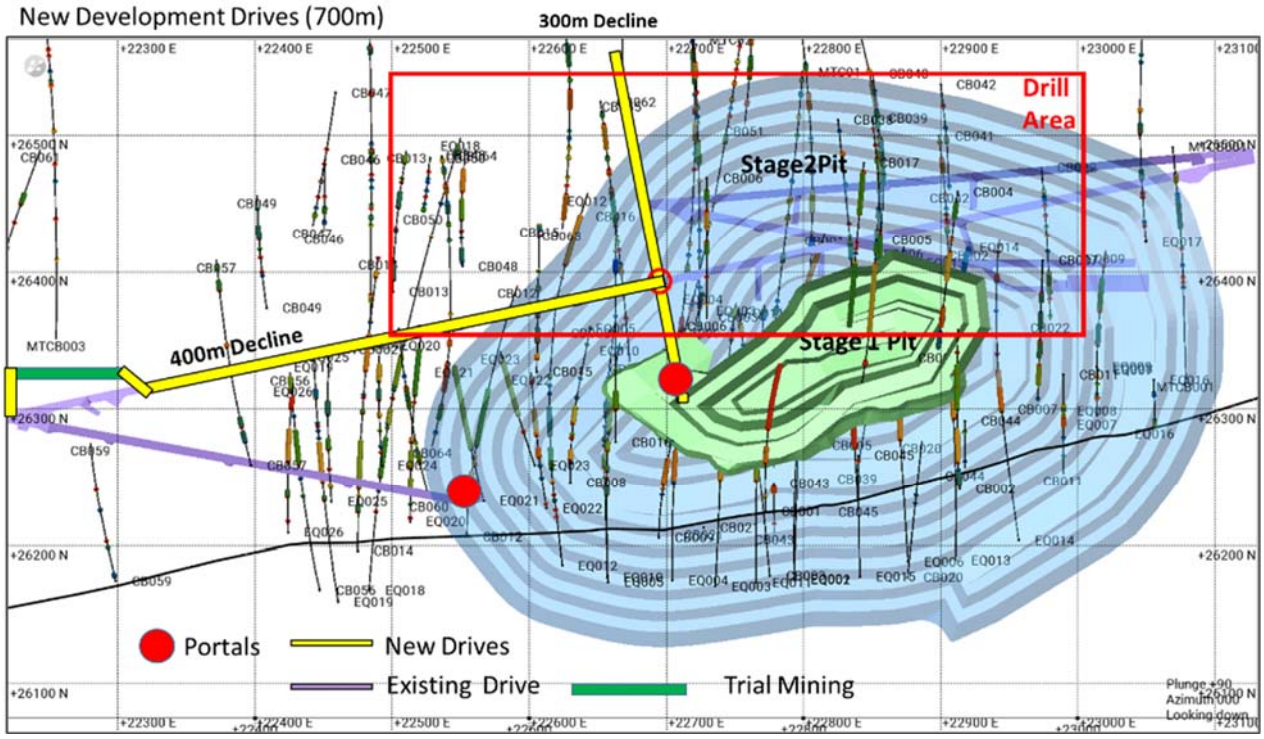


Figure __ Location relevant to the Planned Stage II Open Cut.

3.6. Drilling Required.

A total of 24,000m of drilling is required to bring 2.2Mt of underground resources into Indicated Category. This drilling is scheduled to be completed using an LM75 Underground Rig on a daily contract rate.

Drilling costs are planned at $120/m on contract with expectations of drilling taking 1 year to complete including drilling 6,000m from Underground (Existing decline). This is a total planned cost of $2.88M.

Drill spacing of 25m is targeted in each area of 500m strike 300m vertical and 2.25m width will give approximately 1Mt. We have several parallel systems and require a total of 2 veins of this dimension to give us our target tonnage.

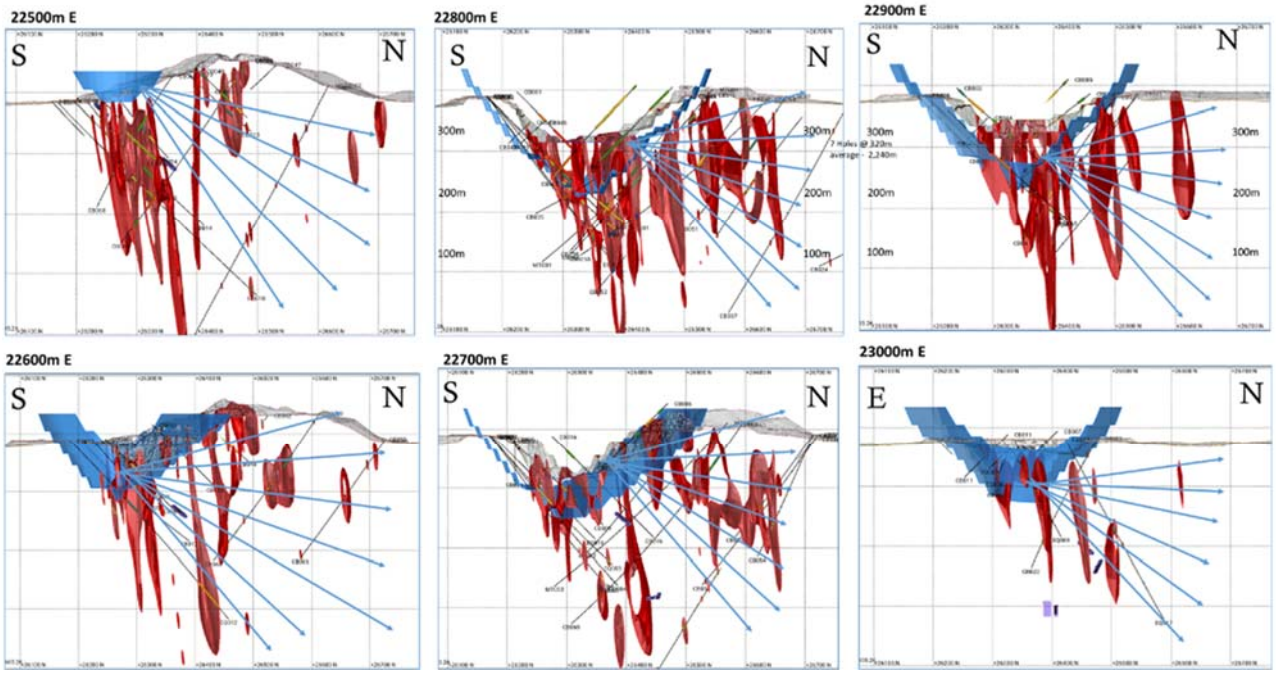


Figure __ 500m strike along the Iron Duke system showing multiple targets for resource definition. Drilling is to be undertaken from drill cuddies in the pit.

4. Underground Re-modelling

4.1. Assumptions

1. Assume we can define into Indicated Category +2Mt of ore in a defined single area (Iron Duke shows the greatest potential)
2. Assume a target tungsten price of US$320 per APT Mtu
3. Assume a 10% dilution during mining process
4. Assume water pumping costs are reasonable.
5. Power to be supplied by Grid power
6. Exchange rate of 0.65 for USD / AUD
7. Jumbo can deliver 220m of ore drive per month on double daily blast schedule. Two Jumbos and a Long Hole Rig (250m per day) are required.
8. Assume trucks haul from no further than 1km underground. Same trucks can deliver ore to ROM pad.
9. Suitable workforce is available as required for owner operator fleet and rates are similar to todays rate
10. Diesel is $2 per litre.
11. Assume blasting is undertaken by Orica from Port Douglas.
12. 16.25km of tunnel costs for owner operator are $5,200pm for 5.0 x 5.0m decline & $3,300 for 3.5 x 3.5m Ore drives for total development cost of $63M
13. Ventilation is $2000 per meter for raise bores.

Project Name:	Mt Carbine UG Scoping Study	
Project Start Qtr	Q1, 2023	
Project Start Yr	1905	
Revenue	**Units**	
FOREX	AUD:USD	0.65
Final Concentrate	%WO_3	50.00
APT Price	USD/mtu	320.00
- concentrate payable component	%	0.720
Concentrate revenue	USD/mtu	$230.40
APT (50% WO_3)	$USD/t conc	$11,520
	$AUD/t conc	$17,723
Quarry Product	$AUD/t	$0
State Govt Royalty	% of gross value	2.5%
Site Consumable Costs	**Units**	
Power	kWhr	0.15
Diesel	$/L	1.80
Site Processing Costs	**Units**	
Dry Processing Cost	$/t ROM feed	2.00
Ore Sorter Gravity Cost	$/t ROM feed	1.49
Gravity Processing Cost (incl. tail mgmt)	$/t wet plant feed	12.45
Other Site Overheads	$/t ROM feed	0.00
Return Travel Cost (to site)	$/flight	$500
Messing & Accomodation Cost	$/man day	$100
UG Ventilation Demand	m3/s per kW	0.05

Table_ Mine Parameters used in scoping modelling

Fleet Requirements

Used	1 x Sandvik 220 Jumbo (Set up for rock bolting)
	1 x 10t Sandvik Dump Truck
	1 x 1500 Sandvik Scooptram 3m^3 bucket
New	2 x Sandvik Jumbos for drill & blast
	2 x Sandvik Scooptram 5m3 buckets

3 x Sandvik 40t UG Moxy trucks
1 x Scaling & 1 x Maintenance Trucks.

Development Capital			Owner Operator	
Total Development Costs		Three veins	Cost / m	Subtotal
400000	tonnes per year	400,000		
	tonnes per stope	3,699		
	No of stopes	108		
	area per stope	600		
	strike of veins	500		
	vertical extent	250		
	No of stopes per level	3.0		
	Stope Width Average	2.3		
	Specific Gravity Ore	2.74		
Decline	Exploration Decline	700		
Decline between levels (m)	20 levels @ 140m / level	2,800		
Total 5 x 5m drives (m)	Total of declines	3,500	$5,200	$18,200,000
Ore drives (m)	Top & Bottom Stopes	11,250	$3,300	$37,125,000
X cuts / Level (m)	Decline to Draw Points	1,500	$5,200	$7,800,000
Development Cost per 400,000t (3 veins)				**$63,125,000**

Table _ Summary of 5 yr development drives and costings.

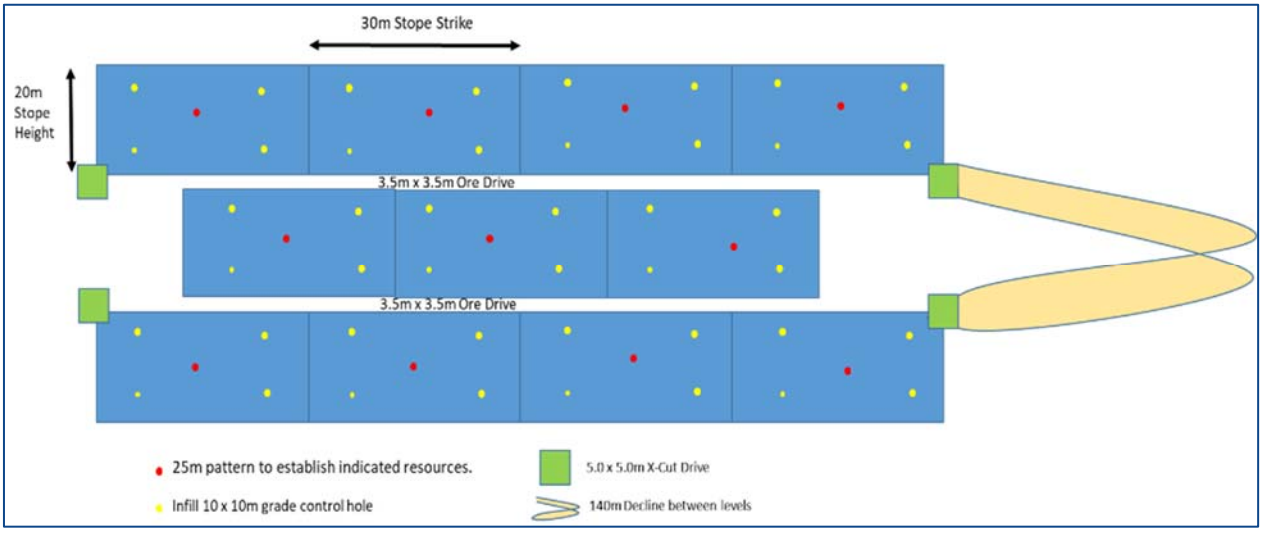


Figure _ Concept Design of Modified Advoca Stopes (30m x 20m) showing two stage drill out.

4.2. Processing Rate

Target is to ramp up to 400,000tpy over 3 years once approval has been made. Year 1 is 800tpd rate using fleet and development of a stope every 4 days. Constraints are with the Jumbo doing developments and ore drives with each Jumbo scheduled for 220m per month (500m total driving per month). Each Stope requires 60m ore drives and 20m of non ore development.

5-6 stopes are planned with a total of 20-21,000t of ore being mined each month

4.3. Cash flow

Based on a 2 year development including commissioning and a 5 year mine life it is estimated the project has the following financials (Scoping level)

Evaluation Expenditure	$ 12.0m (18 months)
Gross Revenue	$265.0m
Operating Costs	$ 30.1m
Capex Costs including UG Development	$ 86.9m (over 5 years)
Development Costs	$ 68.2m (over 5 years)
Administration	$ 4.5m
Pre Tax Cash flow	**$138.1m**
NPV	
IRR	

Mt Carbine UG Scoping Study - CASHFLOW ANALYSIS

exchange rate	0.65	2,024	2,025		2,026	2,027	2,028	2,029	2,030	TOTAL
		Testing & Development		Commissioning	Year 1	Year 2	Year 3	Year 4	Year 5	
Ore Mined (to ROM)	t	0	0	120,000	250,000	350,000	400,000	420,000	450,000	1,990,000
Grade	%WO_3	0	0	0	0	1	1	1	1	1
Contained Metal	mtu	0	0	48,000	112,500	182,000	208,000	218,400	234,000	1,002,900
Total Wet Plant Feed (mtu)	mtu	0	0	46,176	108,225	175,084	200,096	210,101	225,108	964,790
Concentrate Grade (%WO3)	%WO_3	0	0	50	50	50	50	50	50	300
Recovered Concentrate (mtu)	mtu	0	0	36,941	86,580	140,067	160,077	168,081	180,086	771,832
Recovered Concentrate Tonnes	t	0	0	739	1,732	2,801	3,202	3,362	3,602	15,437
Reliased Price - APT - USD$320 (50% WO_3)	$17,169	0	0	17,169	17,169	17,169	17,169	17,169	17,169	17,169
Revenue	$AUD	0	0	12,684,902	29,730,240	48,096,922	54,967,910	57,716,306	61,838,899	265,035,180
Mine Operating Cost (incl. processing etc @ $15.5/t)	$AUD	830,459	1,515,000	837,120	1,744,000	2,441,600	2,790,400	2,929,920	3,139,200	16,227,699
Dry Processing Cost	*$/t ROM feed*	*0*		*240,000*	*500,000*	*700,000*	*800,000*	*840,000*	*900,000*	*3,080,000*
Ore Sorter Gravity Cost	*$/t ROM feed*	*0*		*178,800*	*372,500*	*521,500*	*596,000*	*625,800*	*670,500*	*2,294,600*
Gravity Processing Cost (incl. tail mgmt)	*ft wet plant fee*	*0*		*418,320*	*871,500*	*1,220,100*	*1,394,400*	*1,464,120*	*1,568,700*	*5,368,440*
Admin & Wages Costs	$AUD	0	0	837,120	1,744,000	2,441,600	2,790,400	2,929,920	3,139,200	13,882,240
Other Site Overheads	$/t ROM feed	0	0	0	0	0	0	0	0	0
Total Opex	$AUD	830,459	1,515,000	1,674,240	3,488,000	4,883,200	5,580,800	5,859,840	6,278,400	30,109,939
Operating Cost ($/t - ore)	$/t	0	0	14	14	14	14	14	14	14
Operating Cost ($/mtu - produced)	$/mtu	0	0	198	238	161	147	141	132	152
Drilling, FS, Trial Mining	$AUD	3,460,000	7,030,000	1,200,000						11,690,000
Underground Development, Drives, Decline, X- Cuts	$AUD		1,735,000	2,195,000	13,110,000	12,910,000	12,910,000	12,760,000	12,625,000	68,245,000
Equipment Capital Cost	$AUD	0	604,722	389,445	2,127,225	2,336,670	2,336,670	2,336,670	1,947,227	12,078,629
Processing	$AUD			620,000	1,291,667	1,808,333	2,066,667	2,170,000	2,325,000	10,281,667
Administraiton	$AUD	600,000	600,000	300,000	600,000	600,000	600,000	600,000	600,000	4,500,000
Total Capital	$AUD	4,060,000	9,969,722	5,647,404	17,128,892	17,655,003	17,913,337	17,866,670	17,497,227	86,955,454
Total Expenditure	$AUD	4,290,459	9,149,722	7,321,644	20,616,892	22,538,203	23,494,137	23,726,510	23,775,627	123,437,160
Op Cash Flow	$AUD	-830,459	-1,515,000	11,010,662	26,242,240	43,213,722	49,387,110	51,856,466	55,560,499	234,925,241
Op Cash Flow including Capex		-4,290,459	-9,149,722	3,689,018	5,625,348	20,675,518	25,892,974	28,129,956	31,784,872	127,273,720
Royalties	$AUD	0	0	317,123	743,256	1,202,423	1,374,198	1,442,908	1,545,972	6,625,879
Net Profit Before Tax	$AUD	-4,290,459	-9,149,722	3,689,018	5,625,348	20,675,518	25,892,974	28,129,956	31,784,872	115,797,686
Tax	$AUD	0	0	1,106,705	1,687,605	6,202,655	7,767,892	8,438,987	9,535,462	34,739,306
Net Profit After Tax	$AUD	-4,290,459	-9,149,722	2,582,313	3,937,744	14,472,863	18,125,082	19,690,969	22,249,411	67,618,200
Net Cash Flow Exc. Tax	$AUD	-4,890,459	-11,484,722	-11,484,722	8,370,092	24,356,295	30,099,576	32,546,888	36,517,300	138,113,787
Net Cash Flow Inc. Tax	$AUD	-4,890,459		-9,149,722	6,682,488	18,153,640	22,331,684	24,107,901	26,981,838	84,217,370

5. Phases of Development

The study highlights what it would take to bring this project up to BFS stage so a decision on mining can occur.

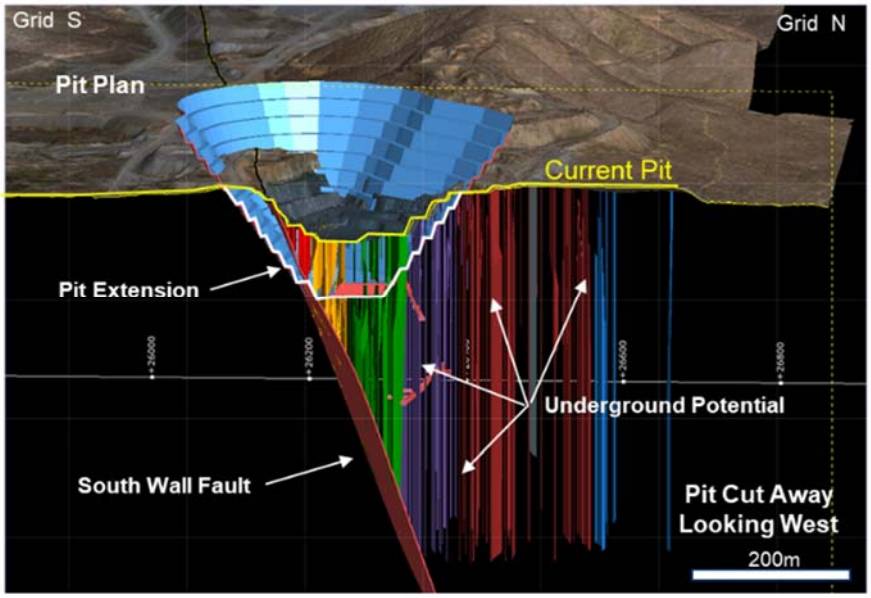


Figure 2: Pit Cross Section Depicting Underground Potential

The phases of development going forward are as follows:-

5.1.1. Phase 1 : Resources - Drilling and opening of existing portal

A planned program of 24,000m of drilling has been designed to bring 2.2Mt of Inferred ore into indicated ore category for Feasibility Purposes. This is drilling of 25m spacing over a 350m strike and 300m vertical on the basis we see at least 3 high grade veins namely :- Ruby, Dazzler and Crowne veins.

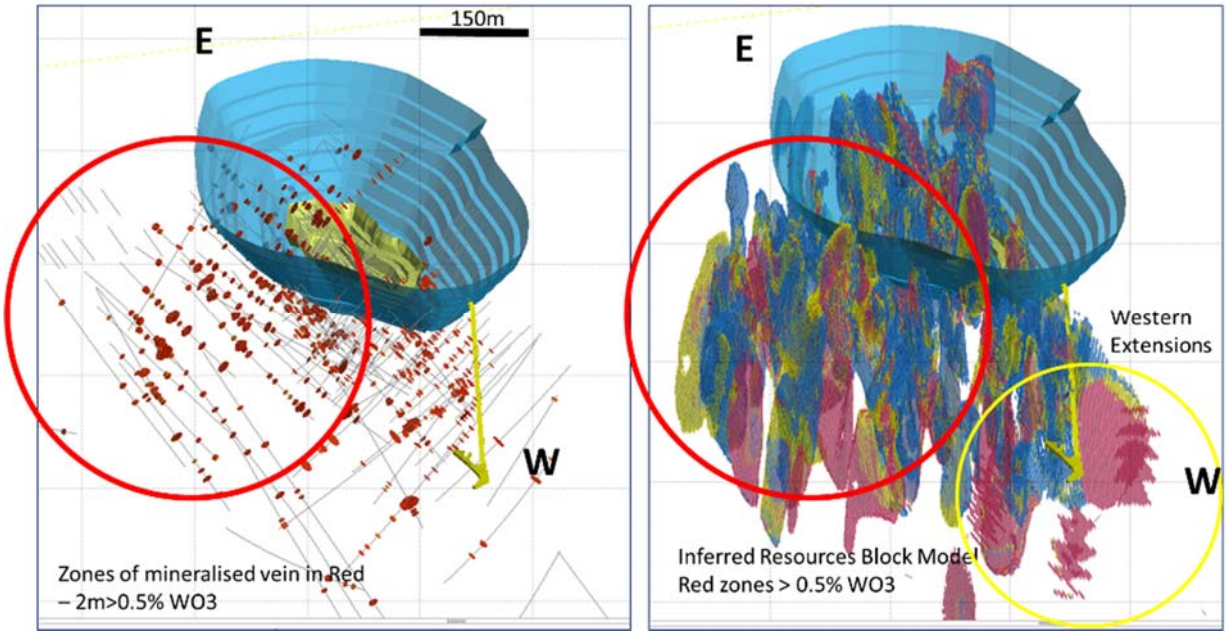


Figure _ Targeted zone for drilling out inferred resources to indicated resources.

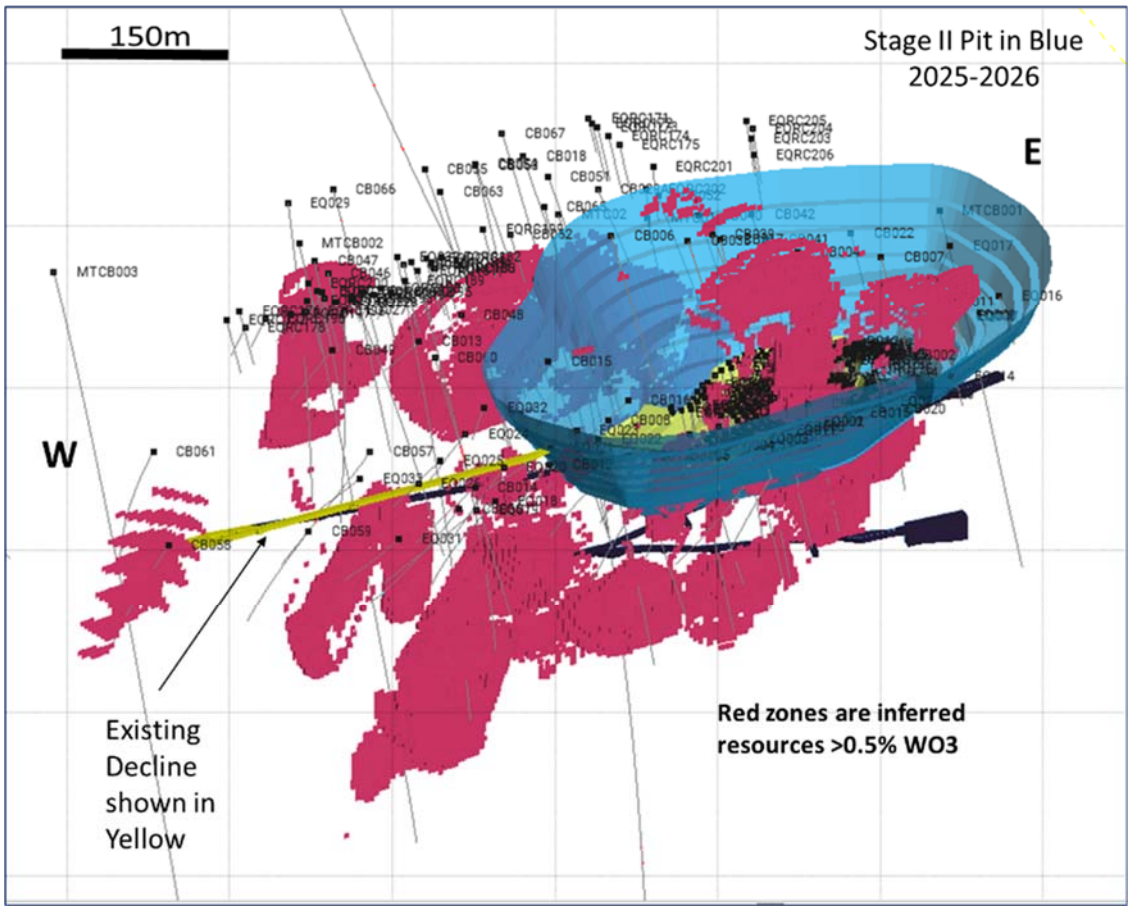


Figure _ High grade zones shown in model. The patchy zones are due mainly to lack of continuous drilling.

The ruby has been drilled down to 40m from surface in a RC campaign in September, 2023 and results indicate the following -Strike 450m; Width 2.5-4m; Grade 0.4-2.2%m

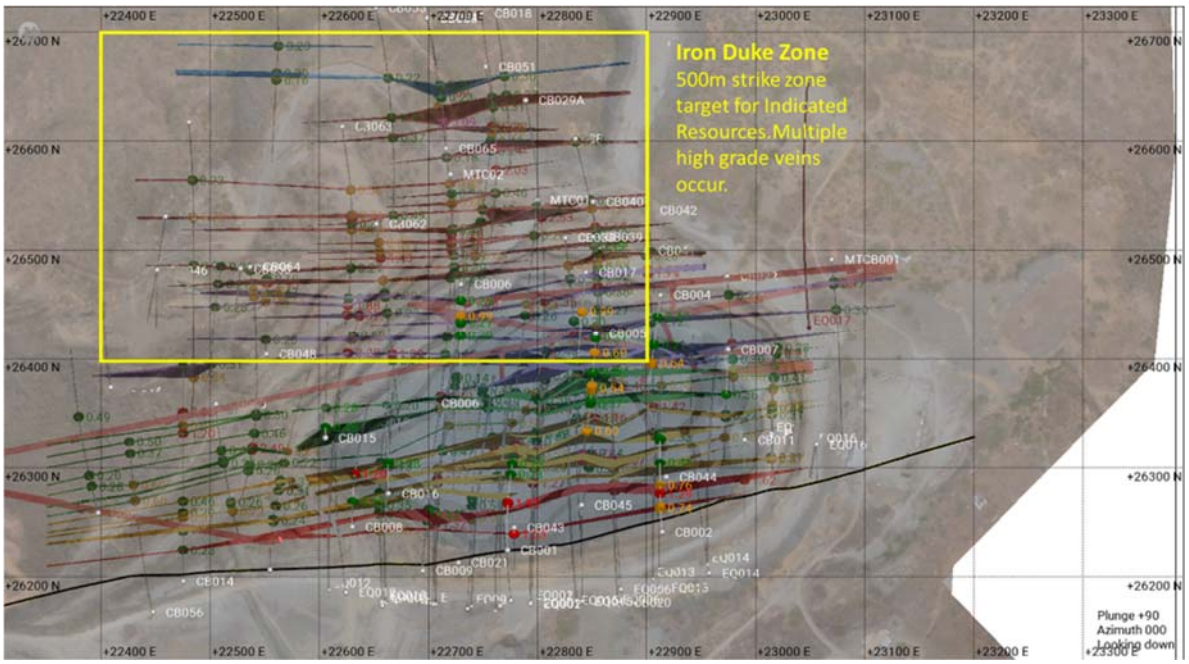


Figure_ Diagram showing the individual veins in the target drill out area relative to the current pit.

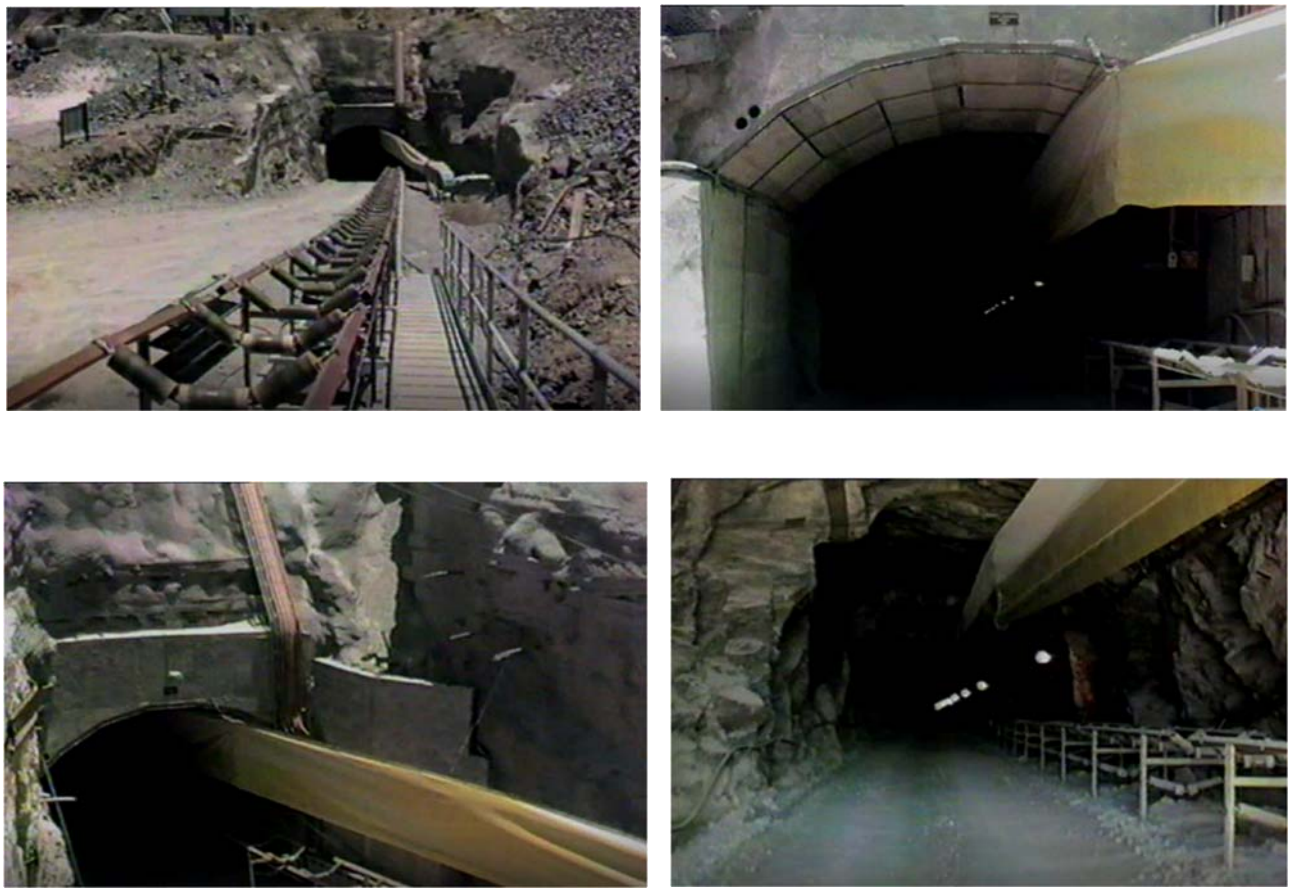


Figure _ Historical photos of decline showing conveyor and excellent dry ground conditions

5.1.2. Phase 2 New Portal and complete 2nd Egress.

Completion of 700m of new underground declines to lin the new portal within the pit to the existing underground workings. A further 6,000m of underground drilling to be undertaken during this phase. Geotech and water management plans to be investigated and implemented.

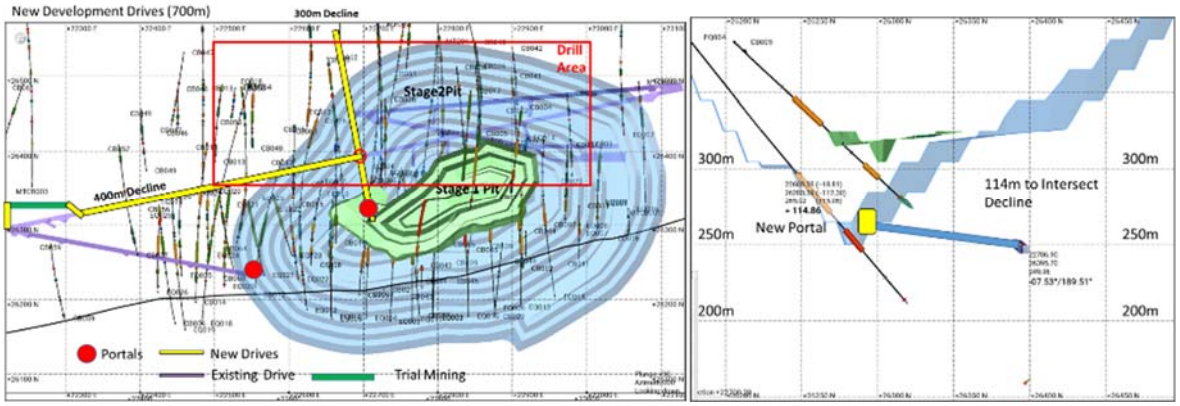


Figure _ Planned design of new decline and connection to open cut. Target area shown in Red.

This phase is to be undertaken by contract mining using EQR,s fleet of new equipment (Jumbos, Scoop tram & Trucks). Development of personnel and integration of the Company's safety policies etc.

5.1.3. Phase 3 Trial Mining

The company sees it necessary to undertake a trial mining phase of at least 2 stopes to establish continuity, reconcill the drilling and establish safety controls. The issues of ore grade continuity will be investigated by

trial mining of stopes and establishment of what drill spacing is necessary to give reliable results for the Stope Grade.

The trial mining will involve the installation of top and bottom drives that will be trialed as the smaller 3.5 x 3.5m size and establishment of long hole drilling practices. The minimum mining of width of 2m will also be established and blasting trials will also be required to understand the powder factors and resulting comminution.

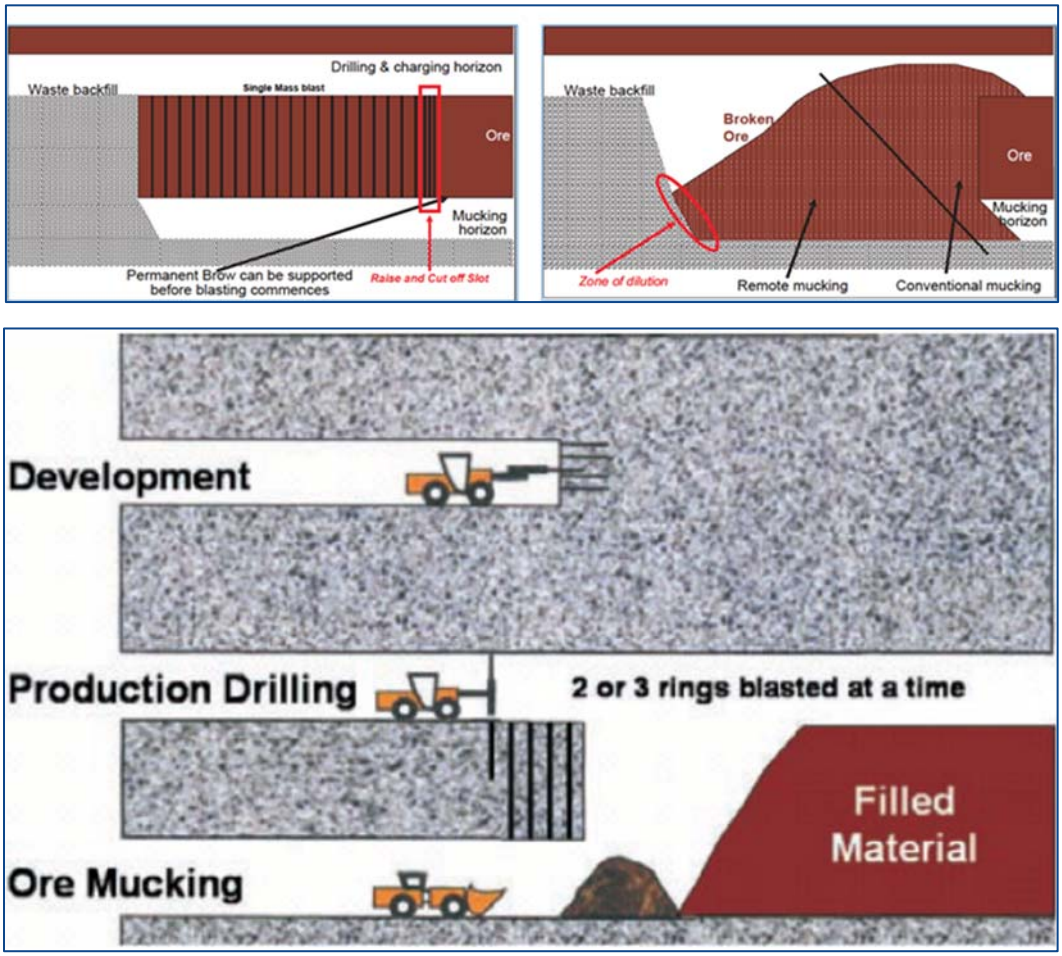


Figure _ Schematics of Modified Avoca Mining Method. This method offers the best way to change designs on the fly. Width and panel dimensions can be planned for the ore body shape. Good for 1-4000tpd narrow vein mining methods.

As part of this investigation proposal for Mt Carbine it is necessary to conduct some trial mining stopes to assess the viability of the Modified Avoca method. This will be determined by local ground conditions and grade continuity.

Pros & Cons of Modified Avoca Stoping

Pros

- Less time to complete the stope.
- Reduced exposure of workers to stope edge.
- Whole stope is drilled out in one campaign.
- If the stope is backfilled in one campaign then only the one access is required.
- Blast-holes break through into the level below, allowing drill accuracy to be checked.
- Drill penetration rate will be higher (less damage).
- Usually only two production blasts required.
- Low re-drill requirement.
- Reduced requirement for remote mucking (50%).
- Better fragmentation.
- Reduced dilution compared with Avoca method.

Cons

- Production blasting can't commence until production drilling is complete and mucking brow is supported.
- A slot raise is required for each stope.
- Increased requirement for accurate drilling and raise reamer holes (uncharged void holes).
- Requires exact detonator timing and use of electronic detonators and highly trained supervision or mining engineer.
- Still some dilution from the mixing of the backfill with the broken ore.

6. Conclusions

- The project has great potential and needs to be brought into a resource category that a Feasibility can be completed on. This report outlines the steps to evaluate the ore body for a 5 year underground mine life and the timing for this to occur.
- The resources are currently inferred (MRE, Feb, 2023) and need to be brought up to indicated category by completing a 24,000m diamond drilling program. Most of 2024 is planned to complete this drilling from the existing pit and underground declines.
- If 2.2Mt of indicated resource can be defined above 0.5% WO^3, a detailed Feasbility Report is recommended to investigate suitability for a 5 year mine underground operation. (Mining a total of 1.1Mmtu).
- The resources remaining after this would still be more than 60% of the known inferred deposit as it stands today.
- An estimated $12m is required to complete the Phases 1 – 3 which would bring this mine up the production ready point. The keys to success on this study are

  1. Resource Definition completed
  2. Installation of 700m of new decline to provide underground drilling access.
  3. Trial mining to establish mining method, grade continuity and geotechnical aspects of the mining

- Approximately $15m of sustaining capital is required per year for development works and equipment requirements.
- The 5 year mining plan would generate around 3,000t of concentrates and has a total pre-tax net revenue of $138M.

7. Appendix

7.1. Environment & Governance ESG.

7.1.1. Current Perspective

ESG has grown in prominence thanks to capital investment pressures, heightened consumer and stakeholder expectations, and global regulatory pressures for greater ESG reporting disclosures. Underpinning this is the broad realisation that its relevance in not only about addressing climate change, but also providing organisational long-term performance insights, both operationally and financially. ESG is not a separate business strategy, but the application of shared values and principles that realise commercial benefit whilst achieving positive social and environmental outcomes.

7.1.2. ESG Maturity

EQR appreciates the opportunities that an ESG focus can provide. As a resource efficient, value-oriented and resource critical mining company of the future, EQR has already aligned its purpose, mission, and values with some high level ESG objectives. The Company aims to contribute to sustainable development and align to United Nations Sustainable Development Goals, refer Table 2.

EQR defines their ESG adoption profile as an 'early adopter'. Existing ESG environmental initiatives include:

The implementation of a new waste sorting technology;

A review of pollution prevention treatment options; and

Ongoing participation in a pilot greenhouse gas (GHG) emissions tracking scheme in partnership with the University of Queensland.

They also have several 'S' centric employee attraction and retention programs underway centering on improving employee diversity and capability within the organisation. Additionally, EQR sponsor a range of community programs and events, engaging regularly and collaboratively with the community to develop initiatives that positively impact employees and the local community.

- Table 2: EQR ESG Alignment with United Nations Sustainable Development Goals (SDG)

ESG Framework SDG Alignment		
Environment	We are committed to embedding and embracing resource efficiency in our operations. As a producer of a new economy critical mineral, we aim to minimize our impacts on the environment and prevent degradation through the optimal extraction of tungsten from a secondary source and through the integration of advanced processing technology.	
Social	Safety is a core value and a strategic priority, and we are committed to promoting and enhancing a safety culture in our operations. Our commitment to society includes promoting workforce diversity and inclusion, empowering local communities through creating employment opportunities, sourcing materials locally where possible and investing in our employees and communities for social development.	
Governance	As a value-oriented resources company, we are committed to acting in a transparent, accountable, and responsible manner in all our business dealings and operations.	

Through active engagement with local communities, environmental experts, and supply chains, EQR is building solid credentials for the future. Underpinning a philosophy of pragmatism and effectiveness, EQR has taken a multi-process approach including:

- Working sessions with the Leadership Team on purpose, core values and key principles;
- Revision of the Risk Management Policy; and
- The completion of an independent ESG Stakeholder Sentiment Survey and ESG status report.

7.1.3. Stakeholder Sentiment

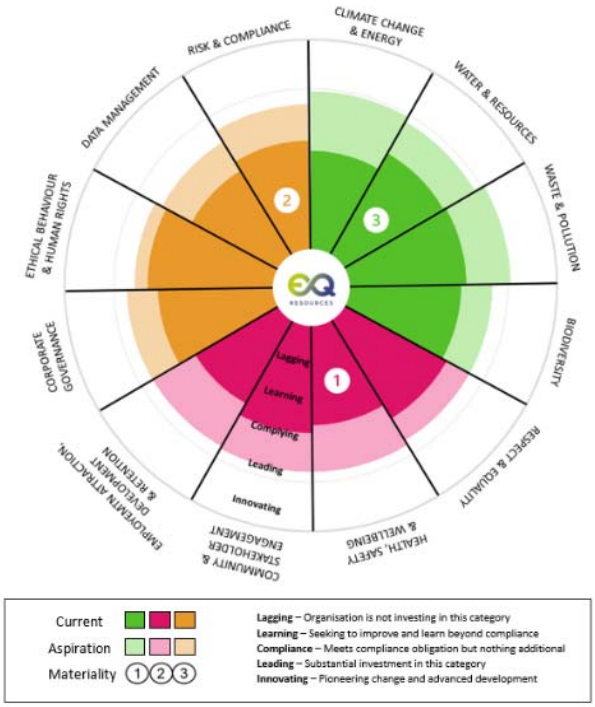
An ESG Stakeholder Sentiment Survey was disseminated to 22 EQR stakeholders, with 19 respondents. The survey consisted of 56 questions and took approximately 10 minutes to complete.

Survey questions were broken into 12 themes aligning to the three Environment, Social, and Governance pillars. The purpose of the survey was to gather information on which ESG themes that stakeholders felt are of material importance to EQR.

Survey respondents were a mix of internal and external stakeholders including representation from the senior leadership team, shareholders, employees as well as external stakeholders such as local community members, suppliers, and financial service providers.

Stakeholders were asked to rate whether the organisation was perceived to be leading or lagging across each of the 12 ESG themes. They were asked to do this for both the current state of the business, as well as for where they felt the organisation should be positioned / aiming to be.

The results are in included in Figure 3.



- Figure 3: Stakeholder Sentiment and Materiality Survey Summary

7.2. Exploration Potential

Figure 11-2: Regional Targets Within EQR's Exploration Tenements

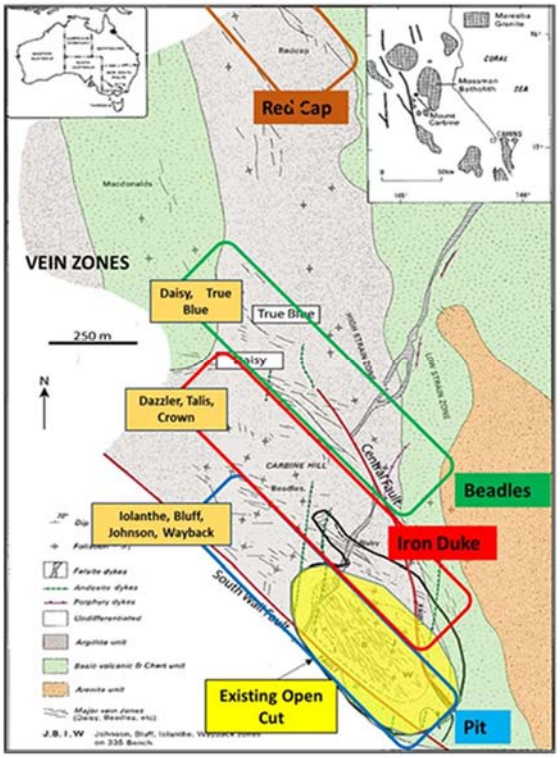


Figure 11-3: Targets within EQR's Exploration Tenements

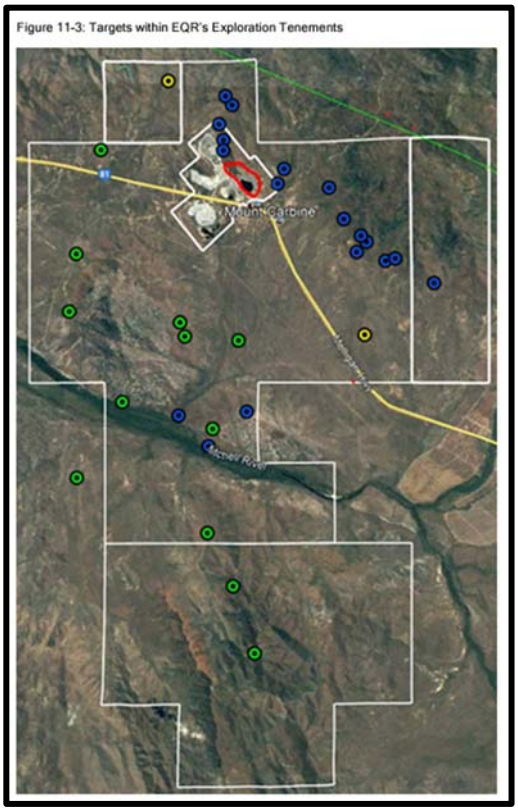


Figure 4-3: Tungsten Conceptual Deposit Models (after Yidou,1993)

Zone	Vertical Extent	Vein Width		Wolframite	Cassiterite	Chalcopyrite	Sphalerite	Molybdenite
I	100-200 m	<1 cm						
II	50-150 m	1-10 cm	Mt Carbine Hill					
III	150-250 m	10-50 cm	Mt Carbine Pit					
IV	200-450 m	>50 cm	EQR Extension					
V	>50 m	1-50 cm						

7.2.1. Structure

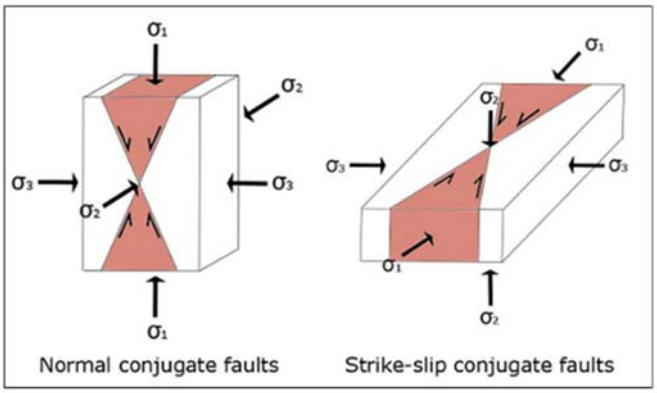
Other minor faults are typically orientated on a north-south strike direction and exhibit localised movement. The Central / Iron Duke and Christmas Faults both show strike-slip movement and in the case of the central fault, there is strike-slip movement across a dyke of 120 m in a left lateral direction. Whereas minimal throw is noted on the Christmas fault. Within the confines of the pit, the rocks have been hornfelsed but several deformation lineations can still be seen i.e. S0 (bedding), S1 minor folding and S2 isoclinal folding planes. The mineralised veins postdate this basement deformation, and there is little or no movement on the pit scale. Veins can be traced over vertical distances of 300-400 m and strike distances for over 1,200 m with very few offsets. Occasionally in the pit, a regular low angle fault occurs that locally shifts the veins up to 3-4 metres. This low angle fracture regime has a tendency to form blocks which will require geotechnical considerations for underground mining.



Figure 1. Mt Carbine pit from lookout.

Figure 4-6 illustrates the formation of veins at Mt Carbine outlining the structural stress at the time (Oliver, 2021). The veins are tensile veins with two general environments: 1. Bulk N-S extension (and potentially related normal faults (left)); and 2. A N-S extension component within a transpressional or transtensional (strike-slip) environment (right). Figure 4-6: Vein Formation at Mt Carbine outlining the structural stress (after Oliver, 2021) The Mt Carbine tungsten deposit is similar to sheeted vein-type tungsten deposits in South China and these are divided into endo-contact (granite hosted) and exo-contact (wall-rock hosted) types. Mt Carbine is an exo-contact type. The vertical structural zoning model for vein-type exo-contact tungsten deposits observed in China (Yidou,1993) directly applies to the Mt Carbine vein system. Figure 4-7 shows a stereonet illustrating the orientation of veins at Mt Carbine outlining the structural stress at the time (Oliver, 2021)

Figure 4-6: Vein Formation at Mt Carbine outlining the structural stress (after Oliver, 2021)



7.2.2. 4.4 MINERALISATION

The Mt Carbine tungsten deposit consists of numerous vertical to sub-vertical sheeted quartz veins ranging in width up to 7 metres but averaging around 50 cm. Approximately 20% of the quartz veins are mineralised due to an early barren quartz event and a later high-grade quartz event. Economic minerals are the tungsten minerals of wolframite and scheelite mineralisation.

A typical section through the centre of the deposit shows quartz veins ranging from 10 cm to 6 m in width with 5-8 zones of secondary narrow mineralised quartz veins of 10 cm to 150 cm in width.

These high-grade veins contain rich quartz-feldspar tungsten minerals and have been designated as “King Veins”.

The tungsten occurs as a coarse crystalline variety of wolframite with up to 10 cm crystals and varying degrees of intergrown scheelite that is volumetrically less significant. Tungsten minerals can form up to 50% of the quartz vein zone, and because of the coarse crystalline nature, has the potential to cause a nugget effect to the mineralisation. In later retrograde stages of the mineral deposition, a secondary scheelite overprinting event occurred that is represented mostly as fine scheelite fractures and replacement over wolframite.

The scheelite-wolframite ratio is seen to increase to the grid north and grid east of the deposit and this mostly appears to be a local effect due to the host rocks becoming more calcareous. In general, the veins are persistent, widespread and are a product of structural control. The mineralisation interpretation is that there are two primary mineralising events with the first phase being a pervasive gaseous front that forms broader scale silicification/veining and deposits a lower grade background level of tungsten mineralisation.

This was followed by a rich brine incursion and fracturing of the now silicified rock. These brine veins are recognized to have higher temperature and higher salinities in fluid inclusion work attesting to their direct magmatic origin. Conversely, the gaseous veins result in fluid inclusions with increased gas and a composition suggesting interaction with groundwater occurred. The King Veins can be as high as 50% WO3 but typically are in the 1-2% WO3 range. Figure 4-8 shows King Veins with various coarse vein textures of the large wolframite crystals.

The matrix has about 10% scheelite and the cream gangue mineral is feldspar. Figure 4-9 shows King Veins in Drill Core with late replacement of coarse wolframite by fine network retrograde scheelite. Minor Molybdenum is found in the deeper parts of the system and the western parts of the vein zones. Molybdenum generally deposits before tungsten, and this gives a rough fluid outflow direction. Mineralisation at Mt Carbine (except Johnson's vein) demonstrates a localized level of control, with the bulk of the tungsten occurring in the 200-350 m RL zone. At these RL’s the veins are 10-50 cm thick but as the same veins go deeper below 200 m RL the vein width increases dramatically and a decrease in tungsten content is noted. Similarly, at higher elevations, the veining also changes dramatically, thinning down to 1-10 cm veins/ stringers with low and variable amounts of wolframite present. Along the grid E-W strike to the mineralisation, the veins have been grouped into lenses, where one or more of the high-grade King Veins are close enough to define a composite value above a cut-off of 2 m at 0.25% WO3 it has been recorded a lens.

It should be noted that these King Veins often form on the margins to silicified zones or the margins of pre-existing barren quartz veins. Typically, an “ore zone” or lens is 3-5 m in width and will contain one or more King Veins. Widths of high grade can occur up to 15 m wide where 5 or 6 King Veins are seen close together. Figure 4-10 illustrates sheeted veins at the base of the pit that narrow towards the top and widen as going deeper into the system and wolframite on the left side from drilling.



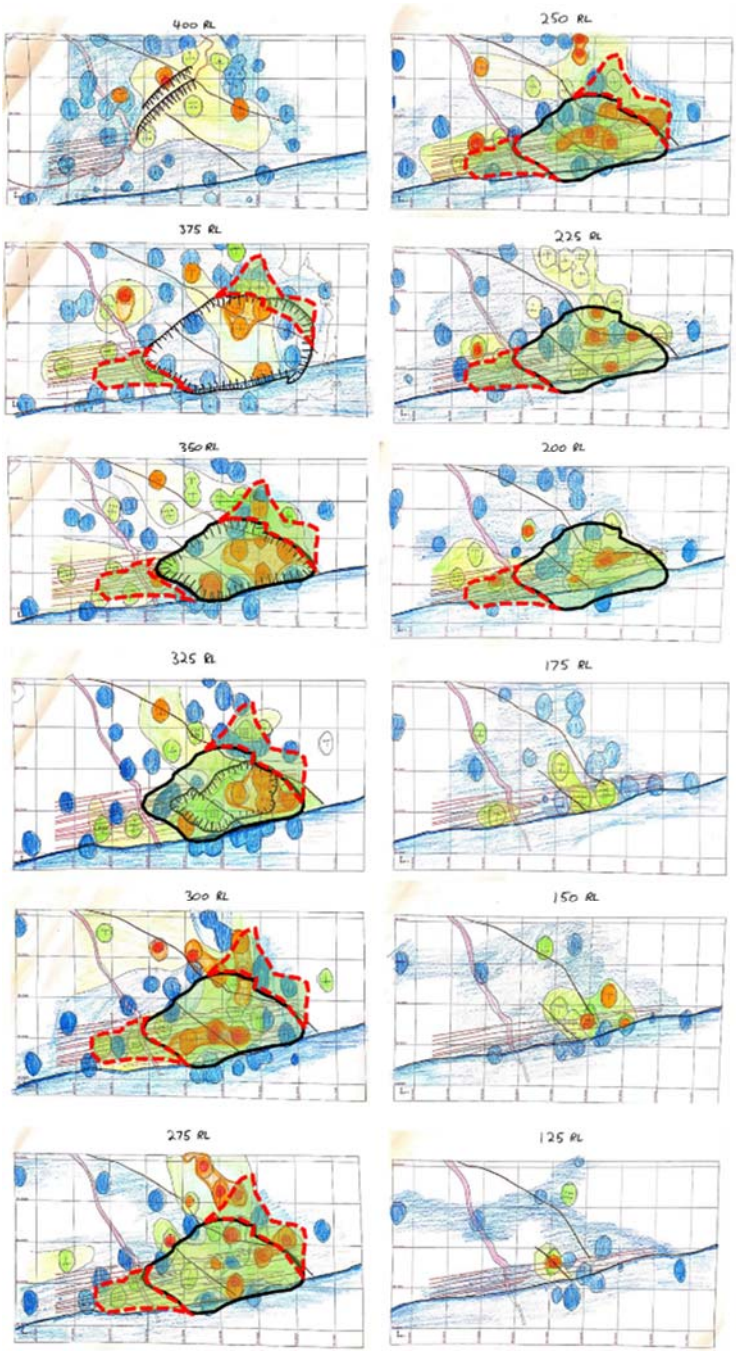
Figure 4-10: Sheeted Veins at the Base of the Pit and wolframite on the Left Side.

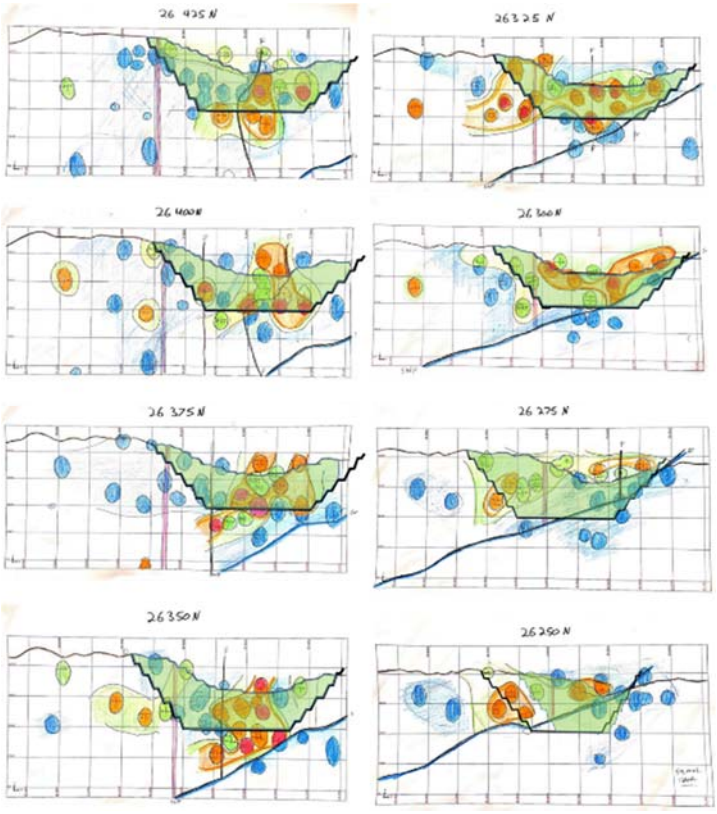


7.2.3. ALTERATION

Alteration minerals associated with the wolframite mineralisation consist of brown tourmaline, biotite-muscovite, apatite, clinopyroxene and silicification. Very minor molybdenite and bismuthinite occur with the wolframite. Minor fluorite–chlorite–cassiterite–pyrite/arsenopyrite and calcite are randomly present. There is only mild marginal vein alteration typically of sericite-clay-chlorite for only a few centimetres if at all. The mineralised veins appear to have had little effect on the host rocks with the fluids entering hot rocks at depth. The observed fact that Mt Carbine is a Boron System (significant tourmaline) as compared to a Fluorine System (little fluorite) would suggest that the deposit occurred in hydrostatic equilibrium with the rising brine fluids with little or no pressure build-up occurring.

Fluorine rich deposits are more volatile and typically form breccia pipes, stock working and large intensive alteration systems e.g., Wolfram Camp, Tommy Burns etc. Alteration minerals are minor other than pervasive early-stage greenschist facies, which has replaced the pelitic mudstones with fine chlorite.


400 RL
250 RL
375 RL
225 RL
350 RL
200 RL
325 RL
175 RL
300 RL
150 RL
275 RL
125 RL



7.3. Strategy and Market Analysis

EQR Business Framework

EQR is focusing on being a low-impact miner through utilisation of advanced technologies, re-using historical mine footprints and creating beneficial reuse through the final waste materials produced. Mt Carbine has both a mineralised stockpile on surface that is tungsten bearing as well as a historic open pit that has been defined to have an accessible high-grade ore body. The focus of EQR currently is on the Mt Carbine Project to maximise value from the resource, while minimising the Company's environmental footprint and creating value for shareholders.

The Mt Carbine Project will benefit the wider minerals sector in Australia through alignment with the priority agenda of the Australian Government to expand its critical minerals industry and enhance the capabilities with regards to mine waste management and social licence to operate. EQR remains committed to responsible mining and sustainability with the aim to proactively minimise waste though reprocessing and innovative re-use of waste materials to generate a new, sustainable supply of (critical) minerals.

Product Specification

Based on the Off-take Agreement in place between CRONIMET Australia Pty Ltd, CRONIMET Asia Pte Ltd and Mt Carbine Retreatment Pty Ltd (a wholly owned subsidiary of EQR) in 2019, the specifications for tungsten concentrate are provided in Table 3. Further details of the ownership structure between EQR and CRONIMET are provided in Chapter 15: Ownership, Legal and Contractual.

Table 3: Tungsten Concentrate Specifications

Name of Element	Specification
WO_3	50% min
S	1.5% max
Sn	0.50% max
Mo	0.40% max
Sb	1.0% max
As	0.15% max
H_2O	1.0% max
Radioactivity: ≤1,000 bq/kg	

These specifications are in line with the overall market requirements for tungsten concentrate and shall remain applicable on the new products being defined in the frame of this feasibility study.

It must be noted that unlike what was considered in the Off-take Agreement, the feasibility study is now considering two separate products, a scheelite concentrate, and a wolframite concentrate, with the latter expected to be of suitable quality for further processing into ferrotungsten. The feasibility study is also including an arsenic removal circuit to ensure compliance with the arsenic specification.

This leads to additional, more stringent requirements applicable only on the wolframite product which are provided in Table 4.

Table 4: Wolframite Concentrate Specifications

Name of Element	Specification
Sn	0.30% max
Mo	0.30% max
P	0.05% max

Market Fundamentals

Market supply and demand forecasts are based on data provided by Roskill, a subsidiary of Wood Mackenzie. Further details can be found in EQ Resources Tungsten Market Report included in Chapter 2: Strategy and Market Analysis.

Disclaimer: *"The data and information provided by Roskill should not be interpreted as advice and you should not rely on it for any purpose. You may not copy or use this data and information except as expressly permitted by Roskill in writing. To the fullest extent permitted by law, Roskill accepts no responsibility for your use of this data and information"*

Tungsten Concentrate

Most tungsten concentrate supply, and a large proportion of secondary tungsten, is converted into ammonium paratungstate (APT). APT production is estimated at 102.7kt contained tungsten (W) in 2020, with the bulk of this produced by China. APT production is more concentrated than mine supply, with only a handful of major smelters active in the ex-China market.

Very little APT is consumed directly in end-use applications. Instead, it is used as feedstock for the production of other refined tungsten products, but mainly serves as feedstock for tungsten oxide – which itself is then converted to tungsten metal powder, and finally into tungsten carbide. Tungsten carbide is the main raw material used in cemented carbide tools.

The other major market for tungsten concentrates (and to a lesser extent, scrap) is in the production of ferrotungsten. Ferrotungsten is a master alloy used in the production of tungsten-containing steels, including tool steels such as high-speed steel. Raw materials used are high-grade ore or concentrates of wolframite or scheelite but artificial scheelite or soft scrap can also be used. Tungsten trioxide in these compounds can be reduced either carbothermically in electric arc furnaces or metallothermically with silicon and/or aluminium. A mixed carbothermic-silicothermic production method is also used. Commercial ferrotungsten contains 75-85% W.

Demand

Cemented carbides make up more than half of the first-use consumption of tungsten demand. Cemented carbides then form the major component of the top three end-use sectors:

- Automotive;
- Industrial; and
- Mining & Construction

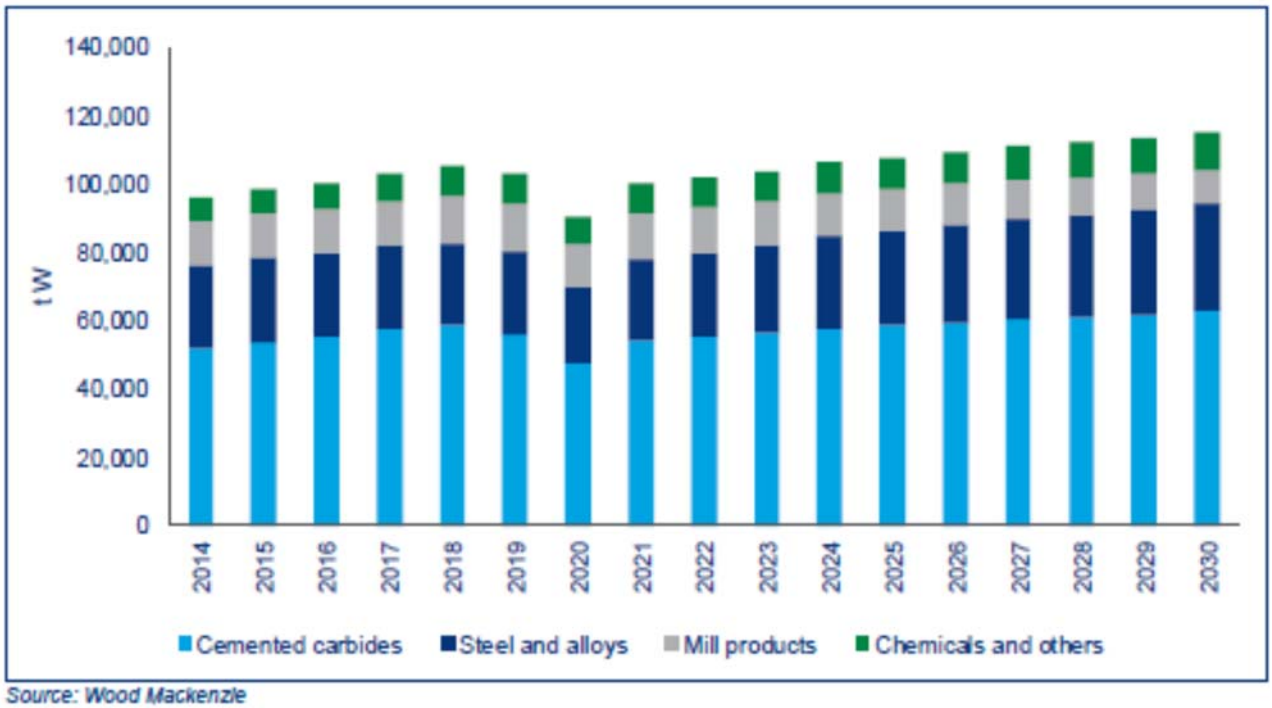
China is the major tungsten demand centre, accounting for just under half of global demand currently and for the remainder of the forecast. Europe and the US are the next largest demand regions, with both expected to grow demand over the coming decade.

First-use Demand

Cemented carbides are the largest first-use market for tungsten, accounting for 53% of tungsten consumption in 2020. Cemented carbide consumption peaked in 2018 at 58.6 kt contained W. Cemented carbide tools are used across a wide range of manufacturing industries and their demand growth correlates closely to GDP, and major consumer markets such as automotive output.

The other leading first-uses for tungsten are steel and alloys (24% in 2020), mill products (such as tungsten wire for lamps; 14% in 2020), and chemicals (including catalysts, and tungsten hexafluoride) which is combined with other uses to account for the remaining consumption (9% in 2020).

A decline in cemented carbide consumption, combined with declining steel and alloys consumption resulted in an overall decline in tungsten demand of 0.9% CAGR between 2014 and 2020. However, growth is forecast to return from 2021. Cemented carbides will also improve its share of overall demand, reaching 55% by 2030. The first-use consumption by product types is shown in Figure 4.



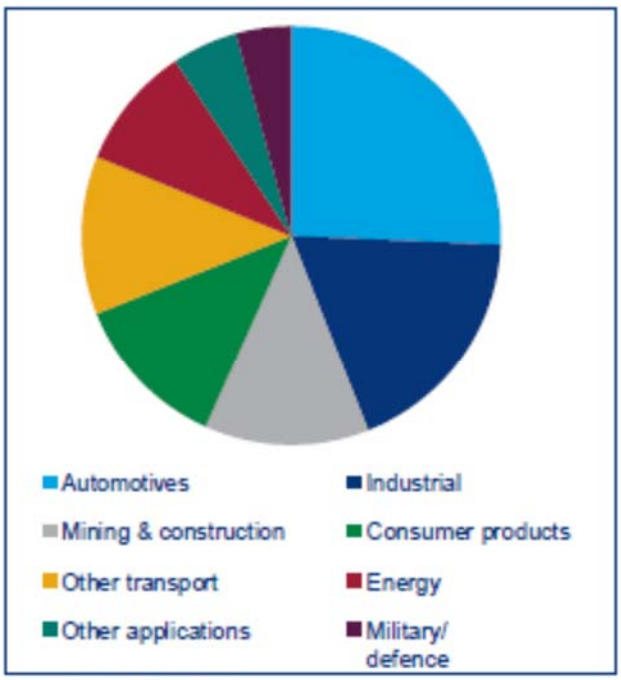
Source: Wood Mackenzie

Figure 4: First-use Consumption

End-use Demand

The consumption of tungsten by end-use in 2020 is illustrated in Figure 5. The automotive market was the largest end-use sector for tungsten in 2020 at 26% of the total, mainly in the form of cemented carbide tools for machining vehicle components. Industrial applications were the next largest segment at 18%. Other transport, mining & construction, and consumer goods combine to form 37% of demand, each consumed around 11-12 kt W in 2020.

Figure 6 shows additional detail of the proportion of first-use products in each end-use demand sector for 2020.



Source: Wood Mackenzie

Figure 5: End-use Sector Consumption (2020)

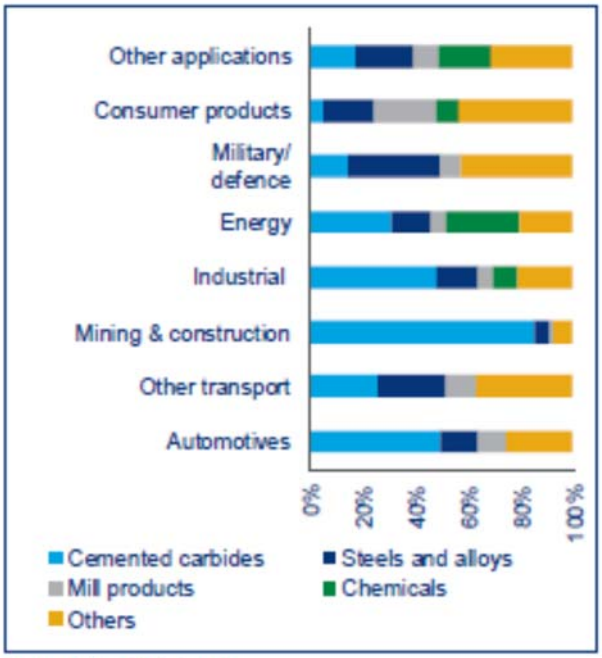


Figure 6: First-use Product Consumption by Sector

Demand by Region

Global demand has been dominated by China in recent years. From 2014-2020, China accounted for just under half of global demand in most years except for 2017 and 2020 where demand surpassed 50% by a small margin. For the period 2021-2030 China is expected to maintain its dominant position with around 49% of global demand in each year. Other major demand centers are Europe (19% of global demand in 2020), United States (14% of global demand in 2020), and Japan (6% of global demand in 2020). The demand per region is shown in Figure 7.

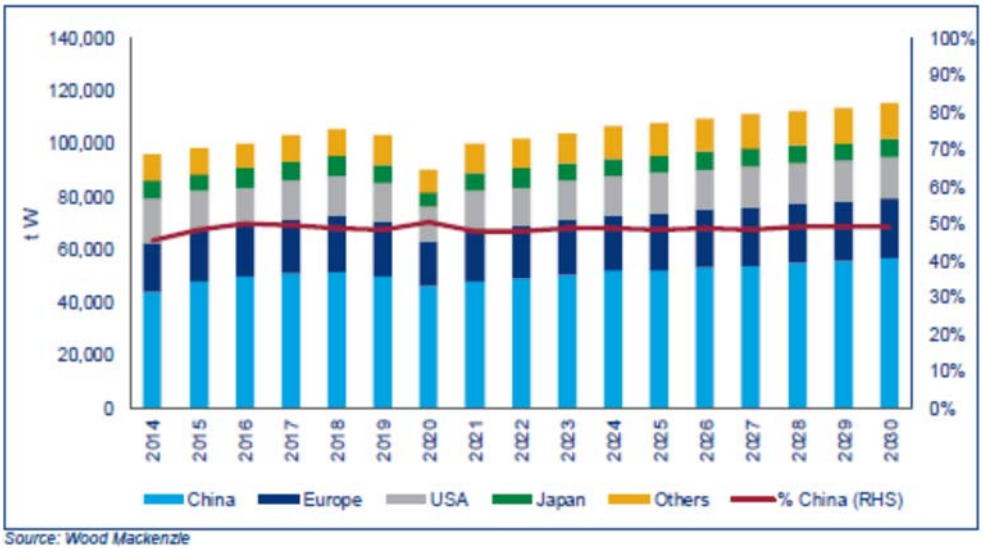


Figure 7: Demand by Region

Supply

Most tungsten is mined as a primary or co-product metal, and in lower volumes as a by-product. World mine production has remained relatively stable across this period between 2014 and 2020, with moderate drops in 2016 and 2018. The period between 2014 and 2020 marks substantially higher annual production than across earlier years. This was initially supported by a period of historically high APT prices, which themselves were at least partially driven by the failed Fanya Metal Exchange in Kunming, China, which traded APT.

Mine supply in 2019 recovered as a result of strong output from Chinese mines, despite reduced demand, depleting mine grades in Russia and Vietnam, and the mothballing or closure of other assets (Mongolia and the UK). In 2020, mine supply has risen again to historic highs, despite the impacts of COVID-19. Chinese output is again the principal contributor to this, with record production levels. Much of this increase to Chinese output is estimated to have been driven by strong tungsten by-product production, with many tungsten-only focused mines suffering from depleting grades.

Global mine production of tungsten by country is shown in Figure 8.

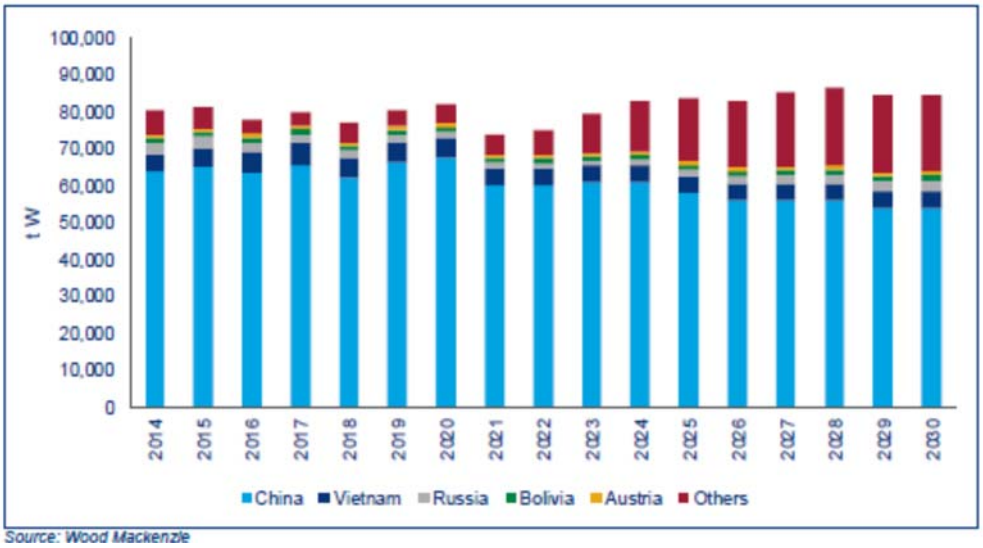


Figure 8: Global Mine Production

In 2014, production of concentrates outside China accounted for 20% of global supply, which by 2019 had dropped to 17%. In recent years Vietnam has become an increasingly important supplier, albeit for domestic consumption, following the start-up of the Nui Phao operation in 2014. It is now the second-largest producer globally, accounting for 5.4kt W in 2020. Other important non-Chinese tungsten producers include Russia, Bolivia, North Korea, Spain and Portugal.

Market History and Opportunities

The global tungsten market was in surplus in 2020 for the second successive year. This can be attributed to a sharp decline in demand in 2020, largely as a result of the impacts of the COVID-19 pandemic. Global consumption in 2020 fell by 11.3% year-on-year. Despite record mine output in 2020, primarily from a strong Chinese production, low availability of secondary material led to the lowest total supply levels since 2012.

However, low total supply only partially offset the sharp decline in demand. Consumption fell to its lowest level since 2010 and far below total supply for the year. The surplus supply of 12.5kt is the highest surplus level overhanging the market since 2013, when the now-defunct Fanya Metals Exchange was operational and tungsten prices were at record levels.

Historic and forecast supply and demand for tungsten is shown in Figure 9.



Source: Wood Mackenzie

Figure 9: Market Balance

While annual tungsten supply and demand has returned to surplus in recent years, it had been in deficit for several years after the collapse of the Fanya Metals Exchange. Prior to this the market had remained sufficiently supplied owing to the drawdown of stocks. In the 2013-2015 period there was substantial oversupply of tungsten into the market, which was linked to artificial demand from the Fanya Metals Exchange.

With the exception of the ex-Fanya APT stockpile held by China Molybdenum Co Ltd (CMOC), there is little inventory in the upstream portion of the tungsten supply chain as of Q1 2021. Most industry stocks are thought to be in the form of tungsten metal, tungsten carbide and finished tungsten products, with much of this residing in China.

A deficit of around 5.1kt W is expected in 2021, which may be partly met by CMOC's APT stocks, US DNSC concentrate stocks, and the drawdown of finished product inventories. The deficit is forecast to reduce and swing to a marginal surplus in 2023 as mine output from existing producers increases. Several large new Projects came online in 2019 and suffered delays to ramping up in 2020/2021 as a result of COVID-19.

Further ramping up is set to continue through 2022 and will replace the fall in output from longer established mines. New mine Projects will be able to meet the market supply requirements through the middle of the 2020s but will begin to fall short towards the end of the forecast. By 2029 new mine supply may not cover demand which is again likely to underpin higher prices.

Supply Strategy

Mt Carbine is exceptionally well positioned to supply tungsten concentrates into the market after the successful completion of pilot operations, trials, optimisations, and the recent drilling program. It now has the proven capability of producing tungsten from the resources at Mt Carbine on a low-cost basis.

Through site-based pilot-scale operations, focusing initially on the historic LGS, the aim was to prove the economic viability of mine waste retreatment by recovering industry-critical tungsten minerals. A geometallurgical approach to characterising mine waste materials was undertaken since it has significant benefits for evaluating and quantifying resource potential at historical sites. This was coupled to sensor-based particle sorting whose recent advancements in technologies made a significant step-change possible for the mining sector through the development and site-specific optimisation of a flexible and cost-efficient material handling and sorting solution.

Ore sorting at Mt Carbine was key to the early restart and cashflow generation of the mine. The use of XRT sorting on the ore at Mt Carbine reduces the volume of non-mineralised material entering the downstream processing stream. This reduction positively impacts the economics of the Project and simultaneously reduces the capital footprint of the processing plant whilst producing a quarry aggregate product through the inert sorter waste products produced.

Market Value Assessment

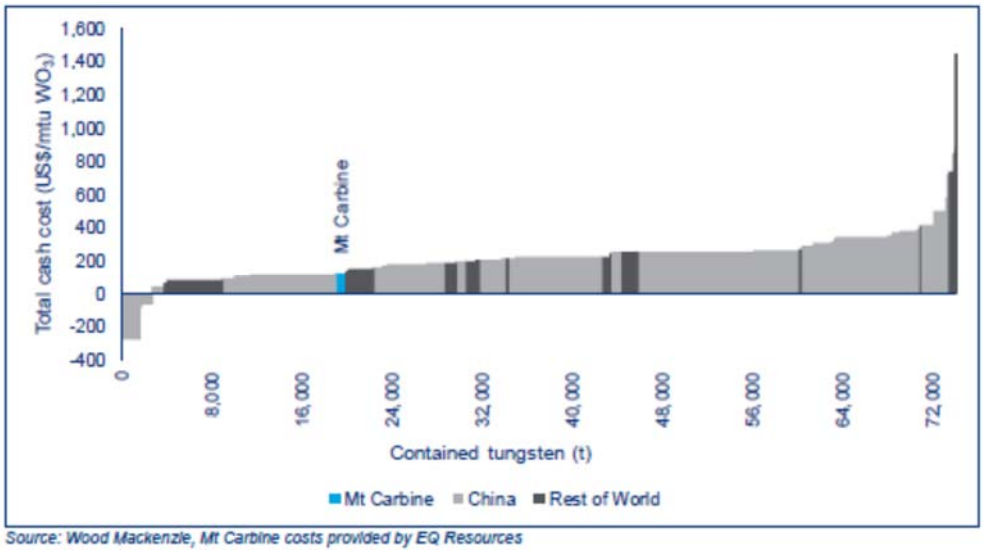
EQR developed a market value model as a basis for revenue modelling for the Project. The model was informed by the current contractual elements that are in place for the sale of concentrate from the Mt Carbine site as well as considering end-user purchase prices as known to EQR.

Market value modelling was then developed to adjust the baseline reference prices to reflect the value of Mt Carbine products in the global market. The parameters selected for price adjustments were:

- Base Price: Calculated on a metric tonne unit (MTU) of WO_3 contained in a dry metric tonne delivered FCA Mt Carbine (INCOTERMS 2010);
- Index: London Metal Bulletin (LMB) European APT;
- Pricing: Low and High European APT averaged for the calendar month of delivery for the tungsten concentrate;
- APT payable: A floating payable is considered, covering the period under the fixed off-take contract with CRONIMET and for the period afterwards;
- Payment terms: 95% payment upon delivery of product and 5% balance payment upon final settlement based on weighing and assay results.

Cost Curve Analysis

The Mt Carbine mine is a low-cost operation, with total cash costs (including royalties, but excluding potential by-product sale of processing waste through the quarry) well below global average. It is also forecasted to be one of the lowest cost “tungsten-only” producing mine, with most of the first quartile suppliers producing tungsten as a by-product of another metal, which is particularly notable for the first two producers which are reporting a negative production cost for their tungsten. The cost curve for the total cash cost of tungsten including Mt Carbine’s position is shown in Figure 10.



Source: Wood Mackenzie, Mt Carbine costs provided by EQ Resources

Figure 10: Total Cash Cost Curve - 2020

It must be noted from the above cash cost curve that in order to sustain the growing demand, and despite the new projects expected to come online over the coming years, prices will have to remain at levels which incentivises production of the third, and even likely the fourth quartile suppliers, which will in addition face in

future higher costs due to falling ore grades. For Mt Carbine, this guarantees that its production cost will be well covered, and that significant margin shall be generated.

Pricing Basis and Forecast

Tungsten Concentrate

Tungsten concentrate prices are predominantly based on a discounted APT price, and thus followed similar trends to prices for APT.

Prices for tungsten concentrates have broadly followed the same trend as APT in recent years, although since 2015 the premium of APT over concentrates has reduced. This is believed to be because availability of concentrates has become tighter, particularly in the ex-China market. In 2018, the premium widened again, suggesting adequate supply of feedstocks – in this case, likely representing greater volumes of scrap onto the market. In 2019 and 2020, the premium of APT over concentrates once again generally reduced, with some temporary upticks, as availability of concentrates tightened once more in tandem with falling mine production.

Historical pricing for WO_3 concentrate is provided in Figure 11.



Figure 11: Chinese Tungsten Concentrate Prices

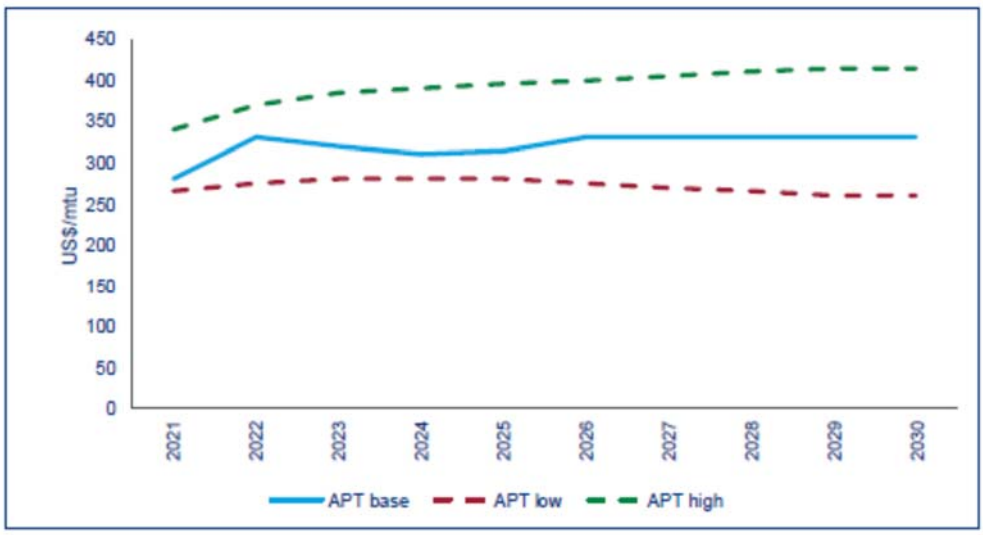
Forecast APT Prices

The range of factors contributing to APT prices means that forecasts for future prices are best examined under several scenarios. In the base case scenario, it is assumed that a deficit does occur in the early 2020s, as demand recovers and spikes after several years of decline, but that this is partly offset by either the continuation of CMOC's release of the Fanya APT stocks, by consumption of existing finished product inventories, or by new mine supply ramping up earlier than expected. As new mine projects come online however, the market is likely to move into balance during the mid-2020s. Towards the end of the forecast period, new mine supply may not cover demand, likely providing an upside driver to prices.

In the low-case scenario, a combination of factors may weigh down on the sector – such as the impacts of the COVID-19 pandemic leading to a sustained period of suppressed tungsten demand, a negative resolution to the US-China trade talks, or a higher penetration rate of electric vehicles than forecasted. New mine projects could also contribute to lower prices if more are successfully brought online than the market can sustain.

By contrast, the high-case scenario sees a deficit occurring in the early 2020s, which is not alleviated quickly enough by stocks or new mine projects. Furthermore, the high-case scenario makes a provision for Chinese environmental inspections occurring again in 2021-2022 when the market is already in a deficit. Prices would rise rapidly under these conditions, potentially exceeding US$370/mtu in 2022. If mine projects are not ramped up as quickly as forecast, this could potentially see prices gain to US$385/mtu in 2023. This would, however, likely incentivise new production or greater scrap use, leading to a correction in the price in the mid-2020s.

The APT price forecast is shown in Figure 12.



Source: Wood Mackenzie

Figure 12: APT Price Forecasts

Note on Tungsten Concentrate Price Forecast

In consideration to the above-mentioned APT price forecast, it must be noted that the above discussed prices are all expressed in $/mtu in APT, where typically tungsten concentrate sells for about 75-77% of the APT price on a FCA basis. This payable factor varies with the product quality (WO_3 grade, but mostly impurities' levels), and its delivery term.

Given the range shown above, applying a 70-75% payable factor on the APT price forecast in the financial model has been deemed to be fair assumption of the tungsten concentrate price forecast.

Customers

Currently CRONIMET is the sole off-taker for the Project from the rights secured through early investment into the Mt Carbine Project. Since the start of the Project, concentrate has been sold to customers in Europe, the United States, Vietnam, and China.

While CRONIMET will retain a portion of the off-take at least equivalent to the existing deliveries, new off-takers might be considered as strategic project partners.

In addition, it has to be noted that CRONIMET has also a specific interest in off-taking part of the wolframite concentrate for its "in-house" conversion into ferrotungsten, which shall then be marketed to its existing steel clients.

Going forward, should CRONIMET no longer wish to trade the concentrates from the Mt Carbine operation, several other large commodity trading companies have verbally expressed interest in the concentrate being produced at Mt Carbine and therefore could be engaged if required.

Figure 13: Typical Ore Section Through Open Pit

Table 5: LOM Primary Physical Metrics

Variable	Unit	Annual Minimum	Annual Maximum	LOM
Total Mined Tonnes	t	786,000	5,999,000	25,201,000

Variable	Unit	Annual Minimum	Annual Maximum	LOM
Mined Ore Tonnes	t	783,000	1,006,000	11,384,000
Mined Waste Tonnes	t	26,700	5,129,000	13,816,000
Gravity Plant Feed	t	318,000	408,000	4,775,000
Gravity Plant Head Grade	%	0.18	1.17	0.33
Produced Concentrate	t	950	8,000	26,680

Mobile equipment required for mining operations will comprise two fleets:

- A primary fleet of 1x100-120t class excavator and five to six 50t articulated dump trucks. The focus of this fleet will be open cut (OC) waste movement and some LGS ore mining depending on scheduling; and
- A secondary fleet of 1x50-90t class excavator and 3x50t articulated dump trucks, focusing on OC ore recovery and LGS ore mining as required.

The operation will run on a 24hr, 7-day a week roster, with the exception of LGS load and haul requirements which will be day shift only. Mine management personnel will be on a standard 5-day work week.

7.4. Material Characterisation

Material to be extracted at Mt Carbine can be divided into two main lithologies – hornfels and metasediments. The weathered profile of the two rock types varies considerably, the hornfels is ~2-4 metres, whilst the metasediments have a deep (up to 30 metres) weathered profile, particularly adjacent to the South Wall and Iron Duke Faults. As such, weathered metasediments can be classified as a separate 'material type'.

Characteristics of the material types is detailed in Table 6.

Table 6: Material Characteristics

Material	Estimated Hardness	Unconfined Compressive Strength (MPa)	Insitu Density	Loose Density	Swell Factor (%)	Contaminants (PAF/NAF)	Comments
Hornfels	R4 to R5	62.5 to 91	2.74	2.28	20	No	
Metasediment	R3 to R4	4 to 91	2.74	2.28	20	Unknown	Likely to slake and desiccate based on field observations

The other material characteristic of note is the high quartz content of the tungsten bearing veins. The prevention of silicosis (a lung disease caused by inhaling large amounts of crystalline silica dust) has become a priority of QLD regulatory bodies and the operational management plan should include respirable dust controls. These controls could include specific drill and blast practices and dust suppression through water spraying.

Hydrogeology

A series of groundwater bores were drilled around the Mt Carbine local area in 2011, providing a good groundwater monitoring network for the mining operation. Sampling and analysis of the network was undertaken by hydrogeological consultants Rob Lait & Associates, with a report *"Report on Carbine Tungsten Groundwater Study"* delivered in December 2012.

The findings of the report are as follows:

- There is low hydraulic conductivity within the Hodgkinson Formation aquifers and minimal groundwater inflow is expected into the open cut pit.
- Testing of groundwater samples indicates the open cut pit water is better quality than the surrounding groundwater aquifers.

Based on these findings, groundwater is not considered a major risk from either a ground stability or contamination perspective and will be managed via a typical suite of operational controls – pumping, sediment settling dams, dilution, reuse, and approved discharge if necessary.

Geotechnical

The current pit excavation provides a good opportunity for understanding the future open cut geotechnical performance for the area. Additionally, the underground development has provided further insight into the rockmass condition and has several consultant investigations completed over the years. The previous work has developed a broad understanding, albeit over many decades, during which time changes in geotechnical data collection methodologies and evaluation techniques have evolved.

The geotechnical dataset supporting the basis of the open cut pit shell is as follows:

- RQD and defect information from 79 diamond drill holes across deposit;
- Two images and a powerpoint presentation of the above drill hole information; and
- Four geotechnical reports, entitled as follows:
    - GCPL – MC – 160421 – *Preliminary Geotechnical Assessment of Ground Conditions & Remedial Support (2021);*
    - HCOVGlobal – *Brief Review & Structural Assessment/Scoping of Iron Duke – Petersens – Mt Carbine EPM 14872 (2020);*
    - Golder Associates – *Report to R.B Mining Pty. Ltd. On Mt Carbine Mine Review of Rock Mechanics (1984); and*
    - HD042 – Piteau & Associates – *Slope Stability Analysis & Design of the Open Pit Slopes (1982).*

Current Data Evaluation

Defect and RQD logging of the 79 diamond drill holes (over 20,000 metres of core) was completed by EQ Resources geological personnel. The data was compiled into a three-dimensional model in Leapfrog software and corresponds well with historical fault, shear and fractured zones.

The majority of the fractures observed are associated with the South Wall Fault, being found in the 10-15m zone of foot wall. The South Wall Fault is well exposed in the existing pit and has over eighty intersections recorded in exploration drilling to date. It varies from 0.5 to 2.0m in thickness and is marked by a clay filled fault gouge.

Figure 14 illustrates the defect logging completed and alignment with historical defect mapping.

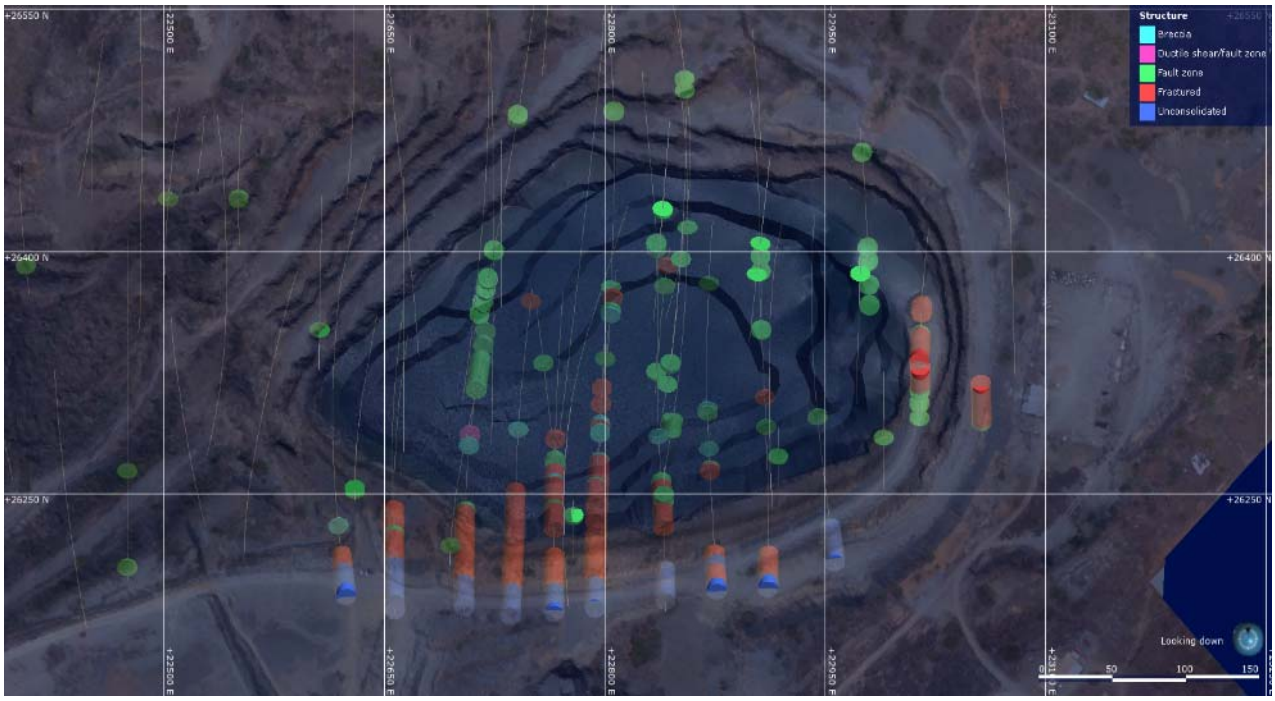


Figure 14: Defect Logging and Structural Model of Exploration Drill Holes (plan view)

Current Pit Design

Geotechnical parameters of the current pit design and ground stabilisation requirements are included in Table 7 and Table 8.

Table 7: Geotechnical Parameters of Open Cut Pit Design

Parameter	Value	Comment
Bench Height (m)	20	Suitable in hornfels material north of the South Wall Fault, see Table 9 for mechanical ground stabilisation requirements south of the fault.
Bench batter angle (^{0})	70	
Bench width (m)	8	
Ramp angle (%)	10	
Inter-ramp slope angle (^{0})	70	

Table 8: Ground Stabilisation Requirements for Southern Pit Wall

Toe Elevation (m)	Length of pit wall (m)	Area (m^2)	Horizontal Spacing	No. of Rows	Min. bolt length (m)	No. of bolts	Bolting metres (m)
380	261	2463	3	2	10	174	1740
360	491	9820	3	4	10	655	6547
340	453	9060	3	6	10	906	9060
320	413	8260	3	5	10	688	6883
300	349	6980	3	5	10	582	5817
280	333	6660	3	5	10	555	5550

260	270	5400	3	5	10	450	4500
240	211	4220	3	5	10	352	3517
220	51	1020	3	5	10	85	850
Total	**2832**	**53,883**				**4446**	**44,463**

The key element of the current pit design is the requirement for mechanical ground stabilisation on the southern wall, behind the South Wall Fault. The ground stabilisation is based off the work completed by Piteau (1982) and comprises the following:

- Horizontal groundwater drainage holes (up to 20m long) at the base of each bench, with associated drainage channel.
- Vertical 10m twin strand cable bolts, two rows at 3 metres spacing, above the 380RL.
- Inclined (-10^0) 10m twin strand cable bolts, four rows at 3 metres spacing, above the 360RL.
- Inclined (-10^0) 10m twin strand cable bolts, six rows at 3 metres spacing, above the 340RL
- Below the 340RL, 10m twin strand cable bolts, five rows at 3 metres spacing for all benches
- Cable bolt loading above the 340RL is 20 tonne, below the 340RL is 50 tonne.

7.5. Processing

7.5.1. Overview

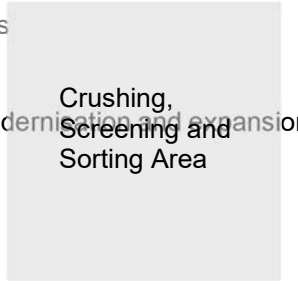
The site processing infrastructure is split into two distinct areas on the site. Adjacent to the LGS is the crushing, screening and sorting area, where ROM material is screened and sized. +6,-40mm material is sorted using XRT sorting equipment where approximately 10% of the XRT sorter feed is then crushed and stockpiled for feeding into the processing plant. The remaining 90% of material is barren of tungsten and utilized as quarry material.

-6mm material and the XRT sorter concentrate are then trucked and fed into the processing plant located on the opposite side of the Mulligan Highway. The processing plant is dry fed and produces a tungsten product and waste tailings material.

The locations of the crushing, screening and sorting area, and processing area is shown in Figure 15.

The details of the current and future processing infrastructure is detailed further in Chapter 5: Processing.

Figure 15: Processing Infrastructure Locations



The scope of the processing infrastructure modernisation and expansion for each of the is split into two distinct phases, these are summarised below.

Crushing Screening and Sorting Area

Phase 1 Overview

The process design philosophy for Phase 1 for the crushing, screening and sorting plant was to achieve the following process outcomes for minimal capital expenditure requirements:

- Modify the existing crushing and screening infrastructure
- Increase ROM throughput to a nominal 170tph of -700mm material

- Introduce wet screening of -6mm material to improve screening efficiencies during the wet season
- Introduce direct process plant feed of -6mm material to reduce materials rehandling requirements

The Phase 1 crushing, screening and sorting circuits were designed in accordance with the design criteria in Table 9.

Table 9: Phase 1 Crushing, Screening and Sorting Design Criteria

Description	Criteria	Unit
General		
Ore Type	Dry and clean ore	
Ore Hardness	7	Mpa
Ore Abrasiveness	0.79	Ai
Maximum Lump Size	750	mm
Design Life	20	Years
Plant Size	1,000,000	tpa

The existing ore sorter circuit will be utilised for Phase 1. The existing ore sorter is shown in Figure 16.



Figure 16: Existing Ore Sorter

The Phase 1 modifications for the crushing, screening and rehandling circuits are shown in **Error! Reference source not found.** and Figure 17.

Figure 17: Phase 1 Rehandling Circuit

Phase 2 Overview

The process design philosophy for Phase 2 for the crushing, screening and sorting plant was to achieve the following process outcomes:

- Construct a new crushing, screening and sorting plant adjacent to the existing plant
- Increase ROM throughput to a nominal 350tph to allow day shift only operations (ore sorter circuit and processing plant to operate 24/7) to reduce the overall operating costs of the operation
- Reduce material rehandling through combining the crushing and screening circuit with the ore sorting circuit
- Increase maximum feed size from 700mm to 1000mm through introduction of a jaw crusher

The Phase 2 crushing, screening and sorting circuits were designed in accordance with the design criteria in Table 10.

Table 10: Phase 2 Crushing, Screening and Sorting Design Criteria

Description	Criteria	Unit
General		
Ore Type	Dry and clean ore	
Ore Hardness	7	Mpa
Ore Abrasiveness	0.79	Ai
Maximum Lump Size	750	mm
Design Life	20	Years
Plant Size	1,000,000	tpa

The Phase 2 crushing, screening and sorting plant is shown in Figure 18.

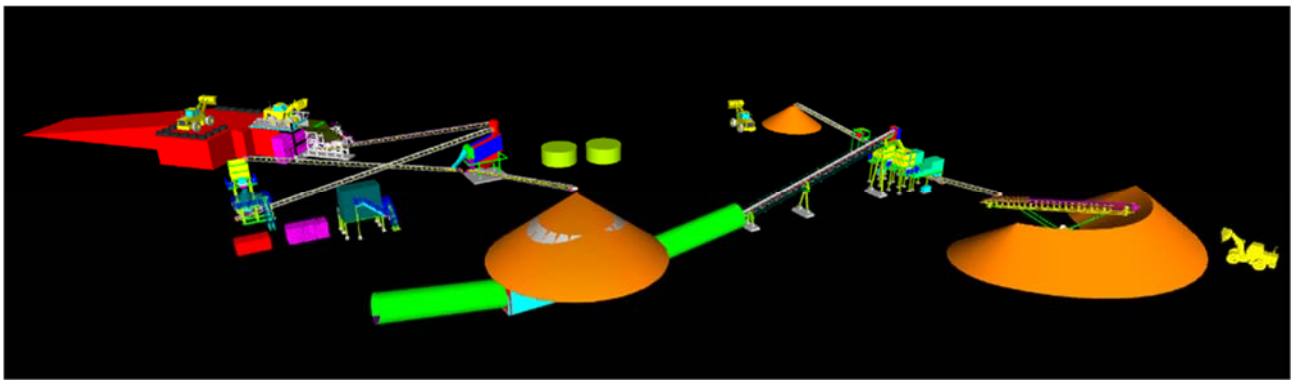


Figure 18: Phase 2 Crushing and Screening and Sorting Circuit

Phase 2

Overview

Based on the current recovery data, the existing processing plant is performing well and the approach to the plant upgrades was to maintain the plant circuitry and process as much as possible while improving the plant recovery performance to support the higher grade feed through the introduction of a scavenging circuit and additional tables capacity.

Operational Review

Ausenco attended the Mt Carbine site on two occasions. The first visit was in May 2021, where preliminary review of operating data and circuit configuration was conducted. Following the site visit several

recommendations were made to improve the reliability and recovery of the operation and to collect data to confirm the tungsten losses and flowrates through the circuit.

A second site visit was performed at the beginning of September to further review the operation and to perform a plant sample campaign to confirm the operating parameters and performance for the plant. Two plant surveys were performed by Ausenco personnel during the visit to provide a snapshot of operational performance and to form the basis of engineering work.

Initial review of the site operating data showed that the Mt Carbine plant had an average tungsten shift recovery of approximately 47% between January and May 2021 producing a concentrate grade of 49% WO_3 during the same period.

Analysis of the operating and shift samples showed that the key issue in the plant recovery was in the jigging circuit, associated with high losses from lower grade material. This data is shown in **Error! Reference source not found.**.

A subsequent review of overall plant recovery by ore feed showed two distinct periods of performance. Since the decision not to retreat tailings was made, plant recovery has increased and the range of performance outcomes has also decreased.

Based on the data below recoveries on 'fresh' ore are ~25% higher than those with tailings mixed, averaging 85% WO_3 recovery vs 60%. The goal of the upgrades is to consistently produce above 80% recovery from the plant through scavenging the jig tailings and increasing the capacity of the table recovery circuit. This is clearly shown in **Error! Reference source not found.**.

Planned Improvements

The Phase 2 scope has been designed to ensure that the plant recovery does not reduce through the introduction of high grade ore from the open pit.

To support the higher head grade, a scavenging circuit will be introduced to minimise potential losses from the jig circuit. Additional tables will be included to account for the increased WO_3 grade in the feed.

Upgrades to the circuit have been developed based on an incremental and modular approach to design, with the additional facilities targeting the areas of major losses from the existing circuit. Where possible, changes to existing equipment have been minimised to reduce interruption to the existing operation, however due to capacity constraints upgrades to some equipment and pumps are required.

The basis for design (Table 11) for the process plant is summarised below:

- Plant nominal capacity of 60 t/h treating ore with a feed size of P95 -6mm
- Capacity to treat ore with feed grades into the front end of the circuit (jigs) of up to 0.5% WO_3
- Capacity to treat 16 t/h of ore sorter product at 0.85% WO_3 into the table circuit, with the balance of feed from the jigging circuit.
- Operate at average tungsten recovery of 77% from ROM feed to the Jig,
- Design flexibility to process 16 t/h of ore sorter product direct to the table circuit. Under this case, the circuit has been designed for 92% overall recovery which represents the maximum for design case.

Table 11: Design Basis

Criteria	Units	Design
Plant Throughput	t/h	60
Feed Size (P95)	mm	6
Design Feed Grade	% WO_3	0.5
Overall Recovery (nominal)	%	79.5

Criteria	Units	Design
Overall Recovery (max for design for table circuit)	%	92%

The main strategy to improve recovery through the circuit is based in increasing current jig capacity to reduce increase jig residence time. Review of the operating parameters and flow through the jigs highlighted that losses in the coarse fraction are most likely due to the low residence time in the jig and also due to the interstitial void of the ragging used.

As an additional means of recovery improvement, the two jigs will treat different size fractions (coarse and fine) which allows individual operating parameters and ragging to be optimised for each size fraction, being:

- Jig Duplication
- Jig Scavenging

In addition to recovery improvements, equipment was checked for capacity constraints. At higher head grades, the table circuit will become overloaded and require additional tables to remain within design loading rates.

Finally flowsheet modifications were driven by the future ore from the pit having elevated arsenic which necessitates removal for sale. As part of the arsenic removal circuit there is the opportunity to produce a separate wolframite product for production of ferrotungsten, being:

- Arsenic removal via the addition of a float cell; and
- Drying and product separation.

7.6. Infrastructure

7.6.1. On Site Infrastructure

Overview

Mt Carbine is currently operating and is well serviced with existing on-site infrastructure to support its operations.

The site infrastructure strategy for the project is to utilise as much as possible the existing site infrastructure and only construct new infrastructure if required to support new or upgraded facilities.

As the overall changes to the footprint and capacity of the mining and associated crushing, screening, XRT sorting and processing infrastructure is minimal, there are only minor site infrastructure modifications required to support the upgraded facility.

Existing Site Infrastructure

The site is already supported by well-established infrastructure supporting the current mine and quarry operations. The facilities include:

- Site access roads;
- Office buildings;
- Car park;
- Laboratory;
- Ablutions facilities;
- Crib areas;
- Power;
- Workshops;
- Site dams & drainage;
- Water supply pipelines;
- Safety and first aid equipment and

- Phone and internet connectivity.

Site Infrastructure Scope (Phase 1)

The scope for the on-site infrastructure work for Phase 1 of the project include:

- High voltage power supply and reticulation upgrades (sufficient for Phase 1 and 2);
- Fuel storage tank capacity increase (additional 12,000L) for mining operations; and
- Workshop and warehouse upgrades to store equipment spares and tools etc (containers);

Site Infrastructure Scope (Phase 2)

The scope for the on-site infrastructure work for Phase 2 of the project include:

- Water production bore prior to pit depletion to supply the sites raw water requirements;
- Waste management facilities at the wet processing plant;
- Containerised igloo workshops will be constructed for use at the crushing and screening plant and for the mining contractor; and
- Existing site offices will be refurbished to improve general amenities

Off Site Infrastructure

Overview

The Project's offsite infrastructure strategy follows the on site strategy, which is to maximise the use of existing infrastructure and only invest capital where required or where value has been identified.

Off Site Infrastructure Scope (Phase 1)

The scope for the off-site infrastructure work for Phase 1 of the project include:

- Utilisation of all/part additional mains electrical supply applied for and approved by Ergon Energy;
- Construction workforce accommodation (contractors and owners team personnel), prioritising the utilisation of several accommodation options in close proximity to the site including:
  - Contractor camp operated by the Mt Carbine Roadhouse;
  - Caravan Park; and
  - Mt Carbine Hotel.

Additionally further accommodation is able to be sourced under an hour from the site in local towns including Mt Molloy, Mareeba, Mossman and Port Douglas.

Construction Safety Approach

EQR's policies, procedures and legislative requirements establishes the minimum standards for safe work practices on the site. EQR's execution strategy will develop a culture where leadership is by example. EQR will demonstrate care and ensure an ongoing process of continuous improvement in this model. This will involve everyone, and the ultimate accountability will be by all.

The Project health and safety strategy will include:

- The safety and health management system (SHMS) will be fully integrated into the Project's delivery;
- Construction contractor's construction safety management plans will be assessed to ensure that at a minimum they meet the requirements of the site's SHMS prior to mobilisation. Where contractor specific procedures and instructions are missing, these will be developed by the contractor, approved by the Owners' Team and incorporated into the sitewide SHMS;
- Statutory requirements as per the Mining and Quarrying Safety and Health Act 1999; and
- Aim to reduce employee risk by minimising high risk activities and reducing the labour requirements on site through the use of off site works, pre-assembly, modularisation and lower labour installation methodologies.

In accordance with the Mining and Quarrying Safety and Health Act 1999, the SSE will be the statutory safety authority over all activities on the mining leases. Once construction commences, the construction team will be required to liaise with the Site Senior Executive (SSE).

The SSE will appoint in writing suitable parties to fulfill electrical obligations for the execution and operations in accordance with the Mining and Quarrying Safety and Health Regulation 2017.

Leadership of safety will be at all levels and a key criteria of individuals' site performance and position descriptions.

Construction Risk

The Owners' Team will actively manage construction risks and work closely with all contractors involved with construction on a regular basis. The Owners' Team will routinely audit the safety performance and risk management activities of its contractors utilising the site's existing risk management platform.

The Project's approach to risk management is detailed in Chapter 14: Risk and Opportunity.

Construction Surface Water Management

There is no requirement to substantially alter the existing drainage infrastructure currently supporting the site and its operations. As far as construction activities are concerned, the only surface water management requirement is to ensure that all local runoff from the contractor's site is captured and directed into the site's existing drainage system.

Error! Reference source not found. below illustrates the site's drainage system.

7.7. Operations Management

7.7.1. Operating Philosophy

The Mt Carbine site is a mature operating site that has been running since the gravity plant started hot commissioning in February 2020. The EQR CEO is involved through strategically guiding the operation and Company from an explorer to a fully-fledged operation. The EQR CEO has over 30 years' of experience in managing mining operations through North America, Europe, and Africa. This experience has aided the development of a cohesive hands-on management approach and operations team development and restricted the reporting chain to ensure employees are empowered in their roles for efficient decision making and optimal outcomes.

EQR is an equal opportunity employer with support for bullying and harassment in the workplace as it works to build a team of skilled individuals from surrounding communities. The operation has an extensive Health and Safety Management system that protects employee's physical safety.

The operations are guided by the Integrated Management System (IMS) which addresses the intended outcomes of ISO 9001:2015 Quality Management Systems, ISO 14001:2015 Environmental Management Systems and IOS 45001:2018 Occupational Health and Safety Management Systems. The application of the Integrated Management System Manual (IMSM) will:

- Demonstrate EQR's ability to consistently provide quality quarry products that meets customer requirements and tungsten concentrate to meet the requirements of CRONIMET Australia and its downstream customers;
- Enhance customer satisfaction;
- Enhance environmental performance;
- Continually improve occupational safety and health;
- Achieve legal and other requirements; and
- Deliver on quality, environment, safety, and health objectives.

Operations Roster

The Operations Roster states the shift and leave cycles and demonstrate the impact of the cycles on productivity, ability to attract the required workforce, lost time, and costs. The operating cycles should be benchmarked against current local practice and international best practice.

Detailed roster information can be located in Chapter 8 – Operations Management.

Operational Approach (Phase 1)

The expansion of operations under the ongoing early works program will see the site mainly owner operated to ensure optimal running efficiency of the equipment and to ensure a low-cost base for the operations due to the focus on the LGS mining and processing. Specialty jobs will be contracted so that EQR does not have to retain these skill sets on a full-time basis.

The Early Works Program will ensure that processing capacities reach the targeted production levels using a combination of historic equipment and selected new capital purchases.

All operators and operations supervisors and management are engaged directly by Mt Carbine Retreatment Management Pty Ltd. Prior to the open pit mining operations commencing while development is completed, operational focus will be on the LGS which is a simplified mining methodology whereby the mined LGS material is delivered to the dry processing plant (crushing and screening). The LGS mining will take place on a day shift only basis while the dry processing plant, XRT Sorting (Sorting) and gravity processing plant will operate on a 24/7 roster.

Operations team employment has been increasing in line with the required processing capacities and roster changes and will have sufficient skilled personnel available to operate the processing plants as required.

Strategic contractors are engaged for speciality jobs to occur at site or should specialty jobs need to occur at off-site locations. Due to the ongoing operations at site, relationships are in place with key contractors which complete regular work on site.

With the ongoing operations, there is continuous maintenance planning and ongoing jobs taking place. EQR has found it best to outsource capital project jobs or sustaining capital projects to relevant contractors and where required external project management. This allows maintenance teams, production, and management to focus on the operational requirements while sustaining capital projects are completed as needed by external contractors.

Operational Approach (Phase 2)

The operating philosophy for Mt Carbine at completion of the Project will split between owner-operated and contract operated.

The open pit mining inclusive of drill and blast will be contract mined. The reasoning for this is that the skill requirement for the mining is outside of EQR's core capability, and to retain a lean organisational chart, contract mining was deemed to be the most sensible approach for the operations.

Given the inherent interrelation between the open pit mining and the LGS mining (a constant feed to the crushing and screening plant is required, though the source between the LGS and the open pit will alternate to suit the mine plan), the mining of the low-grade stockpiles will also be included in the open pit contract miner's responsibilities.

The battery limit for the contract mining will be the discharge of the run of mine (ROM) material either in the crushing and screening plant feed bin or adjacent. The basis of the feasibility study has allowed for the crushing and screening plant to be owner operated. If commercial benefits are identified in shifting to a contracting crushing and screening operation this option may be pursued in the future.

The gravity processing plant circuitry and operating philosophy remains largely unchanged and the operating philosophy for this reason will also remain unchanged. The gravity processing plant operating time will increase from week on-week off to full time operations, so the manning will increase, but the operating philosophy and shift and management structure will remain the same.

EQR will retain responsibility for the overall safety of the site through the SSE and the IMS as a guiding document for the site. EQR will also be responsible for the development of the quarterly mine and production planning along with the ore quality management. All these costs have been accounted for in the EQR financial modelling. More detailed mine planning will be the responsibility of the contract miner appointed at the relevant time in the future. EQR has started engaging multiple contractors for the mining of the open pit based on the information provided by DAS Mining Solutions and their pit optimisation modelling completed with this study.

7.7.2. Maintenance

The full-time maintenance team will comprise of the following positions:

- 1 x Maintenance Superintendent;
- 1 x Maintenance Foreman;
- 2 x Fitter;
- 1 x Boiler Maker;
- 1 x Boiler Maker Apprentice; and
- 2 x Electricians.

7.7.3. Mining

All maintenance on the mining equipment shall be the responsibility of the mining contractor. Mining equipment owned by EQR shall be provided for use free of charge to the contractor. The contractor shall be responsible for the maintenance of the free issued equipment in accordance with an approved maintenance schedule.

Until the mining contractor takes on the maintenance of the heavy earth moving equipment, a maintenance contractor will continue to complete heavy vehicle maintenance at site, working 2-3 days at site each week while the LGS mining is ongoing. This arrangement has been proven to work as it is currently being used on site.

Crushing, Screening and Processing

The day-to-day maintenance of the crushing and screening plant and the gravity processing plant will largely be undertaken by the maintenance team that is on site on a full-time basis. The team is highly skilled in the repair and maintenance of the plant and equipment and are currently providing all standard maintenance for the crushing, screening, and gravity processing plant.

Preventative Maintenance will be completed on an ongoing basis with each section of the processing plants, crushing and screening, sorting and the gravity plant receiving a planned 12hr shut down weekly to undertake required maintenance tasks. Any specialty jobs will have the relevant contractor brought in to complete the work. Capital projects will be outsourced to contractors as and when required to ensure the maintenance team stay focused on the maintenance of the crushing and screening plant.

To manage the maintenance at the Mt Carbine operations, EQR has taken out a subscription on the FIIX Maintenance Management software, this provides for the detailed tracking of maintenance and inventory for the site along with cost allocations to the plant and equipment used by the mine and associated analysis and reporting.

Mobile Machinery

Mobile machinery will be serviced at regular hour service intervals of 250, 500, 1,000, 2,000, 3,000, 5,000 and 6,000. This will be completed by an external service provider such as Toddy's Machinery Maintenance that specialises in work of this nature. A service schedule will be put in place to ensure work is completed according to required scheduled service intervals to maximise life of machines and their continued operational capabilities.

7.7.4. Transport and Logistics

The mine is located at 6888 Mulligan Highway, Mt Carbine which is easily accessible from all main ports, rail heads and cities in Far North Queensland. The highway is completely sealed and in good condition. As the mine is currently operational, supply chains and strong relationships have been setup with all major suppliers for equipment on site and ongoing spares required.

Transport of oversize equipment to site is easily achievable as evidenced by the delivery of the earth moving fleet delivered by CRONIMET in September 2021.

The concentrate is then transported via truck, by others, to the Townsville Port for export. Other Ports available for use are the Port in Mackay and Brisbane. Therefore, there are several major ports available to use for any international shipments.

The Cairns airport is approximately a 2-hour drive from site and is easily accessible for either people or freight deliveries. Due to the site being in Far North Queensland, spares are often flown into Cairns or Townsville and trucked to Mareeba as a central distribution point.

7.7.5. Procurement and Supply

Accounts have been setup with all major suppliers as the operation has been running for nearly two years through its pilot phase operations. Relationships and supply chains required for the operation have been established with a secure supply of parts and consumables required for ongoing operations.

The operation is relatively simplistic in nature and therefore no complicated sourcing of materials is foreseen by the operations team. The site is seen as semi-remote as it is approximately a 1-hour drive from a major township, therefore, planning is required for some of the more mine specific items as major transporters only deliver 3-days per week or for the items that are not be held in stock in Mareeba or Cairns.

With the industrial support base of Far North Queensland industry, it has been found that operationally, most spare parts can be delivered within a 24-hour period should a rush order be required. All deliveries are made via sealed highway, with no access issues to the site for oversized deliveries.

7.7.6. Administration

The administration for the project will continue to operate under the Corporate Services team led by the Administration Manager in a holistically similar manner regarding the current systems and protocols in place for ongoing operations. Going forward, EQR will employ an additional accountant to support the current staff contingent with the Corporate Services team operating on an 8hr per day, 5-days per week basis. EQR has established accounting and procurement systems and service providers to satisfy all requirements.

7.7.7. Health and Safety

Eliminating Hazards & Reducing Risks

Risk planning and management is central to the Company's activities, EQR's operations are only conducted when the risk is within acceptable limits and as low as reasonably practicable (ALARP).

The risk planning and management processes developed and implemented at the Mt Carbine site aim to provide a logical and systematic method of identifying, analysing, evaluating, treating, monitoring, and communicating risks.

The following hierarchy of controls is applied to mitigate risk to a level which is ALARP:

- Elimination/Removal;
- Substitution;
- Engineering/Isolation Control;
- Administration;

- Personal Protective Equipment; and
- Human Behaviour.

The hierarchy of control is to be used to control hazards identified for all risk management processes. Less reliable control measure (e.g., administrative, PPE or safe behaviour controls) should only be implemented as part of a holistic control strategy in addition to controls from the other, more effective categories, or on their own where the level of current risk is ALARP.

Risk Management – Principles and Guidelines

EQR's risk management is developed to comply with the requirements of *AS/NZ ISO 31000:2009 Risk Management – Principles and Guidelines*.

Management of Change

EQR Change Management (EQ RESOURCES-SAF-PRO-0034) procedure outlines processes for the prevention of non-compliances resulting from changes in the workplace at the Mt Carbine operations.

Procurement

All purchasing of materials, equipment and services are undertaken to ensure that any safety and health considerations are considered. Hazards are to be identified and assessed prior to the hire or lease of equipment or the supply of services or goods. Verification must be supplied that the delivery of equipment or supply of services complies with appropriate safety and health specifications, the Procurement Officer on site is responsible for this task.

Contractor Management

Contractors are pre-approved according to Contractor Management Procedure (EQ RESOURCES-SAF-PRO-0017) prior to attending site. Contractors approved by the SSE receive an induction before working on site. The induction covers site procedures necessary for that contractor's role.

If a contractor is required for a short-term emergency task on the mine site (such as repairs to phone lines) then that contractor will receive the visitor's induction and remain under the supervision of a fully inducted person during their time on site.

All contractors are required to provide and maintain a safe and healthy work environment and are responsible, as a minimum, for performing work to EQR safety and health standards.

Safety and Health Monitoring

It is essential to assess performance to evaluate progress against the requirements, targets, objectives, and to establish plans for continuous improvement.

To properly assess needs EQR:

- Conducts a systematic review of the corporate guidelines, standards, systems, and processes to verify the current standards and controls in place;
- Conducts audits and assessments at determined frequencies to measure the level of compliance and progress to the standards, and assist in the correction and prevention of any systemic issues;
- Reviews performance and accountability processes to indicate progress or deviations for early corrections; and
- Ensure procedures for Management Review and Health and Safety Objectives detail the processes to be applied.

Safety and Health Compliance

Periodic, at least annual, evaluation of compliance with applicable legal and other requirements will be planned to use the EQR internal and external audit schedule, in addition, legal compliance system Safety Law provides regular updates (at least monthly) to legal and other requirements.

Environment

The Environmental Programs (EPs) (maintained by EQR) are used to establish, implement, control, and maintain processes to meet the requirements of the IMS and implement the environmental objectives identified by the Company. The Environmental Monitoring and Reporting System (EMRS) records information pertinent to the implementation of the IMS governing the operations. The data is used to identify potential environmental risks that require management to assess achievement of the environmental objectives.

Roles, Responsibilities and Authorities

EQR's SSE has responsibility to ensure that the IMS is implemented. Tasks have been assigned by the SSE to Department Managers. The Department Managers may delegate the task to other personnel; however, the responsibility remains with the Department Manager. Safety, Health, Environmental & Training Manager supports the SSE and other managers in meeting the quality, environment, safety, and health objectives, and have responsibility for monitoring the implementation of the quality, environment, safety and health procedures.

Table 12: Roles and Responsibilities

Roles	IMS Responsibilities
Site Senior Executive	• Establish and communicate overall direction. • Develop quality, environment, safety and health policies. • Consider quality, environment, safety, and health requirements. • Develop quality, environment, safety, and health objectives. • Appropriately resource quality, environment, safety, and health management. • Ensure quality, environment, safety, and health compliance. • Promote continual improvement. • Identify interested party needs and expectations. • Review the operation of the IMS. • Conform to IMS requirements. • Promote customer focus throughout the Company.
Operations Manager	• Consider quality, environment, safety, and health requirements. • Develop quality, environment, safety, and health objectives. • Appropriately resource quality, environment, safety, and health management. • Ensure quality, environment, safety, and health compliance. • Promote continual improvement. • Identify interested party needs and expectations. • Review the operation of the IMS. • Conform to IMS requirements.

Roles	IMS Responsibilities
	• Promote customer focus throughout the Company.
Department Foreman	• Implement quality, environment, safety, and health procedures. • Review the operation of the IMS. • Conform to IMS requirements. • Participate in Management reviews. • Ensure loaded product meets physical and chemical specifications.
Safety, Health, Environment & Training Manager	• Monitor and report on overall IMS performance . • Review the operation of the IMS. • Identify and deliver training requirements. • Communicate and correspond with relevant regulators/local government regarding quality and environmental management. • Conform to IMS requirements. • Develop quality and environmental policy. • Ensure the IMS conforms to the relevant ISO Standards. • Maintain quality and environmental management system changes. • Ensure loaded product meets physical and chemical specification. • Develop safety and health policy. • Maintain safety and health management system changes. • Report on the performance of the safety and health management system to management.
All Personnel	• Conform to IMS requirements. • Discuss quality, environment, safety, and health improvement ideas with management. • Stop the process when the quality of the product is compromised, the environment has or can be affected, or the safety and health of workers is at risk. • Participate in quality, environment, safety, and health improvement programs.

7.7.8. Control of Records

Records shall be kept of all tasks and activities which relate to the IMS and to operational aspects which have the potential to affect the quality of the product, safety and health of people or the environment.

The records to be kept, shall include records required by acts, regulations, statutory codes of practice, and required by Australian Standards referenced in acts, regulations, and statutory codes of practice.

7.7.9. Accommodation

Employment will continue from the local region, so that the employees can work on a drive in, drive out (DIDO) basis. Employees are currently doing this, and it has worked fine for all parties involved. Certain personnel that live in more distant locations, for example Cairns, rent a space at the Mt Carbine Caravan Park, next to the mine site, for the duration of their shift and commute to their place of residence at the conclusion of their swing. The Mt Carbine Motel also offers operators and contractors nightly rates with meals included for those working on shift or performing contracts in the area.

7.7.10. Emergency Response Plans

EQR's Emergency Response Management Plan (EQ RESOURCES-SAF-PLN-0003) minimises the level of risk to life, property, and the environment due to an emergency situation.

The EQR Emergency Response Management Plan describes the immediate actions required by designated site personnel.

All personnel are required to undergo site and specific area inductions to familiarise themselves with locations of emergency equipment and evacuation points. Emergency contact details and procedures are provided during their induction.

7.8. Closure and Rehabilitation

Approach

The closure strategy encompasses a staged approach to rationalising land and water management, environmental monitoring and compliance.

- Stage 1 includes a review of existing site conditions and the Environmental Authorities (EAs); identifying necessary modifications as relevant and developing a plan to affect change.
- Stage 2 is the development of an optimisation plan for the land and water management and monitoring across the Project site.
- Stage 3 involves updating supporting regulatory and management documentation and implementation.

Although a source of licensing complexity, the co-existence of the quarry and mining activities results in the beneficial re-use of tailings and low-grade ore stockpiles located on the site that are remnant from previous operations on the site; as well as the use of non-mineralised material and reuse of process residues associated with the renewed open pit mining. This is a significant outcome for rehabilitation and closure considerations *ie* the solid wastes (process residue and waste rock materials) associated with mining are inventory for the quarry.

Risk

The Risk Assessment for the Project is presented in Chapter 14: Risk and Opportunity. From a closure perspective, failure to achieve the intended outcome, expressed as being the successful surrender of the EAs that apply to the land on which quarry and mining activities occur, is the risk. The reason for failure may be technical or regulatory and are not necessarily independent. Technical reasons for failure broadly concern environmental values such as land and water; whereas the regulatory reasons pertain to, for example, license conditions and overarching legislation.

7.9. Environment and Approvals

Current Status

The land relevant to the Project site is used for quarry and mining activities as per the respective licenses (EA EPPR00438313, dated 16 March 2021 for the quarry and EA EPML00956913, dated 1 December 2020 for the mine). Notifiable activities are defined in Schedule 3 of the Environmental Protection Act 1994 (EP Act).

No notifiable activities are planned to occur as part of the quarry activities under EA EPPR00438313. Lot 13 on Plan SP254833 is included on the Environmental Management Register (EMR) as the site has been subject to the following notifications associated with the mining activity undertaken pursuant to EA EPML00956913: Mine Waste, Mineral Processing, Petroleum Product or Oil Storage. Environmentally relevant activities (ERAs) are defined in the Environmental Protection Regulation 2019 (EP Reg). The ERAs listed in Table 13 are licenced under EA EPPR00438313 for the quarry and under EA EPML00956913 for the mine.

Table 13: Existing ERAs for the Project Site

ERA No.	Activity	Threshold
EA EPPR00438313 for the quarry activity		
16	Extractive and Screening	Extraction and Screening 3: Screening, in a year, the following quantity of material (b) more than 100,000t but not more than 1,000,000t
16	Extractive and Screening	Extraction and Screening 2: Extracting, other than by dredging, in a year, the following quantity of material (b) more than 100,000t but not more than 1,000,000t
EA EPML00956913 for the mine activity		
14	Electricity Generation	Ancillary 14 - Electricity Generation 2: Generating electricity by using a fuel, other than gas, at a rated capacity of (a) 10MW electrical to 150MW electrical
8	Chemical Storage	Ancillary 08 - Chemical Storage 4: storing 200t or more of chemicals that are solids or gases, other than chemicals mentioned in items 1 to 3, under subsection (1)(d)
15	Fuel Burning	Ancillary 15 - Fuel burning: Using fuel burning equipment that is capable of burning at least 500kg of fuel in an hour
31	Mineral Processing	Ancillary 31 - Mineral processing 2: Processing, in a year, the following quantities of mineral products, other than coke (a) 1000t to 100,000t
8	Chemical Storage	Ancillary 08 - Chemical Storage 3: Storing more than 500 cubic metres of chemicals of class C1 or C2 combustible liquids under AS 1940 or dangerous goods class 3 under subsection (1)(c)
8	Chemical Storage	Ancillary 08 - Chemical Storage 5: storing 200 cubic metres or more of chemicals that are liquids, other than chemicals mentioned in items 1 to 3, under subsection (1)(d)
8	Chemical Storage	Ancillary 08 - Chemical Storage 1: Storing a total of 50t or more of chemicals of dangerous goods class 1 or class 2, division 2.3 under subsection (1)(a)
Schedule 3 19	Mining	Schedule 3 19: Mining metal ore, other than a metal ore mentioned in items 11, 12, 14, 15, 16,17 or 18

In regard to the requirement for an End Of Waste (EOW) code for the Mt Carbine Project, the Administering Authority has determined that an EOW approval or code is not required.

Relevant Environmental Legislation

There are Commonwealth, Queensland and local government legislation that are relevant to the broad topic of management of values, a list of legislation is provided below. The Project is an existing activity and is licensed to operate. For the proposed renewal of open pit mining an application to amend the existing EA will be necessary and is discussed in Chapter 10.

Commonwealth legislation:

- Environmental Protection and Biodiversity Conservation Act 1999
- Native Title Act 1993
- National Environmental Protection Council Act 1994

- National Greenhouse and Energy Reporting Act 2007
- Energy Efficiency Opportunities Act 2006
- Clean Energy Act 2011

Queensland legislation:

- Environmental Protection Act 1994
- Mineral and Energy Resources (Financial Provisioning) Act 2018
- Mineral Resources Act 1989
- Aboriginal Cultural Heritage Act 2003
- Queensland Heritage Act 1992
- Water Act 2000
- Planning Act 2016
- Transport Infrastructure Act 1994
- State Development and Public Works Organisation Act 1971
- Nature Conservation Act 1992
- Environmental Offsets Act 2014
- Vegetation Management Act 1999
- Biosecurity Act 2014
- Waste Reduction and Recycling Act 2011
- Local Government Act 2009

Local Government – Mareeba Shire Council

- Local Government is not recognised in the nation's constitution and owes its existence to State Government legislation (Local Government Act 2009). The role, functions and boundaries of Local Governments are subject to the discretion of the State Government.
- Mareeba Shire Council Planning Scheme 2016.

7.9.1. Required Approvals

The EA for the mining activity i.e. EA EPML00956913, dated 1 December 2020, permits mineral processing at an annual rate of 1,000t to 100,000t. An application for an increased rate of mineral processing to an annual rate of 500,000t was submitted on 1 December 2021.

Notwithstanding that the renewed activities:

- will be limited to the existing bounds of the MLs;
- occur on land areas that have been disturbed by previous mining activities; and
- the existing EA EPML00956913 includes conditions relevant to these impacts;

it will be necessary to apply for an EA amendment for the mining activity *ie* EA EPML00956913.

A register of the required approvals in included in Table 14.

Table 14: Approvals Register

Application Path	Permit	Legislation	Agency/ Assessment Manager	Project Aspect	Required to commence construction or to commence operation	Comments
EA amendment application	EA EPML00956913	EP Act	Department of Environment and Science	Mine	Necessary for increased rate of production through the process plant.	Required for Phase 1 processing plant throughput.
EA amendment application	EA EPML00956913	EP Act	Department of Environment and Science	Mine	Necessary for renewal of open pit mining.	Required for Phase 2.
EA amendment application	EA EPPR00438313	EP Act	Department of Environment and Science	Quarry	May be required to align EA EPML00956913 and EA EPPR00438313.	May be required for Phase 2.
Application	Water Licence	Water Act 2000	Department of Regional Development, Manufacturing and Water	Mine	Not expected to be required.	There is no moratorium over the area, or a groundwater management plan, and no requirement for development approval for drilling. It is not expected that a licence will be required.
Application	Road Corridor Permit	Transport Infrastructure Act 1994	Department of Transport and Main Roads (TMR)	Mine	Not expected to be required.	The Project area has been dissected by the State Road since grant of title. It is expected that the Blast Management Plan, developed with stakeholder engagement, will address TMR's requirements. It is expected that use of the culvert for conveyance of pipes will prevail without the need for additional permitting.

7.9.2. Environmental Management and Monitoring

As detailed in Chapter 9: Closure and Rehabilitation, a strategic approach has been adopted to monitoring and reporting. The overarching intent is for all environmental monitoring and compliance programs, together with all associated reporting prepared under the auspices of the EAs, Progressive Rehabilitation & Closure Plan (PRCP) and PRCP schedule and similarly for future regulatory tools, to serve not only the purpose of compliance but to ultimately provide evidence for successful closure and final relinquishment.

7.9.3. Community and Stakeholders

Guiding Principles to Community and Stakeholders

EQR is a value-oriented resource company, sustainably producing and managing new economy minerals and metals. Embedded in our philosophy is minimising our footprint where possible. The guiding principles for community and stakeholder engagement are summarised in Table 15.

Table 15: Guiding Principles

Guiding principles					
					
We will be	**Proactive**	**Flexible and inclusive**	**Genuine**	**Respectful**	**Responsive**
This means	We will engage with communities early and often, so that we understand and respond to their interests and concerns.	We will offer a range of engagement opportunities that are tailored to the variety of needs and preferences of the community.	We will have authentic conversations with the community, clearly explaining what can and can't be influenced.	We understand that not everyone will support our projects. We will create an environment to have professional conversations.	We will close the loop, providing feedback to the community on how input has been taken into consideration.

Engagement Approach

The focus for EQR is delivering value for investors and sustainably producing new economy minerals and metals, while minimising its footprint where possible. This including in the communities in which it operates. The Community and Stakeholder Engagement Plan (CSEP) sets out the framework for effective consultation and engagement. While the implementation plan uses a broad range of tools and techniques to ensure we are meeting the needs of stakeholders and delivering consistent messages in a timely manner.

Gathering different views contributes to a richer understanding of how to effectively meet the organisation's goals and inform the engagement or communication that needs to take place. It is important for EQR because:

- **Support** - It will support its operations and help new growth projects in the region.
- **Social licence** - Maintain and improve its social licence, supporting current and future opportunities in the region.
- **Trust -** Lead the conversation about change, creating trust, and open communication with the community and all stakeholders.

The focus of engagement activities is to work with those most impacted by the Project's operations or who have a high level of influence on the Project at each phase.

Stakeholders

A stakeholder risk assessment was carried out to map relevant stakeholders in terms of their interest in potential sites for different option types and their potential to influence Project outcomes. The analysis identified four overarching stakeholder categories, defined in the Stakeholder Mapping and Consultation Register (the Register). The Register is a living document and to be updated as interactions with stakeholder occur. The Register will help identify trends, monitor activities for which reporting metrics can be extracted.

Figure 19: Stakeholder Matrix (Source: Mara Consulting)



Potential Issues and Mitigations

During the planning and research of developing the plan, a SWOT analysis was completed. This assisted in the evaluation of the Project, including identifying internal and external factors, that may impact the Project in both positive and negative ways. Each statement was examined with appropriate actions identified to capitalise on strengths and opportunities and mitigate weaknesses and threats. An analysis of the items raised helped to set clear priorities for the engagement.

Pre-empting and proactively managing stakeholder issues is crucial to the overall success of the Project. Given the nature and profile of the Project, stakeholder expectations require careful management.

Table 16 identifies risk considerations related to the Project.

Table 16: Risk Considerations

Risk Considerations*	Yes	No	Potentially
Is the Project politically sensitive (either local or state government level)?		✓	
Is the Project likely to cause disruption to essential community services?		✓	
Is the Project likely to impact on environmentally sensitive areas?			✓
Is the Project likely to cause disruption to local residents or businesses?	✓		

Risk Considerations*	Yes	No	Potentially
Is the Project likely to be opposed by any groups or individuals within the community?			✓
Does the Project deal with issues or decisions that are likely to be controversial or divisive?			✓
Is the Project likely to attract a media attention (either positive or negative)?			✓

** Note – the risk considerations will be regularly updated as the Project progresses. This is an overview of potential risks.*

Communication and Engagement

Underpinning the Project team's commitment to effective engagement is mutual respect. The team is committed to:

- Honest and straightforward dealings with stakeholders;
- Providing accurate and timely information to stakeholders;
- Using plain language to describe Project activities;
- Actively listening and acknowledging other points of view; and
- Respecting individual and cultural differences always.

Engagement methods will vary depending on the purpose and expectations of the engagement. Selecting the right tool and taking time to plan the engagement process will help build trust and buy-in from stakeholders.

Complaints and Enquires Management

EQR (or designated contractor) will receive Project enquiries and complaints via a dedicated Project hotline and Project specific email. This contact information will be included on all communications materials related to the Project. The Consultation Register will be used for the duration of the Project. EQR (or designated contractor) will:

- Record details of every complaint or enquiry in the Consultation Register including date and time of complaint and how the complaint was received;
- Record full name, address and preferred method of contact for the complainant;
- Record how the complaint or enquiry was managed and closed out;
- Investigate and determine the source of the complaint;
- Record action taken, officers involved, details of resolution and response times;
- Refer misdirected complaints or enquiries to the appropriate authority; and
- Produce monthly reports to ensure complaints are managed effectively.

Timing

Engagement and communication are a cradle to grave approach, that is it is ongoing through the operations of the Mt Carbine facility. During operations, there will be a need to increase activities to support the Project's lifecycle phase. Specifically, between late 2021 and early 2023 two environmental approvals will be sought.

Phase 1 EA is seeking to increase processing of current stockpiles to 500,000 tpa. The focus is to incrementally improve the mine's productivity and profitability, focusing solely on the mining and processing of the LGS. This is likely to have minimal impacts.

Phase 2 EA is seeking to dewater and recommence mining tungsten in the existing pit area. The crushing and screening plant and processing plant will be upgraded to further reduce operating costs and increase the tungsten recovery. The Project timeline is summarised in Figure 20.

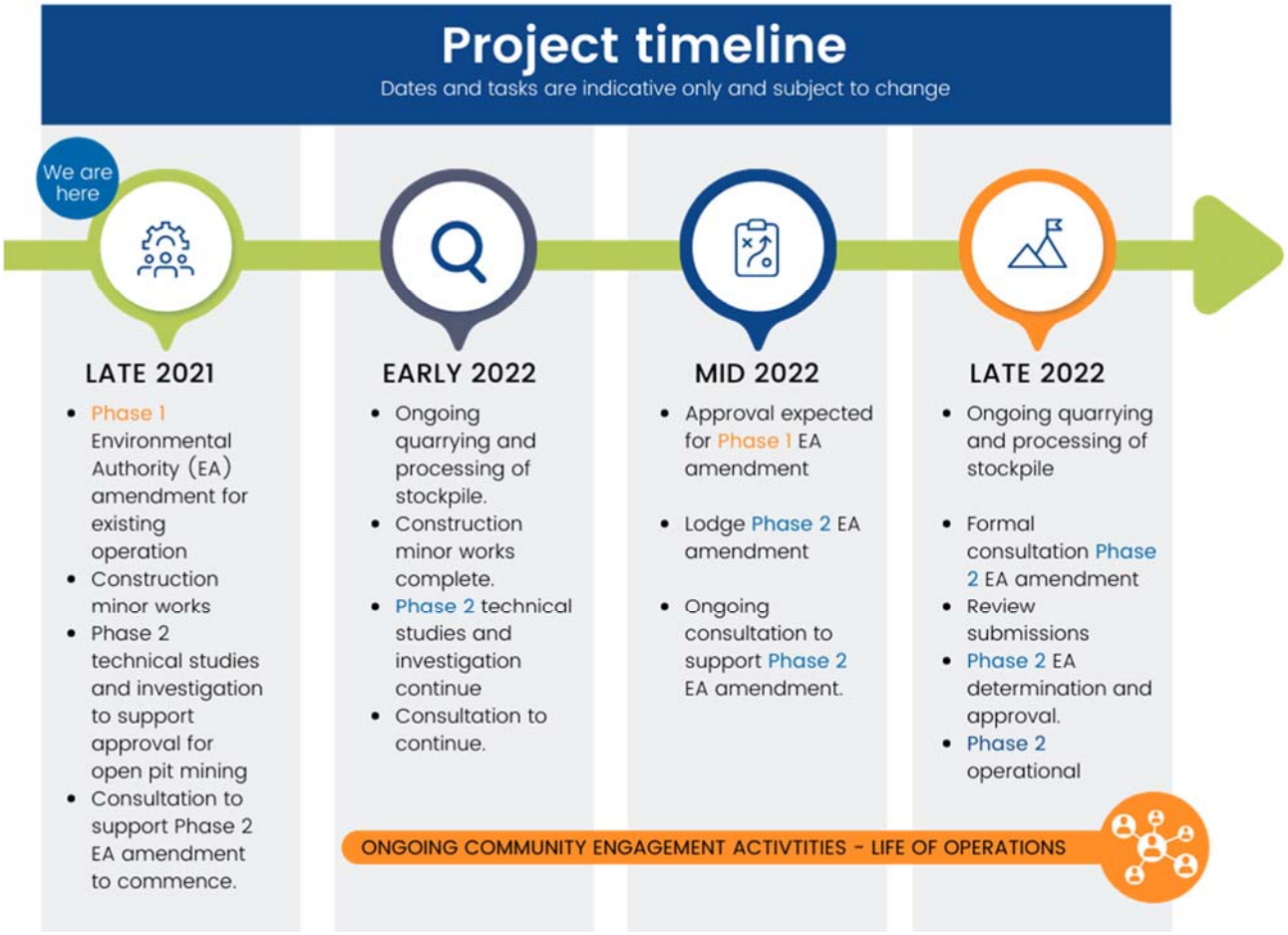


Figure 20: Project Timeline

Consultation will support the technical studies, with targeted engagement with affected stakeholders. An implementation plan will guide communication and engagement tided to the Project timeline. Initially, the focus will be to introduce the operation and amendments to stakeholders, followed by gathering feedback on the Phase 2 proposal, particularly with directly impacted stakeholders.

Communication and engagement are rarely static, and they are likely to change on a regular basis. Mt Carbine will change and have different stakeholder requirements at each stage of the Project. Each stage of the Project will be an opportunity to gather feedback and support the Project. At each point in preparing engagement activities, we follow four general phases: preparation, planning, delivery, and review.

7.9.4. Operating Cost Estimate

Basis of Estimate

Accuracy of Estimate

All operating costs are presented in real terms as of 1 December 2021. All cost assumptions were derived from cost data from varying sources:

- Mining costs were developed using a combination of existing mining data combined with contractor pricing and consultant input (DAS Mining Solutions);

- Crushing screening and sorting pricing from existing data combined with consultant pricing (Mincore); and
- Processing plant pricing from existing data combined with consultant pricing (Ausenco).

Based on the alignment between contract data, and DAS Mining Solutions equipment data base, the order of accuracy for mining equipment has been determined to be between -10%/+15%. This order of accuracy also applies to the crushing, screening, sorting, and processing opex costs based on current expenditure at Mt Carbine.

Source Documentation

For the compilation of the operating cost estimate, all activities were identified relating to the extraction of ore from the open pit mine and LGS to loading of trucks at the mine gate. Cost estimates were then developed for each activity benchmarked against the following:

- First principles estimates;
- Consultants' data derived from similar external projects;
- Use of actual costs from the existing operation; and
- Contracts currently in place at Mt Carbine.

The activities were separated into:

- Mining activities to deliver ore to the ROM pad;
- Crushing, screening, and sorting;
- Processing; and
- Other site related costs.

Key Assumptions

The key assumptions utilised in the operating cost estimate are included in Table 17.

Table 17: Operating Cost Estimate Key Assumptions

Item	Assumption
Base Data	Products or services used in more than one function of the operation were identified and used as standard cost assumptions. These items include diesel fuel, explosives, and electricity.
Diesel Fuel Prices	The fuel price is based on the current average prices of existing operations at Mt Carbine. The wholesale cost of diesel fuel was estimated at AUD1.401. Upon application of the diesel rebate (after GST removal) of AUD0.401/L, the diesel price used for opex costs was AUD1.00.
Explosives Costs	Estimates were provided for drill and blast costs by consultants DAS Mining Solutions, with pricing estimates based on recent experience and unit drill and blast costs benchmarked against contractor pricing from Orana Drilling. Prices were all inclusive as a rock on ground (AUD2.83/BCM) service to include drilling, emulsion supply, loading, stemming, and shot firing.
Electricity	The electricity price is based on the forecast provided by the current mine supplier (Ergon). Forecasted data is based on recent historical usage and was considered the most accurate. The electricity price used for opex costs was AUD0.19 per kWh.
Exchange Rates	The base case AUD/USD foreign exchange forecasts assumed for the duration of the operations was 0.73.

Project Valuation

The Project is expected to generate discounted cash flows totalling $131.5m based on a discount rate of 8% (pre-tax), before considerations for project financing. The pre-tax, ungeared IRR of the project is expected to be 154% with payback by March 2024.

Sensitivity Analysis

NPV Sensitivity

The base case NPV is $131.5m.

The figure below illustrates the Project's NPV is most sensitive to the FX rate, and the tungsten price

The results were as follows:

- The AUD/ USD exchange rate has the most positive effect on the NPV, producing the highest NPV on the graph below of $209 million, when it is decreased by 20% (i.e. a weak AUD increases the AUD revenue). A 20% decrease in the base case AUD of 0.73 would be 0.58. A 10% decrease in the AUD is seen as more likely (resulting in AUD0.67, which was seen as recent as 2020), and that would increase the NPV by $34m, from the base case of $132m to $166m- as noted on the chart below;
- The following assumptions have the most negative effect, producing the lowest NPV of $69m (and thus they appear as one line on the graph below, however are lines on top of each other):
    - Tungsten recovery in process plant;
    - Tungsten price;
    - Concentrate grade; and
    - APT payable.

A percentage change in any of the above four inputs affects the NPV in the same manner.

Changes in capex have the least effect on the IRR, which is logical as capex is small at circa $20m, versus Revenue of $425m, thus percentage changes in assumptions that affect the latter will have a higher effect.

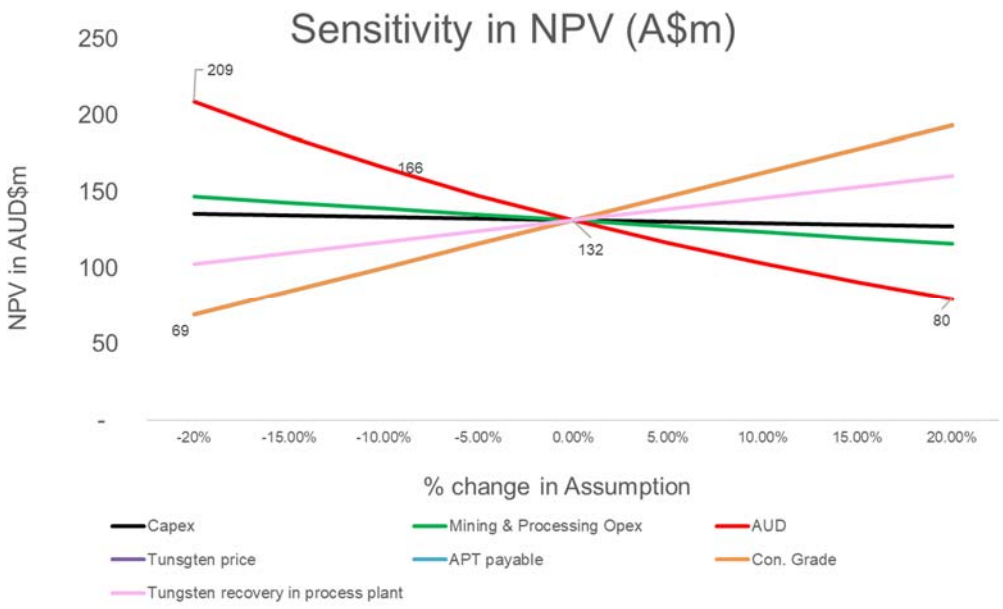


Figure 21: Sensitivity of the NPV to Changes in Key Assumptions

IRR Sensitivity

The base case IRR is 154%.

Changes in the NPV sensitivity inputs, had nearly exactly the same effect on the IRR as they did on the NPV, with the one exception being that a percentage change in the capex affects the IRR slightly more than a percentage change in opex does, as the IRR is calculated on monthly cashflows and the NPV on annual (both totalling the same, however more granularity in the monthly).

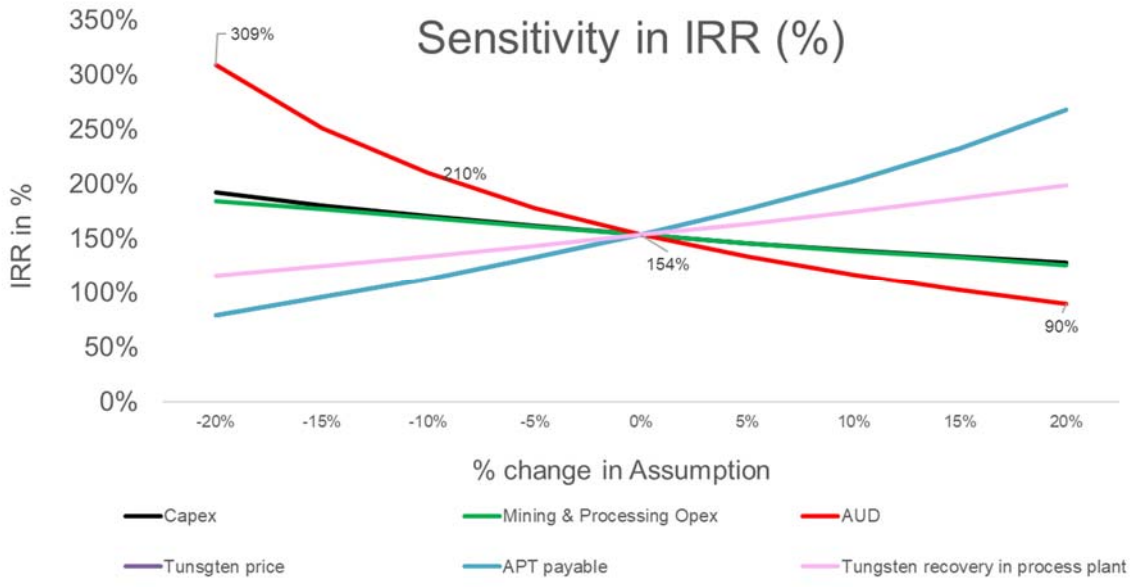


Figure 22: Sensitivity of the IRR to Changes in Key Assumptions

Breakeven Analysis

The model has been tested to determine the change required in key inputs to reach a "breakeven" level, by flexing / changing one input at a time.

A breakeven level can be defined numerous ways but for the purpose of this analysis, it's defined as an IRR of 0% return.

All the inputs behave in the same manner as when testing for the NPV i.e. the inputs which the project is the most sensitive to (FX and revenue related inputs), require the least change to affect the IRR. For the IRR to decrease to 0%:

- the AUD would have to increase by 79% across all years. This would mean the AUD increasing from base case level of 0.73 to 1.422 (a level that has not been seen in 20 years);
- the tungsten price, or APT payable or concentrate grade or recovery rate would have to decrease by 45% across all years; or
- Conversely, the capex would have to increase by 881% (as it's coming off a low base of only circa $20m).

The breakeven analysis is summarised in Table 18.

Table 18: Breakeven Analysis

Assumption	Change Required to reach IRR of Zero
Capex	881%
Mining & Processing Opex	192%
AUD	79%
Tungsten Price	-45%
APT Payable	-45%
Concentrate Grade	-45%
Tungsten Recovery in Process	**-45%**

8. List of Abbreviations

Abbreviation	Description
ADT	Articulated dump truck
ALARP	As low as reasonably practicable
APT	Ammonium paratungstate
Capex	Capital expenditure
CEO	Chief Executive Officer
CMOC	China Molybdenum Co Ltd
CPI	Consumer Price Index
CRONIMET	CRONIMET Australia Pty Ltd
CSEP	Community and Stakeholder Engagement Plan
E&I	Electrical and instrumentation
EMRS	Environmental Monitoring and Reporting System
EOW	End of waste
EP	Environmental Program
EPC	Engineer, procure, construct
EQR	EQ Resources Limited
ESG	Environment, Social Governance
FCA	Free carrier
GHG	Greenhouse gas
HGZ	High-grade ore zone
IMS	Integrated Management System
IMSM	Integrated Management System Manual
JORC	Joint Ore Reserves Committee
JT	JukesTodd
JV	Joint venture
LGS	Low grade ore stockpiles
LMB	London Metal Bulletin
LOM	Life of mine
ML	Mining Lease
MTCRM	Mt Carbine Retreatment Management Pty Ltd
MTU	Metric tonne unit - one mtu equates to 10kg. The term is used as the pricing basis for APT

Abbreviation	Description
Opex	Operating expenditure
RL	Relative level
SCADA	Supervisory control and data acquisition
SDG	Sustainable Development Goals
SHMS	Safety and health management system
SMP	Structural, mechanical, piping
SSE	Site Senior Executive
W	Tungsten
XRT	X-ray transmission

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Appendix P:
Mount Carbine Mine Report on Revegetation Trials (NRA 1994)

111002\REVEGTR1.R01

NATURAL RESOURCE ASSESSMENTS

See Also 931022.R01
931022.R02

MOUNT CARBINE MINE
REPORT ON REVEGETATION TRIALS



111002

MOUNT CARBINE MINE
REPORT ON REVEGETATION TRIALS

Prepared by

NATURAL RESOURCE ASSESSMENTS PTY LTD
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CAIRNS 4870

For

Queensland Tungsten
C\- Mail Centre
MOUNT CARBINE 4871

14 June 1994

111002\REVEGTRI.R01

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Our Ref: 111002\REVEGTRI.L01\TA:ds

6 June 1994

Queensland Tungsten
Mail Centre
MOUT CARBINE 4871

Attention: Dr Dayrell Wolff

Dear Mr Wolff

RE: REVEGETATION TRIALS – MOUNT CARBINE MINE

Please find herewith two (2) copies of the final report describing the establishment and monitoring of revegetation trials for disturbed areas at the Mount Carbine Mine site.

Should you have any queries regarding the information presented, please contact either Tim Anderson or myself. Thank you for the opportunity to assist you with this project.

Yours sincerely
Natural Resource Assessments Pty Ltd

Neil Boland
Director

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1. INTRODUCTION

Natural Resource Assessments Pty Ltd (NRA) was commissioned in December 1993 by Queensland Tungsten to assist with the revegetation program at the Mount Carbine Mine.

The work to be undertaken included the design of revegetation trials on areas of the two major land disturbance types viz tailings dam and the waste rock dump. The trial designs were documented in a previous NRA report dated 21 December 1993 (NRA, 1993).

This report documents the establishment and monitoring of the trial and discusses the outcomes.

2. TRIAL ESTABLISHMENT

Revegetation trials were established on 26 February 1994 in accordance with the general design recommendations described by NRA (1993). Specific establishment details are included in Table 1:

Table 1
Establishment Details

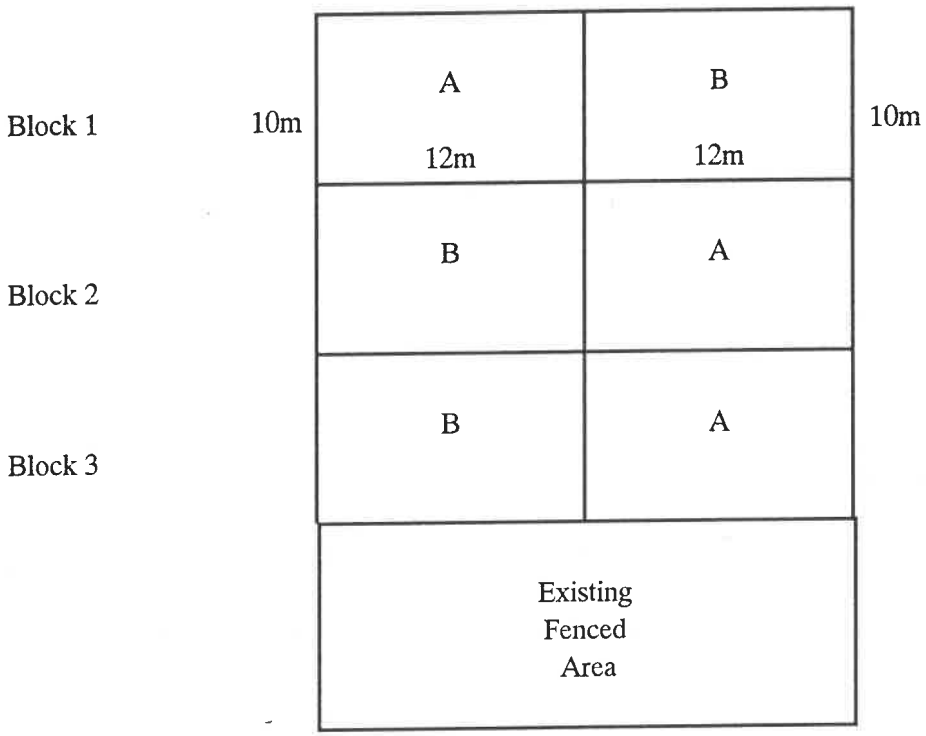
Seed type	**Rate** *
Indian Blue Couch	3 kg/ha
Signal Grass	1 kg/ha
Sabi Grass	3 kg/ha
Japanese Millet	10 kg/ha
Pioneer Rhodes Grass	1–3 kg/hr (flow dependent)
Brachiaria (*Brachiaria humidicola*)	100 g/ha
Verano Stylo	3 kg/ha
Seca Stylo	3 kg/ha
Custom Mix · Indian Blue · Katambora Rhodes · USA Buffel · Gayndah Buffle · Birdwood Buffle · Seca Stylo · Verano Stylo · Omega Stylo	12 kg/ha
Fertiliser type	**Rate**
Diammonium Phosphate (DAP) (19%N, 20% P)	150 kg/ha
Muriate of Potash (50% k)	150 kg/ha

* All seed was purchased from a commercial seed supplier.

The range of seed and rates of seed and fertiliser application were increased relative to that described in the trial design report to maximise the probability of successful establishment.

The trials were undertaken on the tailings dam and waste rock dump areas. Schematic diagrams of these sites are presented in Figures 1 and 2 and accompanying photographs are presented as Plates 1, 2 and 3.

Figure 1
Tailings Dam (No. 4 Tailings Dam) Trial Plot Dimensions

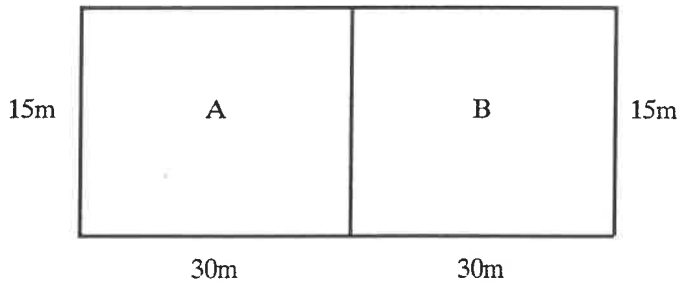


- Three blocks were established; each contained two treatments.
- The two treatments were randomly distributed:

  A = mulch
  B = no mulch

- Each treatment plot was 12m x 10m.
- The trial area was fenced off from stock but there was no internal physical partitioning. The effects of grazing, soil preparation and fertiliser application can be predicted. Therefore variations of fertiliser rates and soil preparation techniques were not trialed.
- The tailings surface was lightly scarified using a truck mounted scarifier. Seed and fertiliser were applied by a tractor mounted spreader.
- Hay mulch was applied by hand to the relevant treatments (A) at a rate of about 20 kg/ha.

Figure 2
Waste Rock Dump Trial Plot Dimensions



- One block was established containing two treatments.
- The two treatments were:

  A = mulch
  B = no mulch

- Each treatment was 30 m x 15 m.
- The surface was not pretreated because the material was rock. Seed and fertiliser were applied by a tractor mounted spreader.
- Hay mulch was applied by hand to the relevant treatment (A) at a rate of about 20 kg/ha.



Plate 1
Tailings Dam Trial Site



Plate 2
Tailings Dam Trial Site – Scarified Surface



Plate 3
Waste Rock Dump Trial Site (trial site in the mid and background)

Supporting Information

- Site rainfall data recorded during the trial is presented in Table 2.

Table 2
Site Rainfall Data

Date	Rainfall (mm)
2.3.94	16.5
5.3.95	47.0
9.3.94	0.5
13.3.94	4.5
29.3.94	0.5
7.4.94	2.5
8.4.94	1.0
17.4.94	1.0

Table 3
'Soil' Analysis – No 4 Tailings Dam

Parameters	Block 1A	Block 1B	Block 2A	Block 2B	Block 3A	Block 3B	Guideline Levels *
Soil colour (Munsell)	Grey	Grey	Grey	Grey	Grey	Grey	–
Soil texture	Sandy Tails	Sandy Tails	Sandy Tails	Sandy Tails	Sandy Tails	Sandy Tails	–
pH (1:5 Water)	8.7	7.2	8.4	8.8	8.8	9.2	5.5–8.5
Organic Carbon %C	0.1	0.1	0.1	0.1	0.1	0.1	–
Nitrate Nitrogen mg/kg	1.5	0.5	1.2	1	0.8	0.9	–
Sulfur mg/kg	8	5	8	6	10	12	15
Phosphorus (BSES) mg/kg	200+	200+	200+	200+	200+	200+	–
Phosphorus (Colwell) mg/kg	3	2	2	2	5	2	30
Potassium meq/100g	0.03	0.02	0.02	0.01	0.02	0.01	0.3
Calcium meq/100g	1.76	1.01	1.24	1.76	1.55	3.72	1.2
Magnesium meq/100g	0.06	0.06	0.06	0.06	0.06	0.1	0.8
Sodium meq/100g	0.01	0.01	0.01	0.01	0.01	0.01	–
Chloride mg/kg	10	5	10	10	10	5	<200–600
Copper mg/kg	0.7	0.6	0.8	0.6	0.5	0.6	0.2
Zinc mg/kg	1.3	1.2	1.2	1.2	1.3	1.4	0.5–1
Manganese mg/kg	1	1	1	1	1	1	2
Iron mg/kg	7	8	5	5	5	6	4.5
Boron mg/kg	0.04	0.03	0.04	0.02	0.05	0.06	–
ESP (%)	0.53	0.9	0.75	0.54	0.61	0.26	<6**
$EC_{(se)}$d S/m	0.4	0.2	0.4	0.3	0.3	0.4	<2***
CEC meq/100g	1.87	1.11	1.34	1.85	1.65	3.85	–
Ca/Mg ratio	29.33	16.83	20.67	29.33	25.83	37.2	–

* Cited in Bell, L C and Bell M A (1988) and ASSSI Refresher course in Soil Science (1985). For nutrients, this is the level below which a plant response to application of the nutrient is expected (Aitken et al, 1984); for Cl, EC and ESP, the critical level is the value above which growth retardation may occur.

** An ESP >15% is classed strongly sodic.

*** An EC_{se} dS/m is considered to have negligible effects on plant growth with many plants affected in soils having an EC in the range of 4–8 dS/m. Beyond 16 dS/m only a few very salt tolerant plants grow.

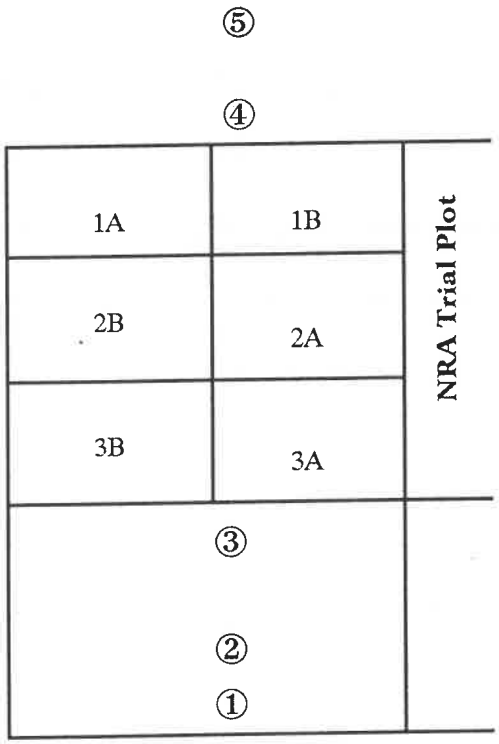
Tailings dam sub–surface water depths are presented in Table 4(a, b)

Table 4(a)
Sub–Surface Water Depths on Tailings Dam

Test Pit No.	Depth to Water
1	0.5 m
2	0.85 m
3	1.5 m
4	2.5 m
5	3.6 m

Note that tailings surface slopes downhill from test pits No. 5 to No. 1 at 5–7°.

Table 4(b)
Test Pit Localities



3. METHODOLOGY

Monitoring of the field trials was undertaken on 27 April 1994, approximately 8 weeks after trial establishment and was in accordance with the methods detailed by NRA (1993).

4. RESULTS

The use of an Ellenbank pasture metre to assess bulk was not undertaken due to poor plant growth on the tailings dam trial (Plate 4) and the absence of plant growth on the waste rock dump trial (Plate 5). Species composition as determined by the rank method with a 1 m x 1 m quadrat was of negligible use due to the lack of plant growth. The method was, however, applied to the tailings dam trial site in order to provide a record of plant emergence. These results are presented in Table 5.

Table 5
Species Composition – Tailings Dam Trial Site

Block A1	Block A2	Block A3	Block B1	Block B2	Block B3
0	HM	JM(15–20), HM	0	0	0
HM	JM(5–10),HM	JM(5–10), HM	0	JM(5–10)	0
HM	JM(0–5),HM	JM(15–20), HM	0	0	0
HM	JM(5–10),HM	JM(15–20), HM	0	0	0
HM,JM(4)	JM(0–5),HM	JM(0–5), HM	0	0	0
HM, JM(12)	JM(10–15),HM	JM(15–20), HM	0	0	JM(0–5)
HM, JM(12)	JM(10–15), HM	JM(10–15), HM	0	0	JM(1)
HM, JM(12)	JM(15–20), HM	JM(15–20), HM	JM(15)	0	0
HM	JM(15–20), HM	JM(15–20), HM	JM(15)	JM(0–5)	0
0	JM(15–20), HM	JM(0–5), HM	JM(15–20)	JM(0–5)	0
0	JM(5–10), HM	JM(0–5), HM	JM(15–20)	JM(0–5)	0
HM	JM(0–5), HM	JM(0–5), HM	JM(0–5)	JM(0–5)	0
JM(8), HM	JM(0–5), HM	JM(10–15), HM	JM(0–5)	JM(5–10)	0
JM(15), HM	JM(15–20), HM	JM(5–10), HM	JM(0–5)	JM(0–5)	0
JM(12), HM	JM(15–20), HM	JM(5–10), HM	JM(0–5)	JM(0–5)	0

JM = Japanese Millet
HM = Hay Mulch
( ) = Refers to the number of individual plants within each 1 m x 1 m quadrat
0 = Bare surface



Plate 4
Revegetation Trial on Tailings Dam ('hay mulch treatment' in background, 'no hay mulch treatment' in foreground)



Plate 5
Waste Rock Dump Revegetation Trial
('hay mulch treatment' on the left and 'no hay mulch treatment' on the right)

5. DISCUSSIONS

5.1 Tailings Dam Trial

The results of the tailings dam trial site monitoring show that plant establishment was poor. Poor establishment was not likely to be due to either nutrient deficiencies or toxicity. This conclusion is supported by:

- the establishment of Japanese Millet on areas of the trial site;
- natural colonisation of species on the tailings material downslope of the trial area; and
- the results of nutrient analyses for the tailings dam trial site.

The lack of stored soil water appears to be the limiting factor to plant establishment on the tailings material.

Natural colonisation is restricted to the periphery of the tailings dam structure. This appears to be a function of depth to ground water; as the depth increases up the slope, the rate of colonisation declines. (Refer to Table 5). Other factors which may have contributed to natural colonisation include:

- downslope accumulation of 'fines' which improved soil moisture holding capacity; and
- downslope accumulation of nutrients.

A trend of increased plant growth (Japanese Millet) was observed in plots having the hay mulch applied. The application of the organic matter would be expected to improve soil physical and chemical fertility by:

- increasing the water holding capacity;
- increasing nutrient status;
- improving the soil structure; and
- reducing surface temperature.

Together, these four items probably account for the observed trend.

The results of this trial indicate that a single application of hay mulch or similar across the tailings dam surface is not sufficient to give rise to successful plant establishment in the short term.

Several options for achieving revegetation on the tailings dam surface remain (not in any order):

- soil amelioration (improve water holding capacity of tailings material, for example, addition of soil);
- passive irrigation (use of groundwater as a water supply and establishing a water recycle system);
- species adaptation (use of drought tolerant natural colonisers and commercially available adapted species for revegetation work; exploit agricultural techniques for maximising the use of proven genetic material); and
- visual screening (selective placement of seedlings for visual screening of the site) which would be primarily for aesthetic reasons.

A combination of the above options – each to a varying degree of implementation – may be appropriate. However the economic implications need consideration. A risk assessment would determine the best course of action.

The risk assessment would consider the costs (financial, non–costed environmental and social, corporate) of various rehabilitation options ranging from "walking away" to "establishing a self–sustaining vegetation cover". Statutory requirements and corporate policies would also need to be considered in the assessment. Based on the risk assessment, a more informed decision as to the extent of effort appropriate for decommissioning may be made.

5.2 Waste Rock Dump

The absence of plant growth on waste rock trial site was most likely due to an absence of soil–seed contact which is necessary for germination. The growing medium is competent hard rock, having an absence of properties necessary for germination and subsequent growth. The application of hay had no observed beneficial effects in terms of plant establishment.

In areas outside the trial site where some fine material (tailings and/or soil) had been spread onto the waste rock good plant growth was observed, however the following options for revegetation on the dumps are suggested:

- soil amelioration;
- use of drought tolerant natural colonisers and commercially available species for revegetation;
- strategic seedling planting (accompanied by soil amelioration); and
- selective plant screening of the site.

As was the case with the tailings dam, a combination of the above options, each in varying degrees, may be appropriate. Prior to undertaking further work, however, it would be prudent to undertake a risk assessment as previously discussed.

6. RECOMMENDATIONS

It is recommended that an analysis of the various rehabilitation options ("walking away" to "establishing a self–sustaining vegetation cover") be undertaken. This analysis would be in the form of a risk assessment and would encompass economic, environmental and corporate considerations.

This approach would provide decision makers with a method of assessing the overall implications of the alternative rehabilitation strategies.

7. REFERENCES

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