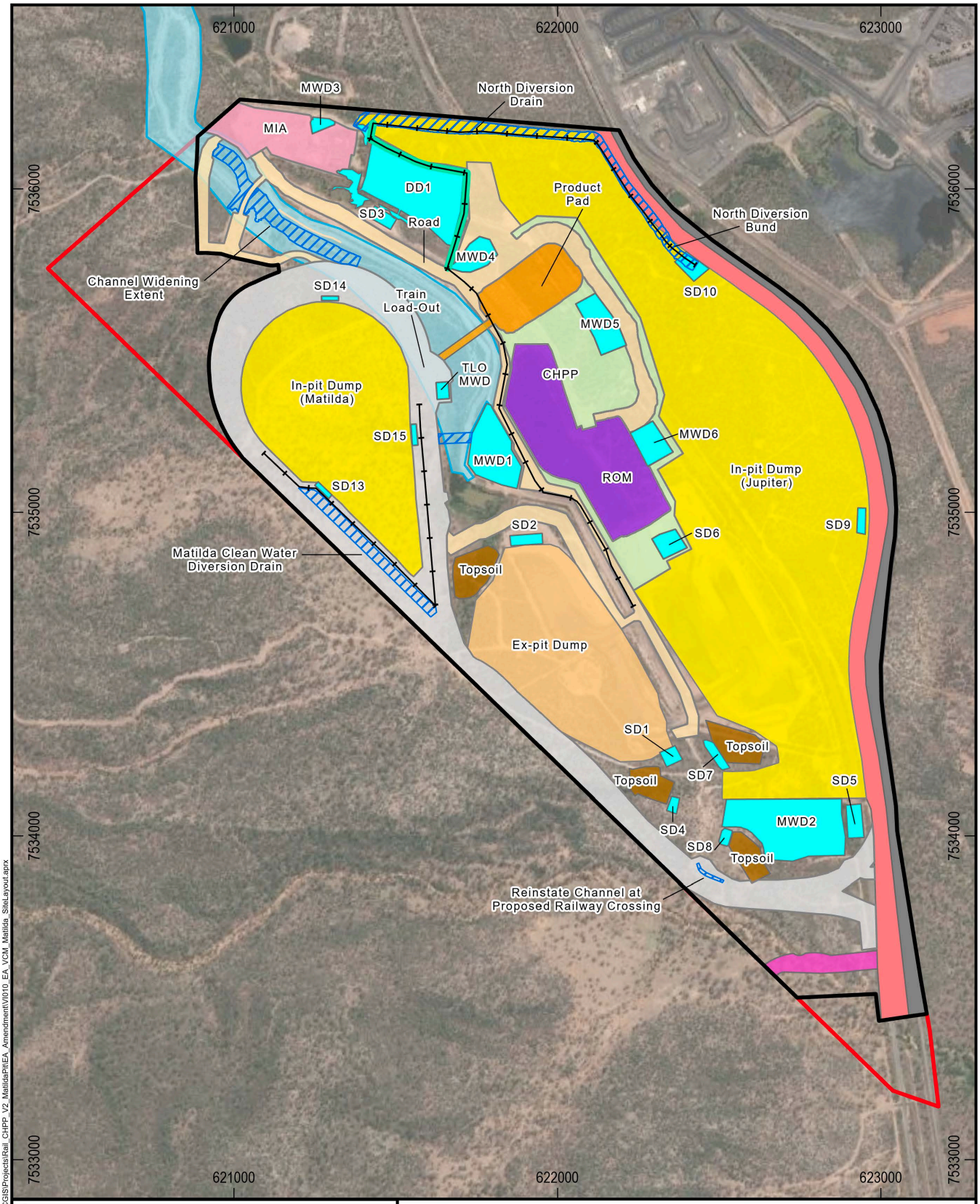


Legend

- ML700060 Boundary
- VCM Revised Maximum Disturbance Footprint
- Dam Wall
- Proposed Flood Levee
- Water Pipeline Corridor
- Proposed levee spillway

Infrastructure

- CHPP
- Ex-pit Dump
- In-pit Dump
- MIA
- Dam
- Rail
- ROM
- Rail Loop
- Road
- Saraji Road
- Stockpile
- Train Load-Out Product Pad
- Open Pit
- Magazine Road
- Water Management

Source: State of Queensland (Department of Resources) 2022, Vitrinite 2021-2022, METServe 2022, Maxar.

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\EA_Amendment\VI010_EA_VCM_Matilda_SiteLayout.aprx

Vulcan Coal Mine

Site Layout

0 200 400 600

Meters

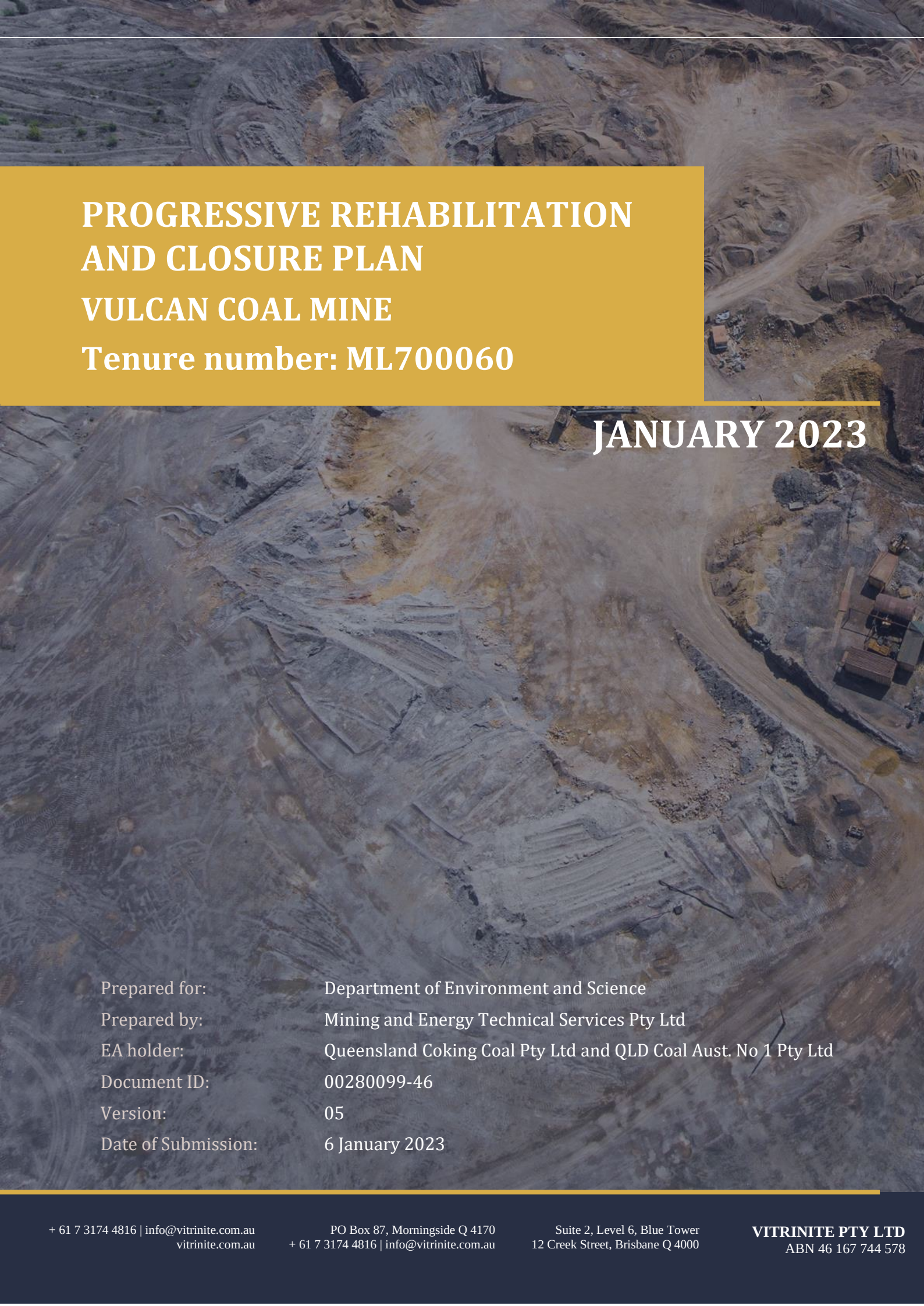
Scale: 1:17,000 (A4)

22/11/2022

Datum: GDA2020
Projection: MGA55

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd



PROGRESSIVE REHABILITATION AND CLOSURE PLAN

VULCAN COAL MINE

Tenure number: ML700060

JANUARY 2023

Prepared for:	Department of Environment and Science
Prepared by:	Mining and Energy Technical Services Pty Ltd
EA holder:	Queensland Coking Coal Pty Ltd and QLD Coal Aust. No 1 Pty Ltd
Document ID:	00280099-46
Version:	05
Date of Submission:	6 January 2023

+ 61 7 3174 4816 | info@vitrinite.com.au
vitrinite.com.au

PO Box 87, Morningside Q 4170
+ 61 7 3174 4816 | info@vitrinite.com.au

Suite 2, Level 6, Blue Tower
12 Creek Street, Brisbane Q 4000

VITRINITE PTY LTD
ABN 46 167 744 578

Table of Contents

1 INTRODUCTION 1

1.1 Project Location 1

1.2 Site Description 1

1.2.1 Resource Tenures 1

1.2.2 Topography 2

1.2.3 Climate 5

1.2.4 Geology 6

1.2.5 Hydrology 10

1.2.6 Hydrogeology 16

1.2.7 Soil 19

1.2.8 Land Stability 22

1.2.9 Vegetation 23

1.2.10 Significant Species 26

1.2.11 Pre-mining Land Use 33

1.2.12 Land Holders 38

1.3.1 Environmentally Relevant Activities 38

1.3.2 Project Description 38

1.3.3 Water Management 44

2 LEGISLATIVE REQUIREMENTS AND GUIDELINES 46

2.1 *Mineral Resources Act 1989* 46

2.2 *Environmental Protection Act 1994* 46

2.3 *Mineral and Energy Resources (Financial Provisioning) Act 2018* 46

2.4 Progressive Rehabilitation and Closure Plans Guideline 46

2.5 Rehabilitation Requirements for Mining Resource Activities 46

2.6 *Environment Protection and Biodiversity Conservation Act 1999* 46

3 STAKEHOLDER ENGAGEMENT 47

3.1 Stakeholder Consultation Plan 47

3.2 Stakeholder Consultation Register 47

4 POST-MINING LAND USE 48

4.1 Accordance with Stakeholders' Requests 48

4.2 Regulatory Constraints 48

4.2.1 Isaac Regional Planning Scheme 48

4.2.2 Mackay, Isaac and Whitsunday Regional Plan 49

4.3 Assessment of Options 49

4.4 Statutory Constraints to be Imposed 51

5 REHABILITATION GOALS 52

5.1 Rehabilitation Objectives, Indicators and Completion Criteria 52

6 REHABILITATION METHODOLOGY 57
6.1 Landform Design 57
6.1.1 Overview 57
6.1.2 Landform Evolution Modelling 57
6.1.3 Design Assumptions and Limitations 59
6.1.4 Cover Design 59
6.1.5 Mine Waste Geochemistry 61
6.1.6 Material Availability 62
6.1.7 Drainage and Surface Water Management 63
6.1.8 Hydrogeology 73
6.1.9 Predicted Stability 75
6.1.10 Landform Evolution Modelling 84
6.1.11 Infrastructure to be Retained 84
6.2 Revegetation 85
6.2.1 Revegetation Objectives 85
6.2.2 Key Flora Species 85
6.2.3 Species of Conservation Significance 86
6.2.4 Top-Soil Management 87
6.2.5 Subsoil Management 89
6.2.6 Revegetation Approach 90
6.2.7 Seed Mix 91
6.2.8 Rehabilitation Trials 93
7 SURRENDER OF THE ENVIRONMENTAL AUTHORITY 94
8 RISK ASSESSMENT 95
9 MONITORING 101
9.1 Milestone Monitoring 101
9.1.1 Rehabilitation Milestone 1: Infrastructure Decommissioning and Removal 101
9.1.2 Rehabilitation Milestone 2: Remediation of Contaminated Land 102
9.1.3 Rehabilitation Milestone 3: Landform Development and Reshaping/Reprofiling 102
9.1.4 Rehabilitation Milestone 4: Surface Preparation 102
9.1.5 Rehabilitation Milestone 5: Revegetation 102
9.1.6 Rehabilitation Milestone 6: Land Suitable for the Commencement of Grazing 103
9.1.7 Rehabilitation Milestone 7: Establishment of Target Vegetation Type 104
9.1.8 Rehabilitation Milestone 8: Achievement of a Stable PMLU 105
9.1.9 Rehabilitation Milestone 9: Acceptance of Saraji Road by Isaac Regional Council 113
9.1.10 Rehabilitation Milestone 10: Transferral of Infrastructure to BMA 113
9.1.11 Monitoring Report 113
9.2 Audits 113

9.3 Annual Return 114
9.4 Progressive Rehabilitation Report 114
9.5 Final Rehabilitation Report 114
9.6 Post-mining Management Report 114
10 PRC PLAN SCHEDULE 115
10.1 Final Site Design 115
10.1.1 Rehabilitation Areas 115
10.2 Schedule of Land Availability 118
10.2.1 Timing Considerations 118
10.2.2 Schedule of Availability 118
10.3 Rehabilitation Milestones 120
10.3.1 Milestone Criteria 121
10.4 PRC Plan Schedule 123
11 REVISION OF THE PRC PLAN 128
12 SPATIAL INFORMATION 129
13 REFERENCES 130

List of Figures

Figure 1-1 Project location 3
Figure 1-2 Site topography 4
Figure 1-3 Average weather conditions at the Mine 5
Figure 1-4 West-to-east conceptual geological model of the Mine area (hydrogeologist.com.au 2022) 8
Figure 1-5 Representative stratigraphy of the Mine area and adjacent formations (hydrogeologist.com.au 2022) 9
Figure 1-6 Surface water hydrology 12
Figure 1-7 Flood Plain Extent 13
Figure 1-8 Maximum Drawdown of Groundwater Predicted 18
Figure 1-9 Soil management units (SMUs) of the Mine (VCM) area 20
Figure 1-10 Extensive gully erosion in heavily grazed portions of the ML 23
Figure 1-11 Field-verified regional ecosystem map of the Mine 25
Figure 1-12 Koala habitat in the vicinity of the Mine 27
Figure 1-13 Squatter Pigeon habitat in the vicinity of the Mine 29
Figure 1-14 Central Greater Glider habitat in the vicinity of the Mine 30
Figure 1-15 Cattle grazing land suitability classes within the Mine area (from AARC 2021) 35
Figure 1-16 Rain-fed broadacre cropping land suitability classes within the Mine area (from AARC 2021) 37
Figure 1-17 Matilda pit rail loop cut and fill design 40
Figure 1-18 Vulcan Coal Mine – Site Layout 43
Figure 6-1 Final landform 58
Figure 6-2 Cover design to optimise plant growth 60
Figure 6-3 Conceptual Final Landform Drainage Plan 65
Figure 6-4 Final Landform Drainage XS-1 66
Figure 6-5 Final Landform Drainage XS-2 and XS-3 67
Figure 6-6 Final Landform Drainage XS-4 68
Figure 6-7 Final Landform Drainage (XS-5 &XS-6) 69
Figure 6-8 Final landform 0.1% AEP flood event (WRM 2022a) 71
Figure 6-9 Natural topography of the local region 77
Figure 6-10 Natural slopes within 3 km of the Vulcan Coal Mine 78
Figure 6-11 Ground cover and slope relationship at natural vegetation sites assessed across the VCM area 78
Figure 6-12 Erosion rate versus percentage rock for Bowen Basin soil materials (figure from Williams 2001) 79
Figure 6-13 Annual sediment loss versus pasture cover on soil and spoil stockpiles at Oaky Creek (Figure from Carroll and Tucker 2000) 80
Figure 6-14 Effect of surface cover on erosion (12-m plots, 15% slope, simulated rain) at Tarong (Figure from Loch 2000). 80
Figure 9-1 Example Infrastructure Decommissioning Checklist for each Rehabilitation Area 101
Figure 9-2 Proposed reference sites for LFA monitoring 107
Figure 9-3 Surface water monitoring locations (WRM 2022a) 110
Figure 9-4 Groundwater monitoring locations (hydrogeologist.com.au 2022) 112
Figure 10-1 Final site design 116
Figure 10-2 Rehabilitation areas 117

List of Tables

Table 1-1 Land Tenure and Real Property Descriptions for the Mine 1
Table 1-2 Mean potential evaporation rates and mean water deficits at the Mine throughout the year 6
Table 1-3 80th percentile values for the combined upstream monitoring points data set compared with the receiving water WQO default trigger values and MMC Table F3 trigger values 14
Table 1-4 Regional ecosystems present within the Mine footprint. Data extracted from METServe (2022) 24
Table 1-5 Species of national or state environmental significance flagged by databases as being potentially present in the local region 31
Table 1-6 Summary of pre-mining land suitability limitations for cattle grazing 34
Table 1-7 Summary of land suitability limitations for rain-fed broadacre cropping 36
Table 1-8 Agricultural land classes (AARC 2021) 38
Table 1-9 Land tenure and real property descriptions for the Mine 38
Table 1-10 Environmentally Relevant Activities 38
Table 4-1 Assessment of PMLU options for the Mine 50
Table 5-1 Rehabilitation objectives, indicators and completion criteria 52
Table 5-2 Proposed receiving surface waters trigger values 55
Table 5-3 Preliminary groundwater quality trigger values 56
Table 6-1 Cover variations in each rehabilitation area 61
Table 6-2 Materials balance for topsoils and subsoils to be used for rehabilitation 62
Table 6-3 Estimated background erosion rates 82
Table 6-4 Predicted soil erosion rates of the Limpopo soil management unit as a factor of slope and cover 83
Table 6-5 Key flora species found pre-mining on each soil management unit 86
Table 6-6 List of Koala food trees suitable for planting on each soil management unit 86
Table 6-7 Maximum topsoil stripping depths for each soil management unit 87
Table 6-8 Seed mixes for each Soil Management Unit (SMU) for low-intensity cattle grazing PLMU 92
Table 8-1 Scoring system used to assess risks 95
Table 8-2 Risk assessment for rehabilitation of the Mine 96
Table 9-1 Proposed reference sites for LFA monitoring 106
Table 9-2 Surface water monitoring locations 109
Table 9-3 Groundwater monitoring bore locations 111
Table 10-1 Schedule of land availability for rehabilitation 119
Table 10-2 Rehabilitation milestones 120
Table 10-3 Milestone criteria 121
Table 10-4 PRC Plan Schedule 124

List of Appendices

Appendix A- Surface Water Assessment Report ..... A
Appendix B- Groundwater Assessment Report ..... B
Appendix C- Soil and Land Suitability Assessment Report C
Appendix D- Terrestrial Ecology Assessment Report ..... D
Appendix E- Stakeholder Engagement Plan ..... E
Appendix F- Landform Evolution Modelling ..... F
Appendix G- Geotechnical Assessment- July 2022 ..... G
Appendix H- Geotechnical Assessment- March 2020 ..... H
Appendix I- Geochemical Assessment- September 2022 I
Appendix J- Geochemical Assessment- June 2020 ..... J

1 INTRODUCTION

The Vulcan Coal Mine (the Mine or VCM) is a small-scale coal mine operated by Vitrinite Pty Ltd (Vitrinite).

A Progressive Rehabilitation and Closure Plan (PRC Plan) accompanied a site-specific application for an environmental authority (EA) to undertake the Environmentally Relevant Activities (ERAs) associated with the Mine. The Mine was approved by the Queensland Government and operates under EA0002912 and in accordance with the approved PRCP schedule (PRCP_EA0002912_V4).

To secure a reliable mechanism for transport of its coal to market, Vitrinite proposes to establish a Coal Handling and Preparation Plant (CHPP), Train Load-out facility (TLO), a dedicated rail loop and a small additional open cut pit on ML700060. Ancillary infrastructure will also be required, which includes product stockpiles, updated water management infrastructure, access roads and several minor amendments to existing infrastructure layouts. The CHPP technology proposed will produce dry tailings, which will be co-disposed with waste rock within existing proposed waste rock dumps. The open cut pit, referred to as the 'Matilda pit' is proposed to be located within the rail loop and will provide supplementary coal to the ROM stockpile.

This version of the VCM PRC Plan incorporates the infrastructure amendments and has been developed in accordance with Sections 126C and 126D of the *Environmental Protection Act 1994* and to meet the requirements specified in the Queensland Government's *Progressive Rehabilitation and Closure Plans Guideline* (DES 2019a).

The PRC Plan comprises two main components. The rehabilitation planning component (**Sections 1** to **9**) provides information on the characteristics of the site, legislative requirements, stakeholders, post-mining land use, rehabilitation goals, rehabilitation methodology, risk assessment and monitoring program. The PRC Plan schedule component (**Section 10**) provides a final site design and a detailed schedule of progressive rehabilitation activities including rehabilitation milestones.

The PRC Plan presents Vitrinite's strategy for managing mining activities in a way that maximises the progressive rehabilitation of the land to a stable condition, as well as specifying the condition to which Vitrinite will rehabilitate the land before the EA is surrendered.

1.1 Project Location

The Mine is located in the Bowen Basin, Queensland. It lies adjacent to Saraji Road, 33 kilometres (km) south-southeast of Moranbah and 34 km north-northwest of Dysart (**Figure 1-1**). It falls within the jurisdiction of the Isaac Regional Council. The Mine is located immediately south and west of existing, large-scale coal operations, the Peak Downs Mine and Saraji Mine.

1.2 Site Description

1.2.1 Resource Tenures

The Mine has been developed on mining lease (ML) 700060 (**Figure 1-1**). The ML covers an area of approximately 407 hectares (ha) and is situated over multiple underlying tenures (EPC 1732 and 1234). The ML overlies adjacent portions of existing Exploration Permit Coal (EPC) 1732 and 1234 tenements (held by Qld Coal Aust No.1 Pty Ltd and Queensland Coking Coal Pty Ltd, respectively). Both Qld Coal Aust No.1 Pty Ltd and Queensland Coking Coal Pty Ltd are fully owned by Vitrinite. A list of the properties, tenure, usage and owners/managers within the ML boundary are outlined in **Table 1-1**.

Table 1-1 Land Tenure and Real Property Descriptions for the Mine

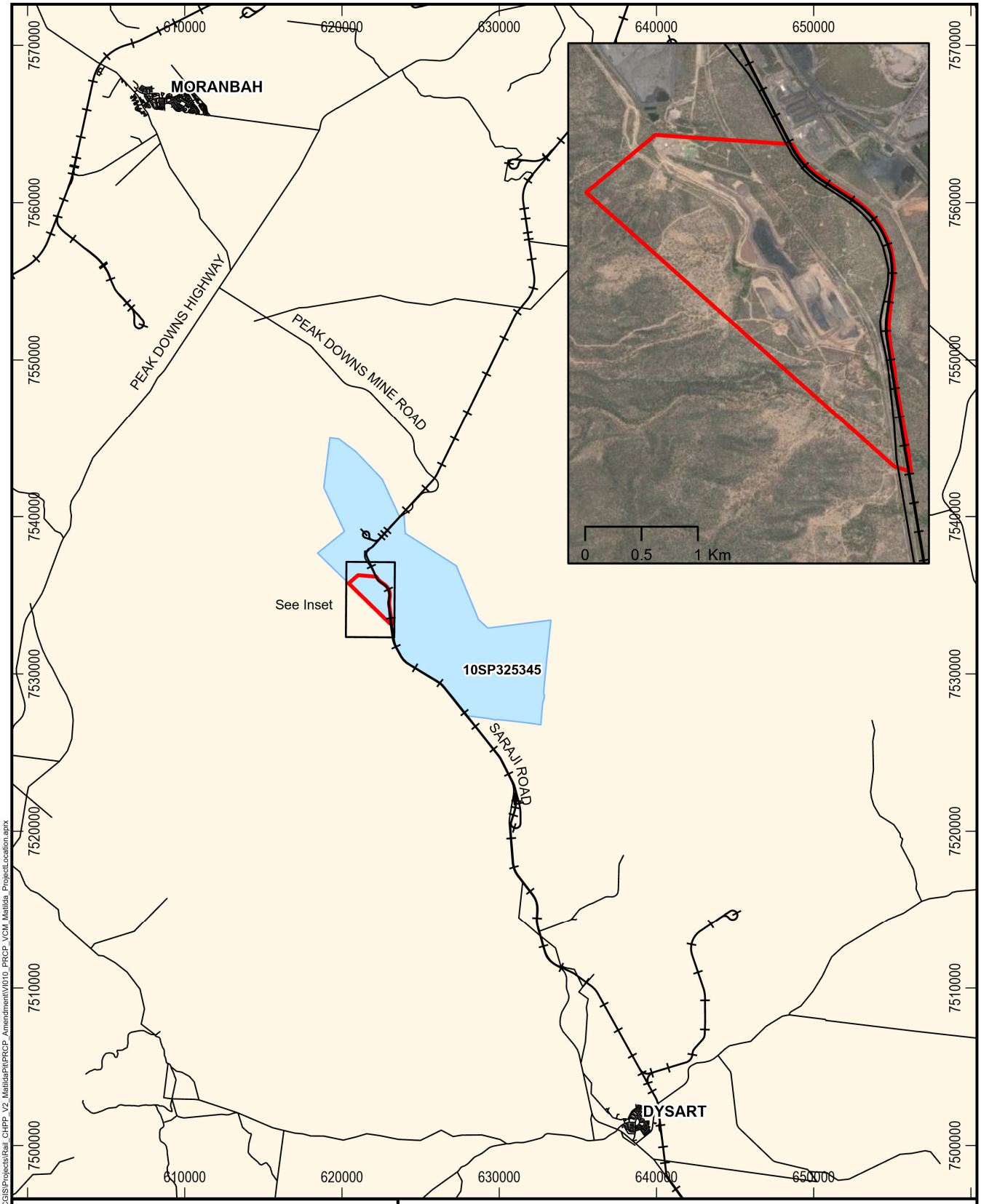
Lot/Plan	Tenure	Usage	Owner	Area (ha)
10/SP325345	Lands Lease	Extractive	BHP Billiton/Mitsubishi Alliance (BMA)	369
26/CNS125	Land Lease	Rail freight transport	Aurizon	13
Saraji Road	Road Reserve	Road for public use	Isaac Regional Council	25

The Mine falls within the Isaac Regional Council local government area. The region has a distinct mining influence with multiple significant coal mining operations in the immediate vicinity of the Mine.

The majority of the land within the ML has been previously disturbed by agriculture and mining-related activities. There are no rural or residential dwellings located within 10 km of the Mine.

1.2.2 Topography

The Mine lies on plains and foot slopes along the eastern edge of the Harrow Range. The Harrow Range (immediately west of the Mine) is generally 100-170 metres (m) higher than the surrounding plain. The plain itself slopes gently towards the east and varies in elevation from 270 mAHD in the west to 250 mADH in the east (**Figure 1-2**).



Legend

- Road
- Railway
- ML 700060
- Lot 10 Plan SP325345

Source: State of Queensland (Department of Resources) 2021, Vitrinite 2022, METServe 2022, Maxar.

Vulcan Coal Mine

Project Location

0 3 6 12

Kilometers

Scale: 1:350,000 (A4)

26/10/2022

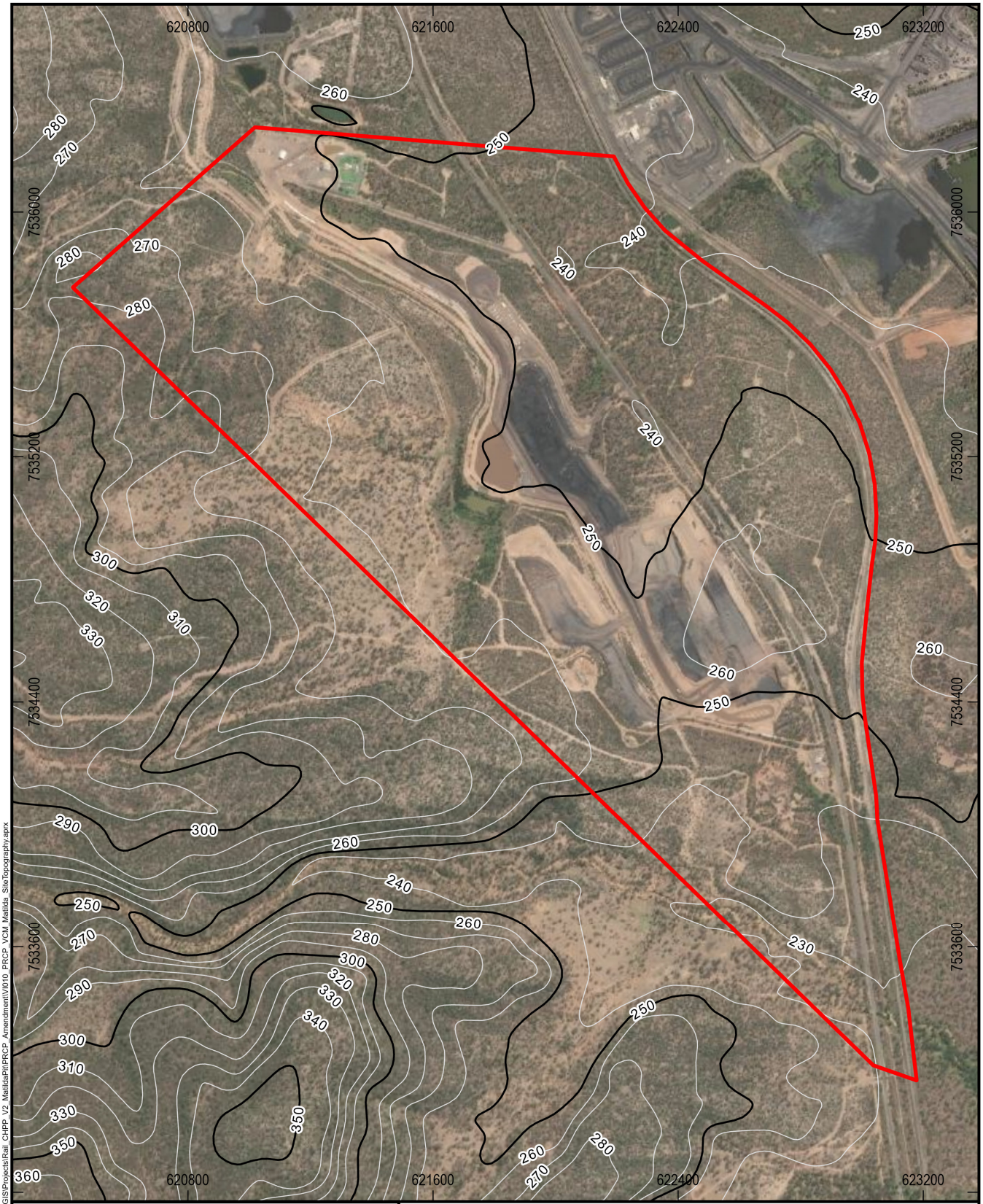
Datum: GDA2020
Projection: MGA55

FIGURE 1-1

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\PRCP_Amendment\VI010_PRCP_VCM_Matilda_ProjectLocation.aprx



Legend

ML 700060

Contours

10m

50m

Source: State of Queensland (Department of Resources) 2019-2021, Vitrinite 2022, METServe 2022, Maxar.

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\PRCP_Amendment\VI010_PRCP_VCM_Matilda_SiteTopography.aprx

Vulcan Coal Mine

Site Topography

0 150 300 600

Meters

Scale: 1:18,000 (A4)

26/10/2022

Datum: GDA2020
Projection: MGA55

FIGURE 1-2

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

1.2.3 Climate

The Mine area is subtropical, with hot summers and mild winters. The nearest Bureau of Meteorology (BoM) weather stations are Mount Lebanon (29 km northwest) and Seloh Nolem (29 km east), both of which are currently closed. The nearest active weather station is Moranbah Airport (35 km north-northwest), which only commenced operations in 2012. A weather station was installed recently at the Mine to acquire site specific data. Given the inconsistency of locally available data for discerning long-term average weather patterns, the Queensland Department of Environment and Science's SILO database was used for estimating average rainfall on site. The SILO database uses mathematical interpolation to fill temporal and spatial data gaps from BoM's weather stations. Based on data generated for the SILO grid point -22.35, 148.20, the mean and median annual rainfall for the Mine is 590.6 millimetres (mm) and 575.1 mm, respectively. However, this varies widely between years: standard deviation = 204.2, range = 275.5 to 1,152.7 mm. On average, 70% of the annual rainfall occurs between November and March (**Figure 1-3**).

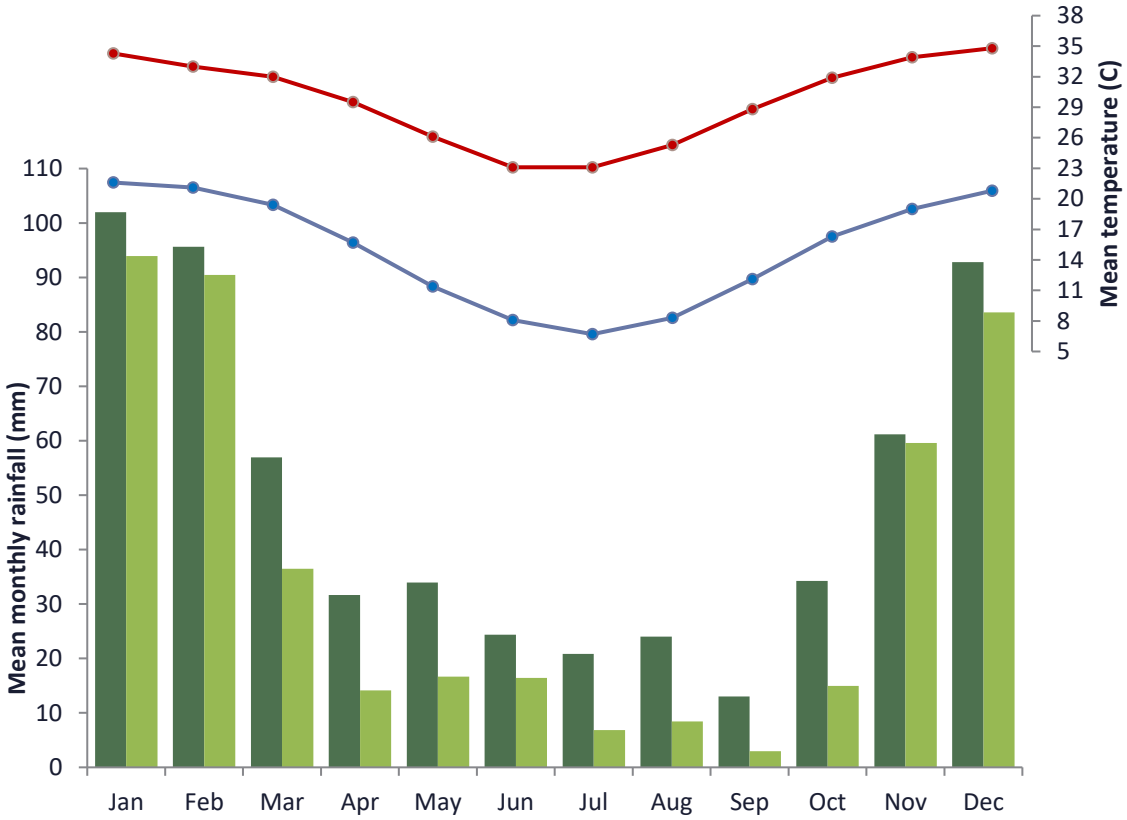


Figure 1-3 Average weather conditions at the Mine.

Green bars refer to the mean (dark) and median (light) monthly rainfall over the past 50 years, as interpolated in the SILO database (DES 2019b) for the SILO grid point -22.35, 148.20. Mean monthly maximum (red) and minimum (blue) temperatures over the past 50 years come from the Clermont Post Office meteorological station.

The mean potential evaporation rate for every month exceeds the mean rainfall for the respective month. However, the size of this deficit varies with season. The period between September and December is historically the driest (**Table 1-2**), which has been considered when planning earthworks and planting programs as part of this PRC Plan.

Table 1-2 Mean potential evaporation rates and mean water deficits at the Mine throughout the year

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean rainfall	102	95.65	56.94	31.64	33.96	24.38	20.86	23.99	13	34.26	61.17	92.78
Mean evaporation	220.2	178.9	182.9	145.3	115.5	91.85	102.2	132.7	173.3	216	225.6	237
Mean water deficit	118.3	83.25	126	113.6	81.56	67.47	81.33	108.8	160.3	181.7	164.5	144.2

(from the SILO grid point -22.35, 148.20).

Climate change models produced by the CSIRO (2015) suggest with medium confidence that there will be long-term decreases in average winter and spring rainfall over the next 80 years. Long-term changes in summer and autumn rainfall are also possible, but the direction is unclear (CSIRO 2015). On the short timescales of the Mine, the influence of natural rainfall variability is projected to predominate over trends due to increasing greenhouse gas emissions (CSIRO 2015), and the rainfall data presented in **Figure 1-3** is therefore most relevant to the Mine during the rehabilitation and vegetation establishment stage. Over the next 80 years, however, an increase in the intensity of extreme rainfall events is projected with high confidence, and the time spent in drought is projected to increase with medium confidence. These long-term changes can affect the prospect of survival for long-lived trees.

The effect of climate change on temperature is projected to be more apparent short-term than for rainfall. For the near future (2030), the annually averaged warming across all emission scenarios is projected to be around 0.5 to 1.4 °C above the climate of 1986–2005 (CSIRO 2015); note that the current climate (as at the end of 2019) is already 0.24 °C warmer than the 1986-2005 average (CSIRO 2015). This warming is projected to be 1.3 to 5.0 °C by 2090 (CSIRO 2015). Temperature changes have been considered both for the vegetation establishment phase of rehabilitation and for the long-term survival of trees post-relinquishment. Species to be used in revegetation all have widespread geographic distributions (including hotter and drier locations than the Mine area). It is therefore unlikely that the Mine area currently represents the limit of environmental tolerance for any of the species utilised.

1.2.4 Geology

The geology of the Mine area is influenced by its position within the Bowen Basin, one of Queensland's largest depositional zones, formed through a period of rifting and subsidence lasting from the Early Permian to the Mid-Triassic. The area surrounding the Mine is dominated by clastic sedimentary rocks of marine and lacustrine origin, including sandstones, mudstones, siltstones and coal (Geoscience Australia 2019). Rock strengths range from extremely-low-strength weathered sandstone to high-strength fresh sandstone.

The solid geology of the region includes the:

- Moranbah Coal Measures – Permian, comprising coal and inter-seam material composed of sandstone, shale, siltstone with minor clay stone; and
- Back Creek Group – Early to Late Permian, comprising quartzose to lithic sandstone, conglomerate, siltstone, carbonaceous shale and coal. Occurs beneath the Moranbah Coal Measures, and outcrops to the west of the disturbance footprint.

The Permian sediments are covered by a thin veneer of unconsolidated to semi-consolidated Cainozoic sediments (Tertiary to Quaternary alluvium and colluvium):

- Qr – Qr - (QLD) (Qr) – Quaternary clay, silt, sand, gravel and soil with colluvial and residual deposits; and
- TQa – QLD (TQa) – Late Tertiary to Quaternary poorly consolidated sand, silt, clay, minor gravel and high level alluvial deposits.

Across the Mine area, the uppermost stratum is generally a highly weathered regolith comprising a heterogeneous distribution of fine to coarse-grained sand, clay, sandstone and claystone. These are either Tertiary sediments or a weathered profile that had developed during the Tertiary on Permian strata (hydrogeologist.com.au 2022). The base of weathering typically extends to depths of 5 to 45 mbgl (metres below ground level), where the unweathered Moranbah Coal Measures commence. In the vicinity of the Mine, the cumulative thickness of coal appears to be between 5 m and 15 m. The Mine intends to access the lower seams of the Moranbah Coal Measures (the ALEX and Dysart Lower-Lower (DLL) coal seams) and the Back Creek Group (MAY and MAT seams).

Outcropping to the west of the Mine is the basal section of the Moranbah Coal Measures, a sequence of sandstones and siltstones, with imbedded coal. The ALEX coal seam lies near the top of this sequence, just below the base of weathering. It is of high quality and low ash content, and is approximately 1 m thick. It overlies resistant, quartzose, medium to coarse-grained sandstone, locally referred to as the Mesa Sandstone due to the characteristic mesa plateaus that have formed in the region. At its base, the Mesa Sandstone grades into the Mesa Siltstone.

The DLL coal seam lies immediately below the Mesa Siltstone. It lies near the base of the Moranbah Coal Measures. The DLL consists of a 2.5-m-thick seam with four plies, and contains moderate to high-ash, good-quality coal. An additional and separate 1-m-thick coal ply beneath the main seam plies, results in a total coal thickness within the target sequence of approximately 3.5 m.

Beneath the Moranbah Coal Measures are the Exmoor and Blenheim formations of the Back Creek Group. The Exmoor Formation of the Back Creek Group is locally mapped by Vitrinite as the Dingo Sandstone, Dingo Siltstone and Wallaby Hill Sandstone (from top down) but contains recognised and laterally extensive coal seams (MAY and MAT seams) (hydrogeologist.com.au 2022).

No igneous intrusions have been encountered within the Mine area to date in either drilling or field mapping exercises. However, neighbouring mining operations (the north and far west of EPC1234 and EPC1729) have localised basalt dykes and potential sills within their leases.

A conceptual diagram of the main geological units is shown in **Figure 1-4**, and representative stratigraphy of the Mine area is shown in **Figure 1-5**.

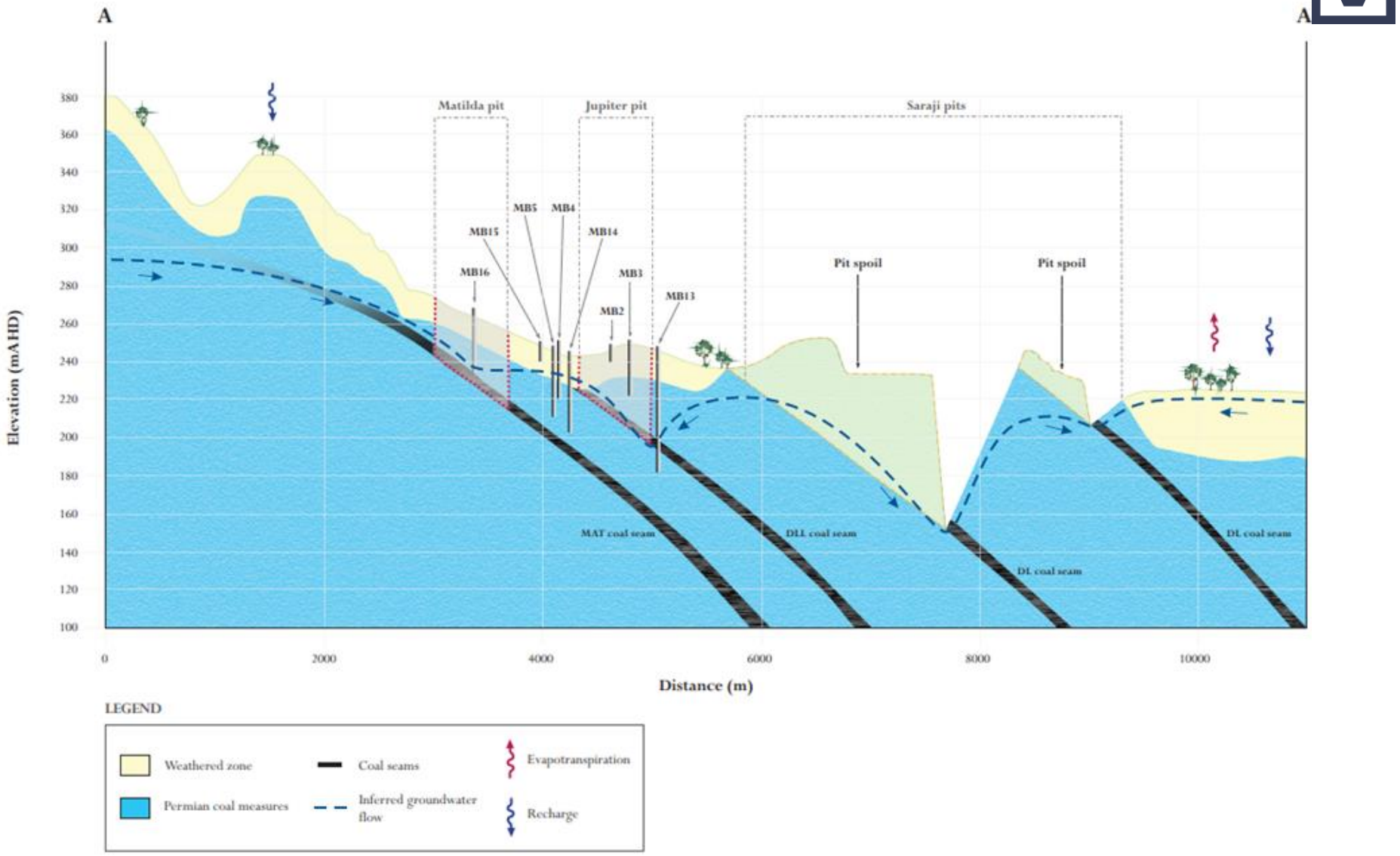


Figure 1-4 *West-to-east conceptual geological model of the Mine area (hydrogeologist.com.au 2022)*

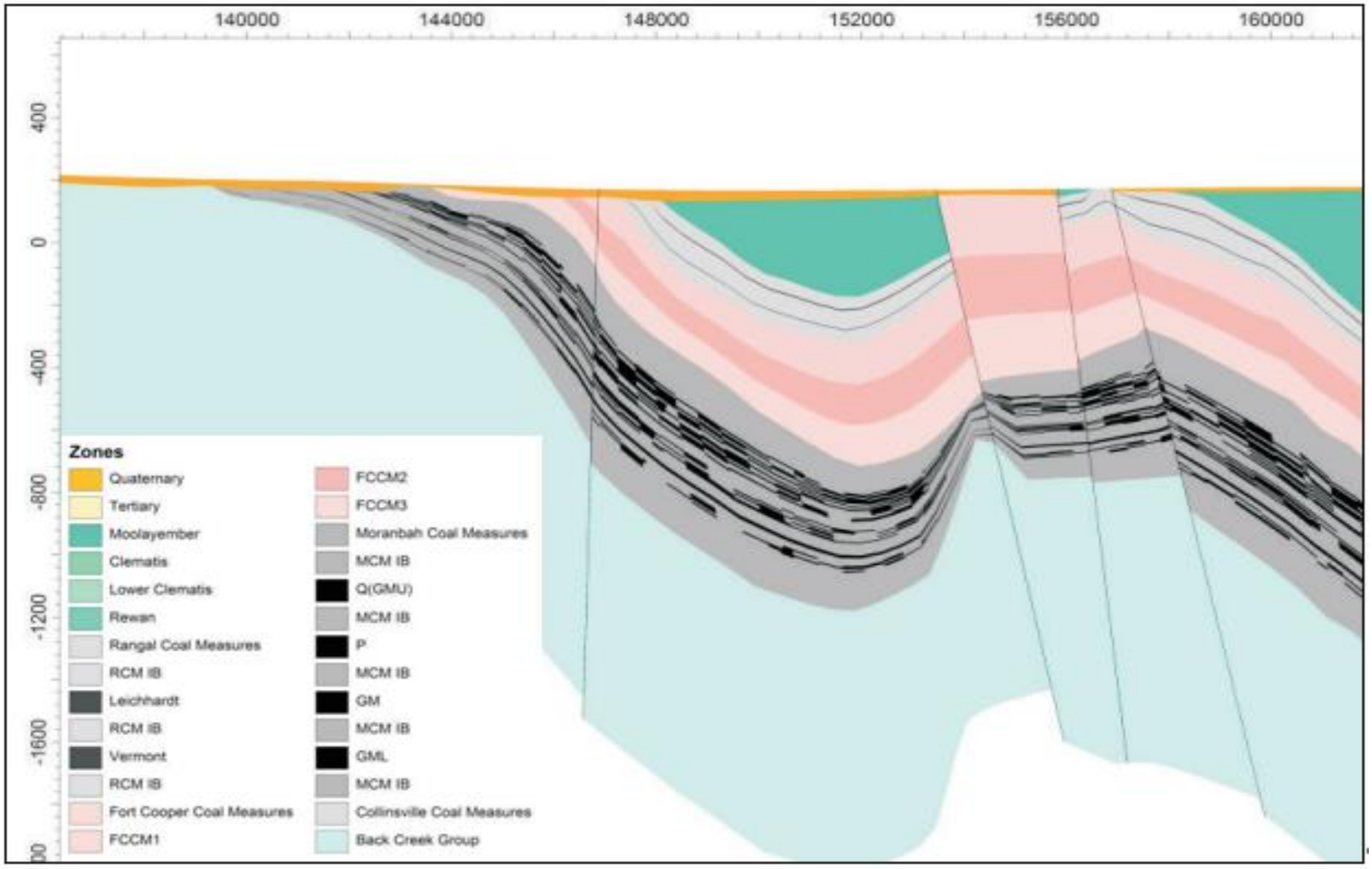


Figure 1-5 Representative stratigraphy of the Mine area and adjacent formations (hydrogeologist.com.au 2022)

The section extends from the west/south-west to the east/north-east. The Project area would plot between ~140,000 m and ~142,000 m, characterised by sub-cropping Moranbah Coal Measures beneath the surficial sediments. Beneath the Moranbah Coal Measures, the Back Creek Group forms the Permian basement and extensively outcrops to the west of the site.

1.2.5 Hydrology

A surface water assessment of the Mine has been carried out by WRM Water and Environment (WRM). This document is supplied as **Appendix A** for reference.

The Mine is located within the 'Isaac western upland tributaries' area of the Isaac River sub-basin, which in turn forms part of the Fitzroy Basin and is the headwaters of the Boomerang Creek catchment.

The Mine area contains several ephemeral tributaries of Boomerang Creek, and all drain towards the east. The tributaries of Boomerang Creek which intersect the Mine area include (**Figure 1-6**):

- Drainage Line 1;
- Drainage Line 2; and
- the existing drainage diversion.

The Boomerang Creek catchment commences to the west of the Mine area and drains in an easterly direction towards Saraji Road, the Norwich Park Branch Railway and the Peak Downs Mine. The headwater tributaries of Boomerang Creek are ephemeral streams which experience flow only after sustained or intense rainfall.

These highly ephemeral tributaries converge before joining Boomerang Creek, which then flows an additional 21 km east of the Mine before joining the Isaac River. The Isaac River ultimately flows into the Fitzroy River, which empties into Keppel Bay near Rockhampton. These ephemeral creeks have limited flow, typically only after heavy rainfall events. Flows typically last for less than a fortnight after heavy rain events.

Drainage line 1 traverses the north of the ML, which drains most of the ML east of the existing flood levee. This tributary flows beneath Saraji Road and the Norwich Park branch railway, before discharging into the Peak Downs Mine, where it feeds existing highly modified water storages. This tributary will be diverted as part of the Mine, to allow access to the underlying coal. The tributary will be reinstated post-mining by constructing a drainage corridor through backfilled spoil as shown in **Section 1.3.3**. A new culvert crossing will be constructed under the realigned Saraji Road just upstream of the existing railway culverts. This will connect to the existing channel and utilise the existing railway culverts. The typical pre-mining dimensions of this tributary through the Mine area are:

- channel bed widths of 2 m to 5 m;
- channel top widths of 10 m to 25 m;
- channel depths 0.5 to 1 m; and
- overbank floodplain widths of 20 m to 50 m.

An existing drainage diversion traverses the ML, along the western edge of the flood levee and drains into Drainage Line 2 to the south of the ML. This diversion and levee were built in the 1970s to allow the construction of a tailings dam within the Peak Downs Mine. The Mine will include upgrades to an existing approved crossing of the existing drainage diversion. A second vehicle crossing will be included as part of the infrastructure upgrades for the Mine.

Drainage Line 2 flows through the south-eastern corner of the ML, where it has the following dimensions:

- channel bed widths of 3 m to 5 m;
- channel top widths of 10 m to 30 m;
- channel depths 1 to 2 m; and
- overbank floodplain widths of 50 m to 150 m.

Drainage Line 2 will not be modified as part of the Mine but has been diverted and significantly modified within the Peak Downs ML.

In accordance with Section 126D(3) of the *Environment Protection Act 1994*, any voids situated wholly or partly within a flood plain (0.1% annual exceedance probability (AEP)) must be rehabilitated to a post-mining land use (PMLU) with a stable condition. While no voids or NUMAs are proposed for the Mine, flood plain modelling was undertaken as part of baseline assessments, to inform mine planning of flood risks during operations and rehabilitation. This flood plain

modelling revealed that small parts of the disturbance footprint for the Mine occur within a flood plain (**Figure 1-7**). Note that this map shows the flood plain according to pre-mining conditions.



Legend

- Local Drainage Feature
- Dam/Reservoir Area
- ML 700060

Source: State of Queensland (Department of Resources) 2021, WRM 2021, Vitrinite 2022, METServe 2022, Maxar.

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\PRCP_Amendment\VI010_PRCP_VCM_Matilda_SurfaceWaterHydrology.aprx

Vulcan Coal Mine

Surface Water Hydrology

0 0.5 1 1.5

Kilometers

Scale: 1:40,000 (A4)

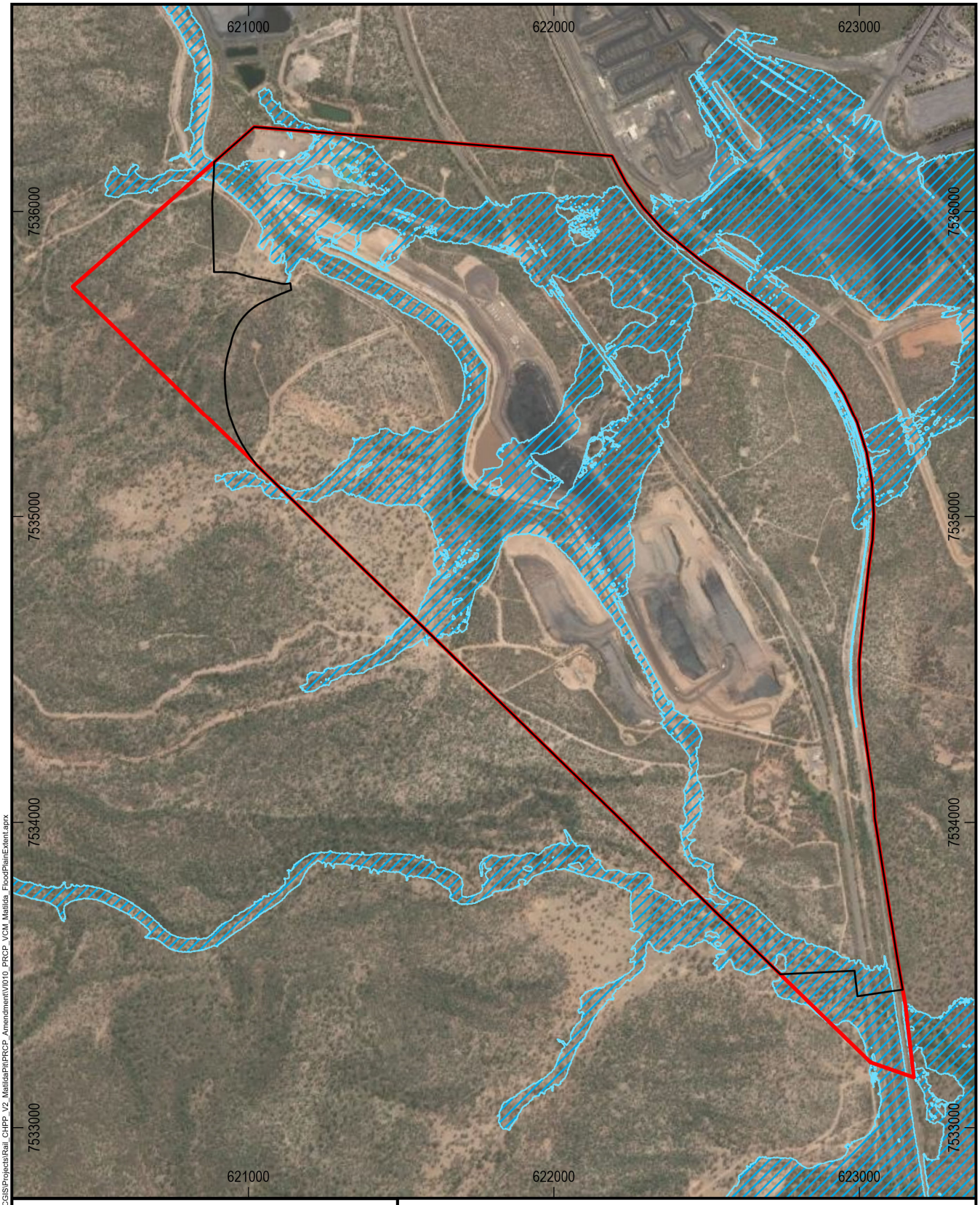
26/10/2022

Datum: GDA2020
Projection: MGA55

FIGURE 1-6

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd



Legend

- ML 700060
- VCM Revised Maximum Disturbance
- 0.1% Annual Exeedance Probability (AEP) peak flood

Source: State of Queensland (Department of Resources) 2021, WRM 2022, Vitrinite 2022, METServe 2022, Maxar.

Vulcan Coal Mine

Flood Plain Extent

0 150 300 600

Meters

Scale: 1:18,000 (A4)

16/11/2022

Datum: GDA2020
Projection: MGA55

FIGURE 1-7

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\PRCP_Amendment\VI010_PRCP_VCM_Matilda_FloodPlainExtent.aprx

The site surface water monitoring data to date has been sampled for between two (2) and up to seven (7) events across the monitoring locations. As data collection is limited to periods of flow in an ephemeral system, the upstream monitoring point samples were combined so that the 80th percentile values could be analysed. In total, 24 samples were taken across the two-year period. **Table 1-3** shows the 80th percentile values for all parameters measured for the combined upstream monitoring point data set as well as the Project Water Quality Objectives (WQO) default trigger values and model mining conditions (MMC) default trigger values.

Table 1-3 80th percentile values for the combined upstream monitoring points data set compared with the receiving water WQO default trigger values and MMC Table F3 trigger values

Parameter	Unit	Upstream monitoring points samples - 80th percentile values	WQO default trigger values)	MMC trigger
No. of Samples		24	-	
Physico-chemical parameters				
pH Value	-	7.382	< 6.5 or > 8.5	
Sodium Adsorption Ratio	-	1.860	-	
Electrical Conductivity	µS/cm	226.000	> 720 (baseflow) > 250 (high flow)	
Total Dissolved Solids (Calc.)	mg/L	147.200	> 2,000	
Suspended Solids (SS)	mg/L	195.200	> 55	
Turbidity	NTU	505.000	> 50	
Dissolved Oxygen	mg/L	8.600	< 4	
Dissolved Metals				
Aluminium	mg/L	0.720	> 0.055	>0.055
Arsenic	mg/L	0.003	> 0.024	> 0.013
Cadmium	mg/L	<0.0001	> 0.0002	> 0.0002
Chromium	mg/L	0.001	> 0.001	> 0.001
Cobalt	mg/L	0.005	-	> 0.090
Copper	mg/L	0.003	> 0.0014	> 0.002
Lead	mg/L	0.001	> 0.0034	> 0.004
Manganese	mg/L	0.217	> 1.9	> 1.9
Molybdenum	mg/L	0.001	-	> 0.034
Nickel	mg/L	0.003	> 0.011	>0.010
Selenium	mg/L	<0.01	> 0.005	>0.001
Silver	mg/L	<0.001	-	> 0.001
Uranium	mg/L	<0.001	> 0.1	>0.001
Vanadium	mg/L	<0.01	> 0.5	> 0.010
Zinc	mg/L	0.013	> 0.008	> 0.008
Boron	mg/L	0.098	> 0.37	> 0.37
Iron	mg/L	0.716	-	> 0.3
Mercury	mg/L	<0.0001	> 0.00006	> 0.0002
Total Metals				
Aluminium	mg/L	8.130	> 5	
Arsenic	mg/L	0.003	> 0.5	

Parameter	Unit	Upstream monitoring points samples - 80th percentile values	WQO default trigger values)	MMC trigger
Cadmium	mg/L	<0.0001	> 0.01	
Chromium	mg/L	0.007	> 1	
Cobalt	mg/L	0.006	> 0.1	
Copper	mg/L	0.011	> 1	
Lead	mg/L	0.011	> 0.1	
Manganese	mg/L	0.280	> 10	
Molybdenum	mg/L	0.006	> 0.05	
Nickel	mg/L	0.011	> 1	
Selenium	mg/L	<0.01	> 0.02	
Silver	mg/L	<0.001	-	
Uranium	mg/L	0.001	-	
Vanadium	mg/L	0.020	-	
Zinc	mg/L	0.032	> 5	
Boron	mg/L	0.156	> 5	
Iron	mg/L	10.440	> 10	
Mercury	mg/L	0.000	> 0.002	
Major cations and anions				
Total Hardness as CaCO3	mg/L	37.400	> 150	> 150
Hydroxide Alkalinity as CaCO3	mg/L	<1	-	
Carbonate Alkalinity as CaCO3	mg/L	8.000	-	
Bicarbonate Alkalinity as CaCO3	mg/L	38.400	-	
Total Alkalinity as CaCO3	mg/L	38.400	-	
Sulfate as SO4 - Turbidimetric	mg/L	15.600	> 770	
Chloride	mg/L	31.000	-	
Calcium	mg/L	5.800	-	
Magnesium	mg/L	5.400	-	
Sodium	mg/L	19.400	> 30	
Potassium	mg/L	7.000	-	
Fluoride	mg/L	0.200	> 2	> 2
Ammonia as N	mg/L	0.562	> 0.02	> 0.74
Nitrite as N	mg/L	0.738	-	
Nitrate as N	mg/L	0.564	-	> 0.248
Nitrite + Nitrate as N	mg/L	0.966	-	
Total Kjeldahl Nitrogen as N	mg/L	1.920	-	
Total Nitrogen as N	mg/L	2.860	> 0.5	
Total Phosphorus as P	mg/L	0.282	> 0.05	
Reactive Phosphorus as P	mg/L	0.658	> 0.02	
Total Anions	meq/L	1.984	-	

Parameter	Unit	Upstream monitoring points samples - 80th percentile values	WQO default trigger values)	MMC trigger
Total Cations	**meq/L**	2.178	-	
Ionic Balance	**%**	7.162	-	
Hydrocarbons				
C6 - C10 Fraction	**µg/L**	<20	-	
>C10 - C40 Fraction (sum)	**µg/L**	<100	-	
Biological				
Chlorophyll a	**mg/m³**	4.400	-	

Note: Recorded exceedances of the WQOs which are adopted as the locally derived WQO have been shaded in grey.

1.2.6 Hydrogeology

In the vicinity of the Mine, all geological formations yield low volumes of groundwater and hence would not typically be classified as aquifers in most hydrogeological settings. However, as individual lithological units within these formations have higher hydraulic conductivities than the intervening units, and groundwater in these formations is to be assessed for the determination of impact, they are referred to as aquifers for the purposes of this plan. A detailed hydrogeological impact assessment has been completed by Hydrogeologist.com.au Pty Ltd for the Mine and is provided in **Appendix B**. The summary below of the hydrogeology has been primarily sourced from the hydrogeological impact assessment.

The following geological formations may contain groundwater (hydrogeologist.com.au 2022):

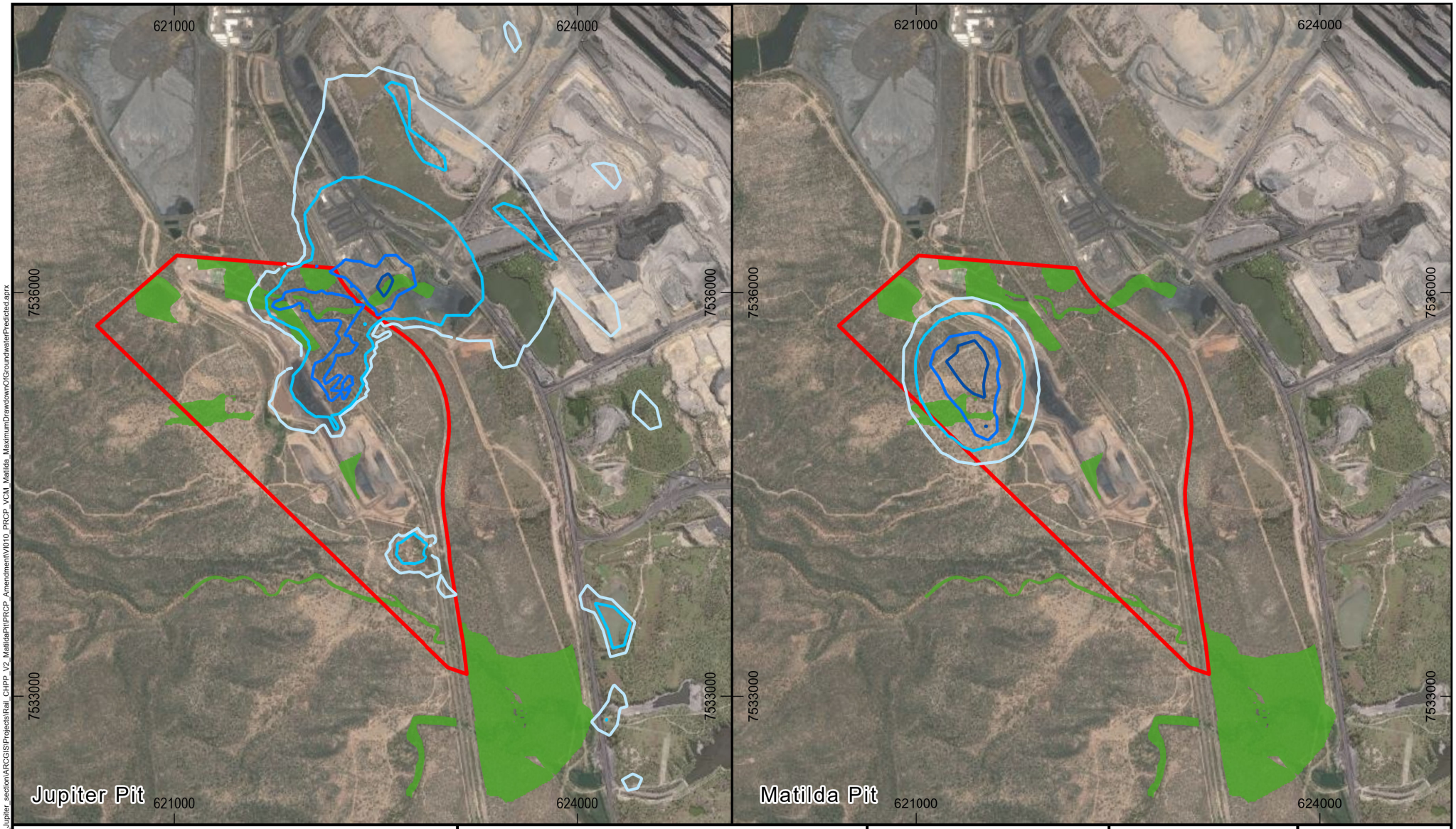
1) Tertiary sediments and weathered regolith: Silts and clays, which comprise the bulk of the regolith overlying the coal measures, are densely compacted, hard and generally dry. Sand and gravel lenses embedded within the regolith are permeable but have low hydraulic conductivity and limited lateral and vertical extent. These have a potential to represent unconfined to confined aquifers, depending on location.
2) Permian coal measures: The ALEX and DLL coal seams are poor aquifers of low hydraulic conductivity. They are confined above and below by low-permeability regolith and sedimentary rocks. Nevertheless, these represent the largest and uppermost aquifers across most of the Mine area.
3) Back Creek Group: This formation of sandstones, siltstones and shale forms a largely impervious layer beneath the DLL coal seam aquifer. However, the Back Creek Group also contains narrow coal seams that can act as poor aquifers.

Groundwater is between 2 m and 30 m deep within the Mine area but generally between 5 m to 30 m deep in the area of the proposed open pit. There are areas on the northern and southern Mine boundaries with depth to groundwater less than 5 m. Due to the depth to groundwater, aquatic groundwater-dependent ecosystems (GDEs) are absent from most of the local land surface. A small extent of possible groundwater-dependent terrestrial vegetation occurs where the groundwater is 5 to 20 m deep (**Figure 1-8**), which is out of reach of most plant's roots, but within reach of some species. Hydrogeologist.com.au (2022) has developed a numerical groundwater flow model of the survey area and broader region to predict the effects of the Mine on local groundwater levels. This assessment was reviewed and updated to consider the effects of the construction of additional infrastructure, including a rail loop, CHPP and TLO facility. The drawdown predicted from the Mine is limited in geographic extent (up to 3,000 m to the northeast toward existing mining) and magnitude (up to 10 m). The zone of drawdown does contain some potential GDEs, but only within the clearing footprint. No remnant vegetation outside the clearing footprint is found within the zone of drawdown. There is no predicted change to groundwater drawdown extent or magnitude as a result of the construction of infrastructure beyond that in the Groundwater Impact Assessment (hydrogeologist.com.au 2022). In summary, negligible impacts to GDEs are predicted to result from the Mine, beyond that which will occur due to vegetation clearing.

Fault zones can influence groundwater transmission rates and flow directions; however, there are no known fault zones in or near the Mine. Within the coal measures, groundwater largely flows along the bedding planes of the coal seams. In general, groundwater flows from the west to the east, mimicking the surface water drainage pattern

(hydrogeologist.com.au 2022). The low hydraulic conductivity and small storage of local aquifers means that their levels have remained largely unaffected by 40 years of dewatering at adjacent mines, just 600 m away.

The pH of local groundwater is neutral to slightly acidic (hydrogeologist.com.au 2022). Salinity levels, however, are relatively high; groundwater is brackish to saline (electrical conductivity of 2,700 to 11,700 µS/cm) (hydrogeologist.com.au 2022). This conductivity is driven mostly by high concentrations of sodium and chloride (with moderate bicarbonate in some samples), consistent with it being sodic water of marine origin. This groundwater is generally unsuitable for irrigation, but it may be used in limited quantities as water for livestock. Conductivity above 7,463 µS/cm is associated with declines in animal health if consumed for prolonged periods (ANZG 2018). All groundwater on site fails to meet guidelines for drinking water suitability for humans. Overall, groundwater on site has no or limited value for most uses, with the exception of limited stock watering and potential industrial purposes related to mining.



Legend

- ML 700060
- Potential Groundwater-Dependent Terrestrial Ecosystems

Predicted Drawdown (m)

- 1m
- 2m
- 5m
- 10m

Source: Bureau of Meteorology 2012, Hydrogeologist.com.au 2020-2022, State of Queensland (Department of Resources) 2022, Vitrinite 2022, METServe 2022, Maxar.

Vulcan Coal Mine

Maximum Drawdown of Groundwater Predicted

0 0.5 1

Kilometers

Scale: 1:40,000 (A4)

27/10/2022

Datum: GDA2020
Projection: MGA55

FIGURE 1-8

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\V1010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\PRCP_AmendmentV1010_PRCP_VCM_Matilda_MaximumDrawdownOfGroundwaterPredicted.aprx

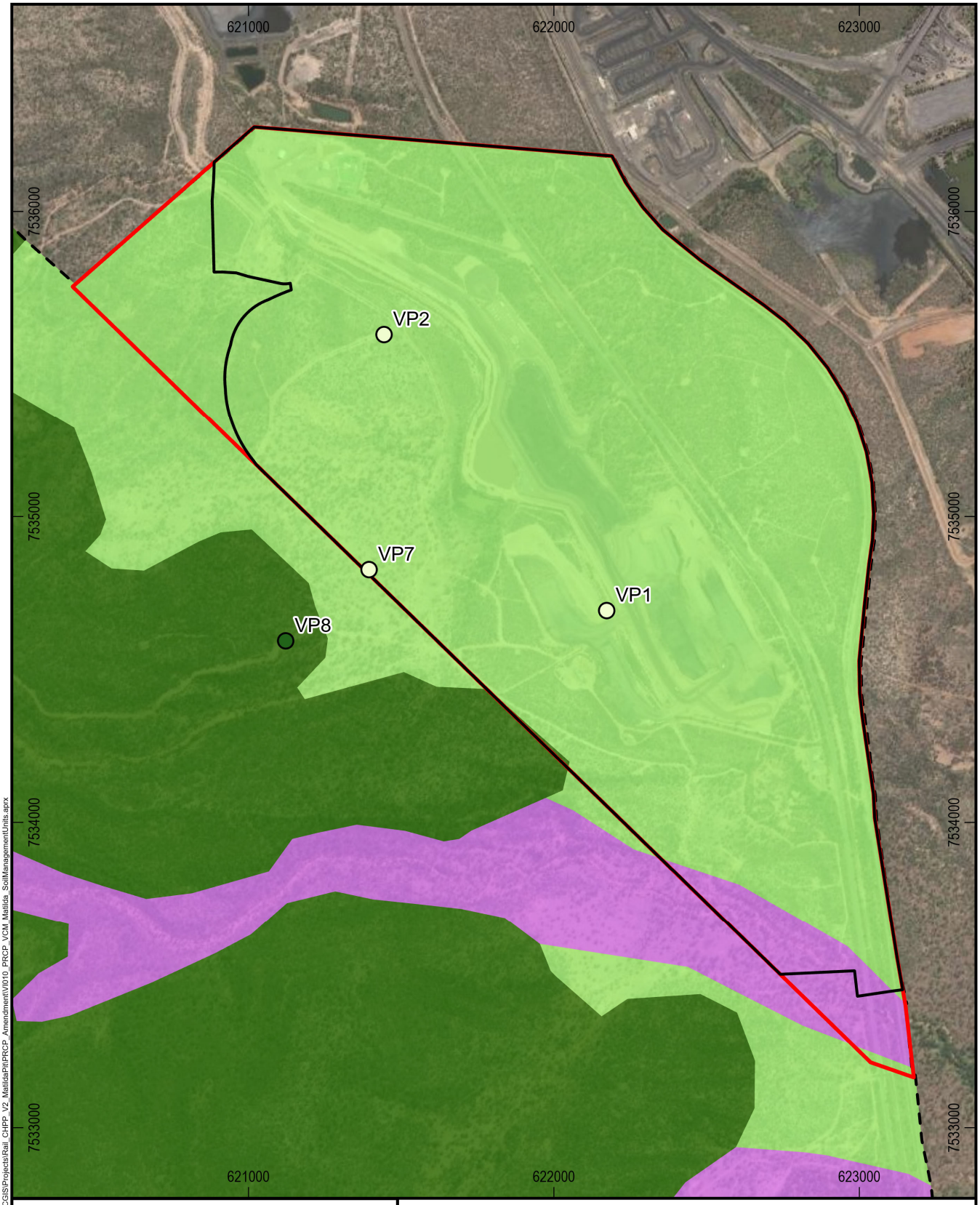
1.2.7 Soil

A Soil and Land Suitability Assessment of the Mine has been carried out by AARC. This document is supplied as **Appendix C**. The below summary of soils and land suitability has been primarily sourced from this technical assessment.

The *Report on Lands of The Isaac-Comet Area* (Story *et al.* 1967), mapped at a scale of 1:500,000, indicates the Mine area contains the following land system units:

- Carborough Land System: The Carborough Land System is characterised by mountains and hills with broken and dissected local relief ranging between 30 m to 400 m. Structural benches and cliffs are common landforms with severe weathering occurring in some areas. This mountainous land system has formed shallow, coarse-textured, rocky soils. A small area of the Carborough Land System is also characterised by lower slopes and hills and alluvial flats with a local relief between 10 m to 60 m. Texture-contrast soils have formed in these areas and possess thick sandy topsoil. Geology in this land system is comprised of partly weathered quartz sandstone.
- Cotherstone Land System: The Cotherstone Land System is characterised by hills and prominent strike ridges as well as gentler undulating terrain associated with low indefinite strike ridges and colluvial foot slopes. The more prominent strike ridges possess a local relief varying between 10 m to 30 m and have developed shallow course-textured to rocky soils. The gentler undulating terrain has a local relief of less than 15 m and is associated with texture-contrast soils with a sandy upper-horizon. The geology in this land system is weathered Permian sandstone and shale.
- Monteagle Land System: The Monteagle Land System is predominantly characterised by low-lying plains and colluvial foot slopes with local relief generally below 6 m. This land system is associated with texture-contrast soils composed of a thick sandy topsoil and neutral to strongly alkaline subsoils. Geology in this land system is comprised of undissected Tertiary sandstones and clays.

Mapping at a scale of 1:100,000, based on soil surveys undertaken on site, revealed two soil management units (SMUs) within the ML (**Figure 1-9**). These are described below.



Legend

Soil Profiles
- Crocodile
- Limpopo
- Study Area
- ML 700060
- VCM Revised Maximum Disturbance

Soil Management Units
- Crocodile
- Limpopo
- Zambezi

Source: AARC Environmental Solutions 2019, Vitrinite 2022, METServe 2022, Maxar.

Vulcan Coal Mine

Soil Management Units

0 150 300 600

Meters

Scale: 1:18,000 (A4)

27/10/2022

Datum: GDA2020
Projection: MGA55

FIGURE 1-9

VITRINITE BRIGHTER COAL

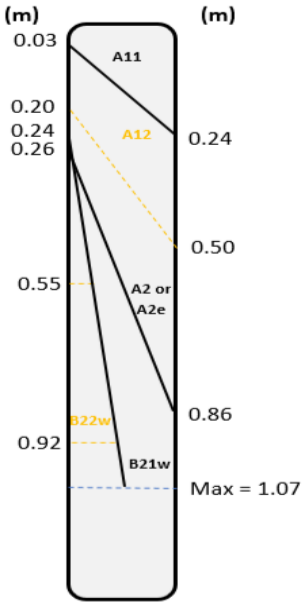
METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\PRCP_Amendment\VI010_PRCP_VCM_Matilda_SoilManagementUnits.aprx

Limpopo SMU

This is a brown texture-contrast soil unit. This soil management unit comprises 95% of the Mine area. Soils are classed as brown sodosols. Soil textures grade from sands to clay sands in the surface soils to light clays in deeper horizons. The Limpopo SMU belongs to the Monteagle land System and the Back Creek Geological Group.

The Limpopo SMU has a moderately acidic soil profile (pH 5.5-5.6). Salinity levels are very low. Sandy surface soils are non-sodic and not vulnerable to dispersion. However, clay subsoils (below 0.5 m) are sodic and susceptible to dispersion. The topsoil is dominated by sand (79%) with 8% silt and 10% clay. This texture may be at risk of slumping. Soils are deficient in phosphorus, nitrates, potassium, copper, zinc and boron.



The Limpopo SMU typically has the following soil profile:

The **surface soil** (A11, A12) is brown to a dark-brown (7.5YR4/4, 7.5YR3/3) sand to loamy sand with a loose structure. It has a field pH that ranges between 5 and 6, with a clear to gradual change to;

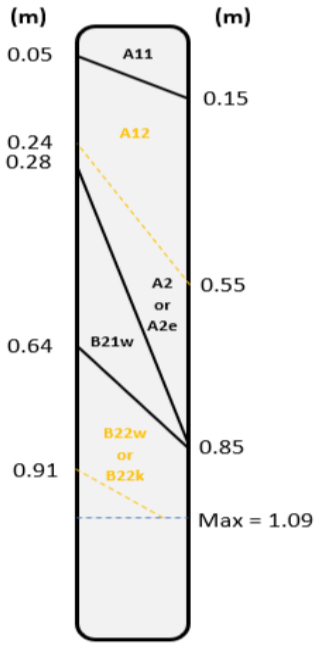
The **lower surface soil** (A2 or A2e) is a brown to greyish brown (7.5YR4/4, 10YR5/2) with some profiles within this soil unit displaying bleaching in this horizon (A2e). Predominant textures observed in this horizon range from sandy loams to sandy clay loams with a loose to weak polyhedral structure and a field pH of 6. Clear to gradual change to;

The **subsoil** (B21w, B22w) includes dark yellowish brown to a dark greyish brown (10YR4/4, 10YR4/2) clayey or sandy loams and light clays clay with weak to moderate strength polyhedral structure. Mottling was often observed in this horizon with colours ranging between red, orange and yellow. This horizon has a field pH of 5.5 to 7.

Zambezi SMU

This unit contains grey texture-contrast soils, with a sandy surface and clay subsoil. Within the ML, this soil management unit is confined to the vicinity of Drainage Line 2. This unit comprises 4% of the Mine area.

Lower horizons display diffuse orange to yellow mottles. Soils are classed as grey sodosols. The Zambezi SMU belongs to the Cotherstone Land System and the TQa geological formation (late-Tertiary to Quaternary poorly consolidated alluvium).



The Zambezi SMU has a slightly acidic (pH 6.4 to 6.7) topsoil (to 0.3 m deep), which becomes progressively alkaline with depth (to pH 9 at >0.8 m depth) and mildly acidic (pH = 6) subsoil. Salinity levels are low throughout the soil profile. The subsoil is strongly sodic and the risk of dispersion is high below 0.3 m depth (Emerson Class 2). The topsoil is dominated by sand (77%), with 14% silt, 9% clay and <1% gravel. It has a loose to weak platy structure, and low organic matter content (2%). Soils are deficient in nitrates, sulphates, phosphorus, copper and zinc.

The Zambezi SMU typically has the following soil profile:

The **surface soil** (A11/A12) is dark brown to very dark greyish brown (7.5YR2.2.5/5, 10YR3/2) coarse-grained loamy sand with loose to very weak platy structure. It has a field pH of 5.5 to 7, with a clear to abrupt change to;

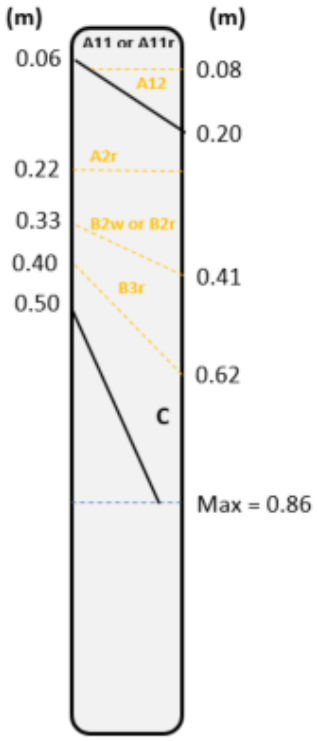
The **lower surface soil** (A2/A2e) is a brown to greyish brown (7.5YR5/4, 10YR5/2) loamy sand, with some profiles displaying this as a bleached horizon with loose single-grained structure and a field pH of 6 to 7.5. Clear to abrupt change to; and

The **lower subsoil** (B2w) is a light grey to grey (10YR7/2, 7.5YR6/1) clayey loam sand to silty clay loam with moderate polyhedral structure. This horizon has a field pH of 7 to 9.

Crocodile SMU

A shallow rocky soil unit associated with hill slopes and plateaus. Soil textures grade from loam at the surface, to loamy sands with depth; often containing rock material with little to no pedologic development throughout the solum. This unit comprises 1% of the Mine area and is confined to the western boundary of the ML.

The Crocodile SMU is strongly acidic throughout the solum with only a minor increase in pH at depth (5.4-5.6). In the upper part of the profile (to an approximate depth of 0.3 m), this has the potential to limit the availability of essential nutrients and increase the risk of aluminium toxicity. Electrical Conductivity and Chloride levels are very low throughout the profile. The topsoil is dominated by sand (52%) and gravel (30%) with 10% silt and 8% clay. This particle size distribution could limit the ability of the soil to hold and store plant available water.



The Crocodile SMU typically has the following soil profile:

The **surface soil** (A11/A11r/A12) is a black to very dark greyish brown (10YR2/1, 10YR3/2) sand to sandy loam with loose to weak polyhedral structure with some profiles containing moderately strong to strong sub-angular rock material. The soil unit has a field pH of 4.5 - 5.5, demonstrating an abrupt to clear change to;

The **lower surface soil** (A2r) is not a common horizon observed for this SMU. It is a dark brown (10YR3/3) loamy sand with an abundance (comprising 50 - 90% of this horizon) of moderately strong coarse fragments approximately 2 - 6 cm in diameter. It has loose structure and a field pH of 5.5 to 5.0. Gradual change to;

The **subsoil** (B2w/B2r) is a dark greyish to reddish brown (10YR3/2, 2.5YR2.5/4) loamy sand to clay loam with weak to moderate polyhedral structure. It can contain rounded to angular course fragments which make up < 10% of the horizon. This horizon has a field pH of 4.5 to 5.5, with a gradual change to;

The **lower profile** (C) contains either consolidated or unconsolidated partly weathered rock material that appear to have originated from underlying sandstone and siltstone with some profiles possessing an overlying transitionary horizon (B3r). Depending on the rock material present, this horizon can range from dark red to light yellow-brown colour.

1.2.8 Land Stability

All soil units contained within the ML are sandy-textured with poor water- and nutrient-holding capacity (AARC 2021). This causes them to support a relatively modest grass cover (usually 20-25%, as assessed in the late wet season: METServe 2020). Furthermore, while topsoils in all local soil management units are relatively stable, subsoils in the most widespread unit (Limpopo) are dispersive and prone to erosion (AARC 2021). Consequently, the land is predisposed to ongoing stability issues in its pre-mining state, and gully erosion is widespread along minor drainage lines in the western half of the ML, where grazing intensity is highest (**Figure 1-10**).



Figure 1-10 Extensive gully erosion in heavily grazed portions of the ML

Slopes within the Limpopo soil management unit are generally less than 10%, which assists in maintaining stability. However, slopes may exceed 30% in certain areas within the Limpopo soil unit (refer **Section 6.1**). Slopes of up to 50% are frequent in the Crocodile soil management unit (along the western boundary of the Mine), but extensive rock outcropping and heavy vegetation cover in these areas protect against erosion (refer **Section 6.1**), and gully erosion was scarce on this soil management unit.

1.2.9 Vegetation

A Terrestrial Ecology Assessment of the Mine has been carried out by METServe. This document is supplied as **Appendix D**. The below summary of terrestrial ecology has been primarily sourced from this technical assessment.

Four regional ecosystems occur in the ML. All four occur (mostly as regrowth) within the disturbance footprint (**Table 1-4;Figure 1-11**). 4.0% of the disturbance footprint comprises remnant vegetation, 33.3% comprises high-value regrowth and the majority (62.7%) comprises cleared pastures. No threatened plant species have been recorded or are likely to occur within the Mine disturbance footprint (METServe 2022).

Heavy grazing was a notable feature of the ML. This manifested through the altered composition of the understorey vegetation (Fensham *et al*. 1999; Walker *et al*. 2006). Native perennial grasses were scarce, while introduced pasture grasses (especially *Cenchrus ciliaris*, *Bothriochloa pertusa*, *Melinis repens* and *Urochloa mosambicensis*) dominated, along with native annual species (e.g., *Alloteropsis cimicina*, *Setaria surgens*, *Dactyloctenium radulans*, *Perotis rara*) (METServe 2020). Across all vegetation sampling sites assessed within the broader region, weeds made up an average of half the understorey biomass, although this varied by regional ecosystem (**Table 1-4**).

Table 1-4 Regional ecosystems present within the Mine footprint. Data extracted from METServe (2022)

Regional Ecosystem	BVG*	Short description	VM class†	Biodiv. Status‡	Mean weed dominance§	Mean canopy cover‖	Mean grass cover	Mean herb cover	Mean bare ground	Area to be disturbed (hectares)	
										Remnant	Regrowth
11.3.25	16a	*Eucalyptus camaldulensis* forest fringing drainage lines.	LC	OC	86.7%	90.0%	43.3%	15.3%	7.7%	1.7	2.6
11.5.9	18b	*Eucalyptus crebra* and other *Eucalyptus* spp. and *Corymbia* spp. woodland on Cainozoic sand plains and/or remnant surfaces.	LC	NC	39.9%	49.5%	23.3%	6.4%	32.3%	0	99.3
11.10.3	24a	*Acacia shirleyi* or *Acacia rhodoxylon* open forest on coarse-grained sedimentary rocks. Crests and scarps.	LC	NC	11.3%	63.2%	25.8%	1.9%	16.8%	13.2	11.9
11.10.7	12a	*Eucalyptus crebra* woodland on coarse-grained sedimentary rocks.	LC	NC	36.8%	54.5%	19.9%	3.2%	35.3%	0	11.3
Non-remnant	-	Cleared pasture, +/- scattered trees or young regrowth.	-	-	92.0%	18.9%	55.3%	3.7%	26.8%	234.8	

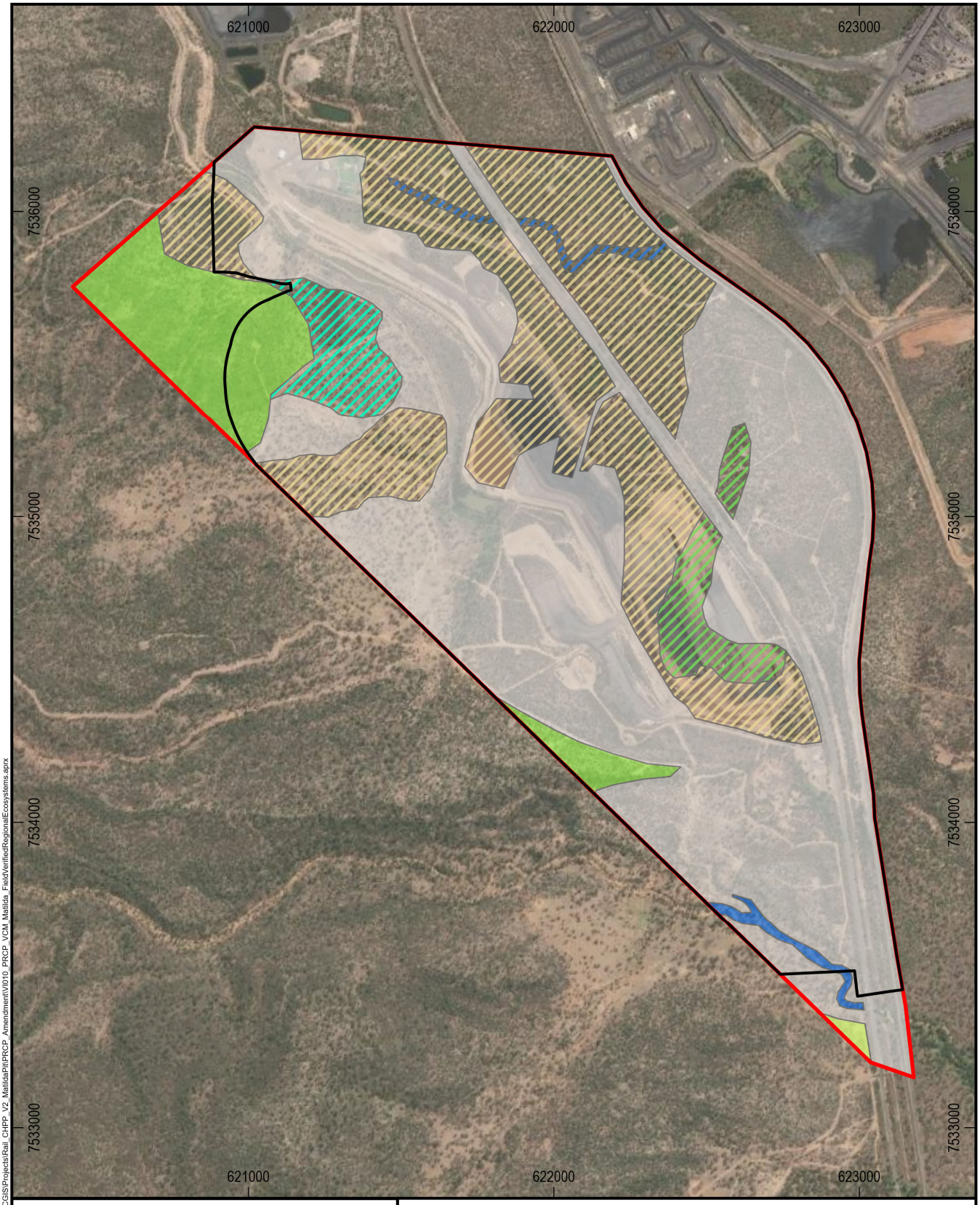
*BVG = broad vegetation group.

†VM class = classification under the *Vegetation Management Act 1999*: E = endangered, OC = of concern. LC = least concern.

‡Biodiversity status relates to environmentally sensitive areas under the *Environmental Protection Act 1994*: E = endangered, OC = of concern, NC = no concern at present.

§Mean percentage of the understorey vegetation within each regional ecosystem that comprises non-native species (pasture grasses and weeds).

‖Canopy cover is the combined foliage projective cover of all woody vegetation (trees and shrubs).



Legend

- ML 700060
- VCM Revised Maximum Disturbance

Field Verified Regional Ecosystems

- 11.10.3
- 11.10.7
- 11.3.25
- HVR 11.10.3
- HVR 11.10.7/11.10.3
- HVR 11.3.25
- HVR 11.5.9
- Non-remnant

Source: Vitrinite 2022, METServe 2022, Maxar.

Vulcan Coal Mine

Field Verified Regional Ecosystem Mapping

0 150 300 600

Meters

Scale: 1:18,000 (A4)

27/10/2022

Datum: GDA2020
Projection: MGA55

FIGURE 1-11

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\PRCP_Amendment\VI010_PRCP_VCM_Matilda_FieldVerifiedRegionalEcosystems.aprx

1.2.10 Significant Species

Field surveys of a 6,552-hectare (ha) area surrounding and including the ML detected 40 species of mammal, 133 species of bird, 35 species of reptile, 14 species of frog and 423 species of vascular plants. Among this biodiversity are five species that constitute matters of state and/or national environmental significance (MSES and MNES, respectively). An additional three species that constitute MNES or MSES are likely to utilise the survey area in some capacity, while a further 17 species are possible inhabitants or visitors (**Table 1-5**).

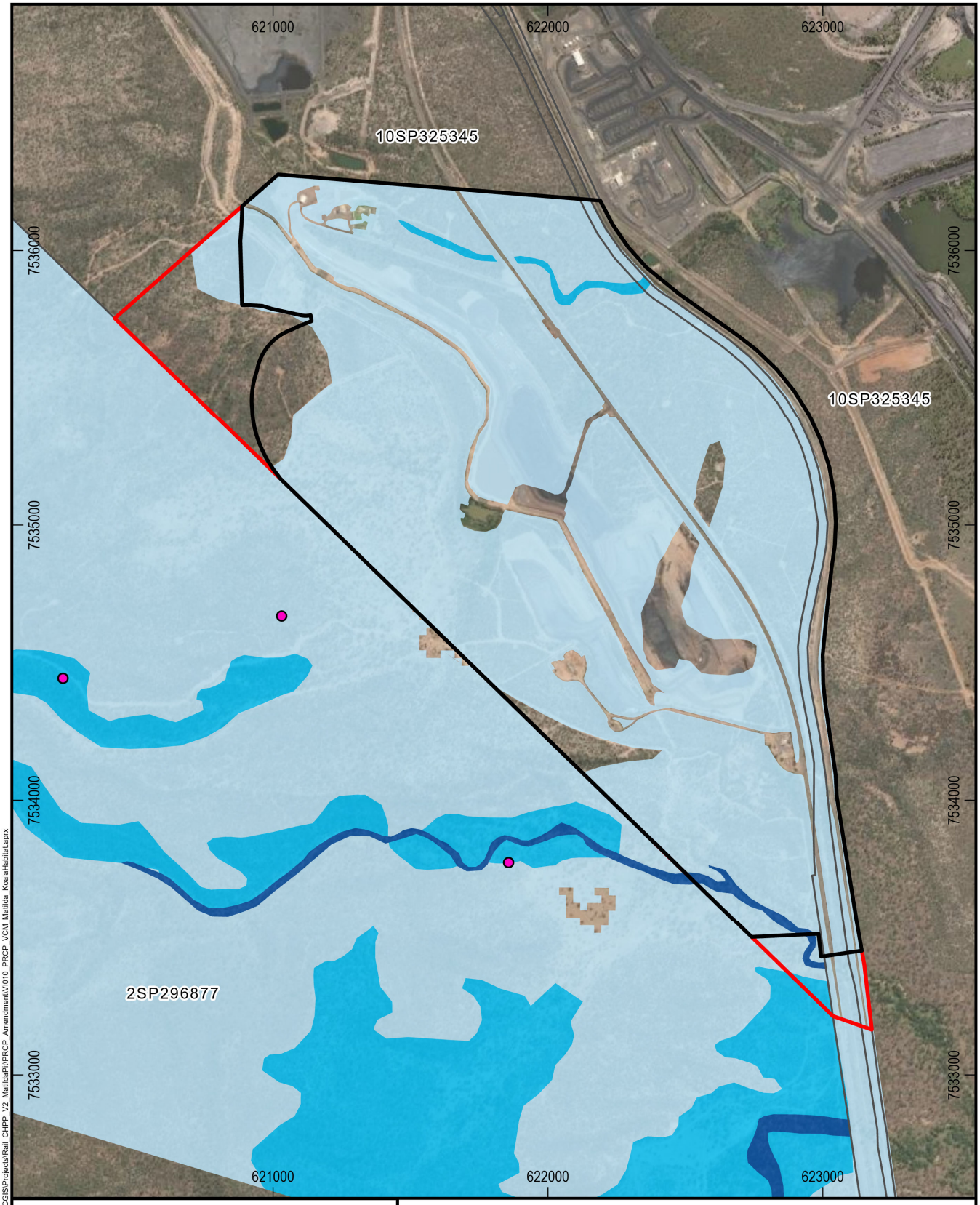
Avoidance of disturbance to habitat for significant species was an important consideration during design of the Mine. Avoidance of disturbance to the maximum extent practicable was achieved by:

1) minimising the total disturbance footprint by incorporating in-pit dumping of waste rock, which negates the need for extensive ex-pit dumping;
2) minimising the total disturbance footprint by utilising accommodation facilities in nearby towns, rather than on site;
3) locating the Mine and ancillary infrastructure away from remnant vegetation where possible; and
4) designing the Mine and ancillary infrastructure so that it avoids disturbance to an existing dam, which is used by Squatter Pigeons for drinking and is possibly used on occasion by other MNES and MSES.

Despite these efforts to avoid disturbance, potentially significant residual impacts to four species (Koala *Phascolarctos cinereus*, Squatter Pigeon *Geophaps scripta scripta*,, Central Greater Glider *Petauroides armillatus* and Short-beaked Echidna *Tachyglossus aculeatus*) may arise as a result of the Mine. In order to reduce the long-term impacts of the Mine on each of these species, their ecological requirements have been taken into account during the planning of post-mining land uses and rehabilitation methodology. A summary of the ecological requirements of these three species are provided below.

Koala

The Koala is a MNES (endangered species) and MSES (endangered species). Koalas inhabit open forests and woodlands containing species that are known food trees. Within the Isaac Regional Council area, primary food trees consist of *Eucalyptus camaldulensis** and *Eucalyptus tereticornis*, while secondary food trees include *Eucalyptus brownii*, *Eucalyptus coolabah*, *Eucalyptus ochrophloia*, *Eucalyptus orgadophila*, *Eucalyptus populnea** and *Eucalyptus crebra** (Australian Koala Foundation 2015). The three species with an asterisk are found naturally within the ML. Three habitat classes (high quality, moderate quality and low quality) have been mapped across the ML and adjacent areas (**Figure 1-12**). The approved disturbance footprint, including the proposed additional disturbance for the CHPP, Rail and Matilda amendment, contains a total of 323 ha of Koala habitat within the disturbance footprint of the Mine. Little of this (1.7 ha) is high-quality habitat and moderate quality habitat (2.6 ha) (the habitat types in which most records occurred). The remaining 318.7 ha of habitat within the disturbance footprint is low-quality habitats The reestablishment of food trees on rehabilitated land is expected to reduce long-term impacts of the Mine on the Koala. This will re-establish moderate and low quality habitat within the disturbance footprint.



Legend

- Koala Sighting
- ML 700060
- VCM Revised Maximum Disturbance
- Property Boundary

Koala Habitat

- High Quality
- Moderate Quality
- Low Quality

Source: Australian Government (Department of Industry, Science, Energy and Resources) 2021, METServe 2020-2022, Vitrinite 2022, Maxar. Koala habitat derived from the National Forest and Sparse Woody Vegetation dataset (Version 5.0) and field verified regional ecosystem data.

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\PRCP_Amendment\VI010_PRCP_VCM_Matilda_KoalaHabitat.aprx

Vulcan Coal Mine

Koala Habitat in the Vicinity of the Project

0 200 400 800

Meters

Scale: 1:20,000 (A4)

27/10/2022

Datum: GDA2020
Projection: MGA55

FIGURE 1-12

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Squatter Pigeon

The Squatter Pigeon is both a MNES (vulnerable species) and MSES (vulnerable species). Squatter Pigeons inhabit a wide range of open forests to sparse open woodlands and scrub, primarily on sandy or gravelly soils, supporting a patchy understorey of grasses and herbs, mixed with areas of bare ground. Squatter Pigeons are not dependent on remnant vegetation, and readily feed on some introduced pastures (METServe 2020). A moderate intensity of grazing is beneficial to the species, as it creates favourable open patches of ground for foraging. Nevertheless, Squatter Pigeons require some degree of tree cover, and based on data gathered from 60 records of Squatter Pigeons across the region containing the Mine, a minimum Normalised Differential Vegetation Index of 0.125 (measured across a 1-ha cell in the late dry season) was required for the habitat to be suitable for the species (METServe 2020). Habitat mapping was undertaken for the species based on vegetation density and soil type (**Figure 1-13**). The approved disturbance footprint, including the proposed additional disturbance for the CHPP, Rail and Matilda amendment, contains a total of 346.5 ha of Squatter Pigeon habitat within the disturbance footprint of the Mine. Breeding and Foraging habitat (combined) comprises an area of 286.2 ha, with habitat for foraging alone being 60.1 ha. The species' frequent use of cleared habitats meant that it was not possible to design the Mine without disturbing habitat for the Squatter Pigeon. Over 2,900 ha of Squatter Pigeon habitat was mapped in the vicinity of the Mine, suggesting that the 3% of vegetation which will be removed will have a negligible impact on local populations of the species. Nevertheless, post-mining land uses that are conducive to the long-term conservation of Squatter Pigeons on rehabilitated land (e.g., native habitats or low-intensity cattle grazing) are preferred. Likewise, the species' ecological needs (e.g., density of tree cover) were considered during the development of completion criteria.

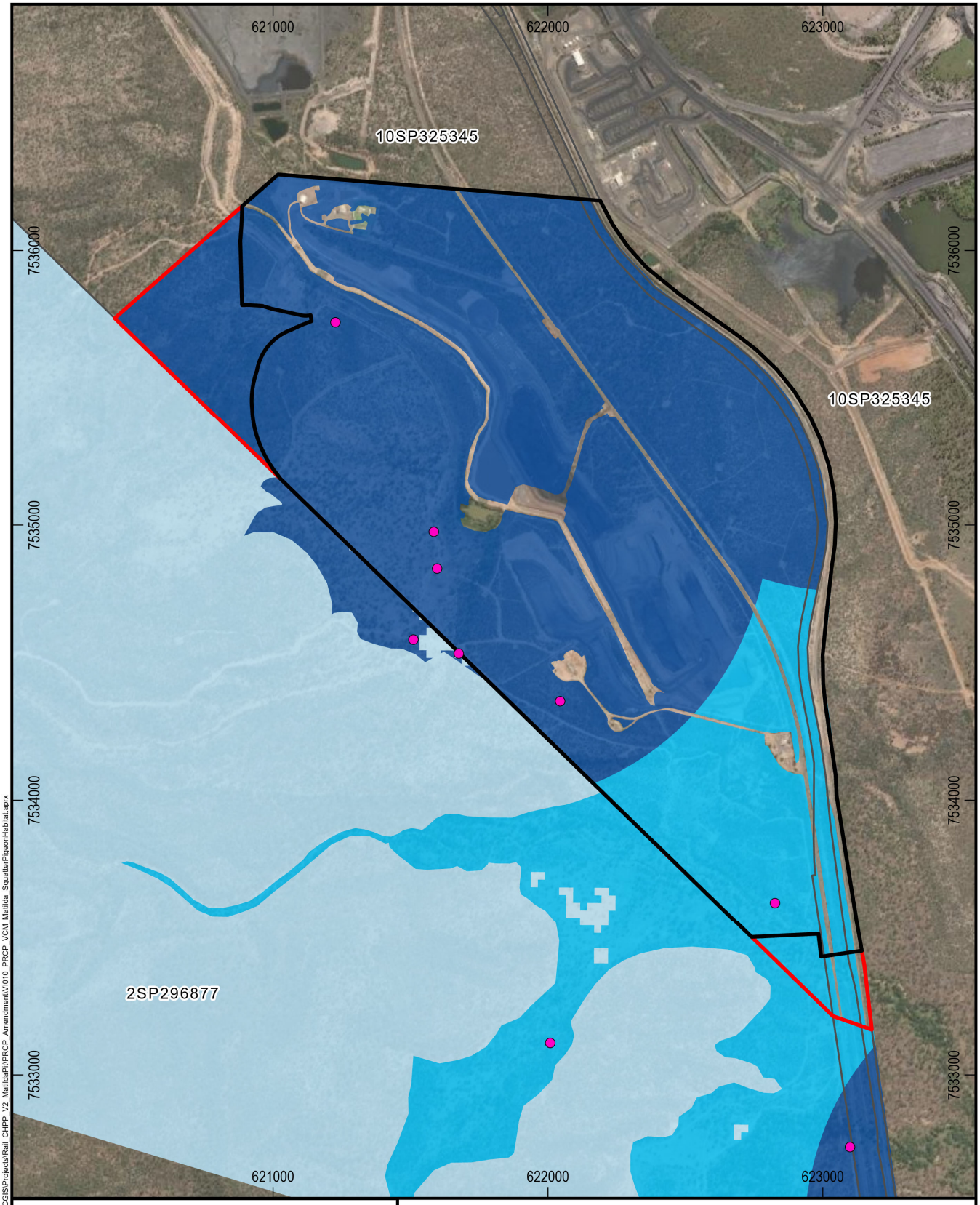
Central Greater Glider

The Central Greater Glider is both a MNES (endangered species) and MSES (endangered species). Greater glider species feed on the young leaves of *Eucalyptus* and *Corymbia* in a broad range of forests across eastern Australia. They have a preference for tall, montane, moist eucalypt forests with abundant hollows and a diversity of tree species present (METServe 2022) but also occur in drier lowland forests, provided tall, hollow trees are present. Each individual requires many large, hollow-bearing trees within its home range of 1-4 ha (METServe 2022). With the exception of the single record, all other Central Greater Gliders were detected in riparian environments with abundant hollows. This is clear evidence for the importance of riparian habitats for local populations of the Central Greater Glider. Habitat mapping was undertaken for the species with only 1.7 ha of habitat being present in the disturbance footprint. **Figure 1-14**).

Short-beaked Echidna

The Short-beaked Echidna is a MSES (special least concern species). Short-beaked Echidnas inhabit all types of vegetation contained within the ML, including cleared pastures. Their chief ecological requirement is a supply of ants and termites on which to feed. Post-mining land uses that support populations of ants and termites, as well as provide a moderate amount of vegetation cover for protection from weather and predators, will facilitate the long-term conservation of the species on site.

Due to the unspecific habitat needs of Short-beaked Echidnas, it is expected that any rehabilitated sites that support other species of conservation significance (i.e., Koalas and/or Squatter Pigeons) will also be suitable for echidnas. The species is therefore not considered further when planning post-mining land uses or appropriate completion criteria.



Legend

- Squatter Pigeon Sighting
- ML 700060
- VCM Revised Maximum Disturbance
- Property Boundary

Squatter Pigeon Habitat

- Breeding and foraging habitat
- Foraging habitat
- Dispersal habitat

Source: Geoscience Australia 2015, Australian Government (Department of Industry, Science, Energy and Resources) 2021, METServe 2019-2022, Maxar. Squatter Pigeon habitat derived from the National Forest and Sparse Woody Vegetation dataset (Version 5.0) and field-verified regional ecosystem data.

Vulcan Coal Mine

Squatter Pigeon Habitat in the Vicinity of the Project

0 200 400 800

Meters

Scale: 1:20,000 (A4)

27/10/2022

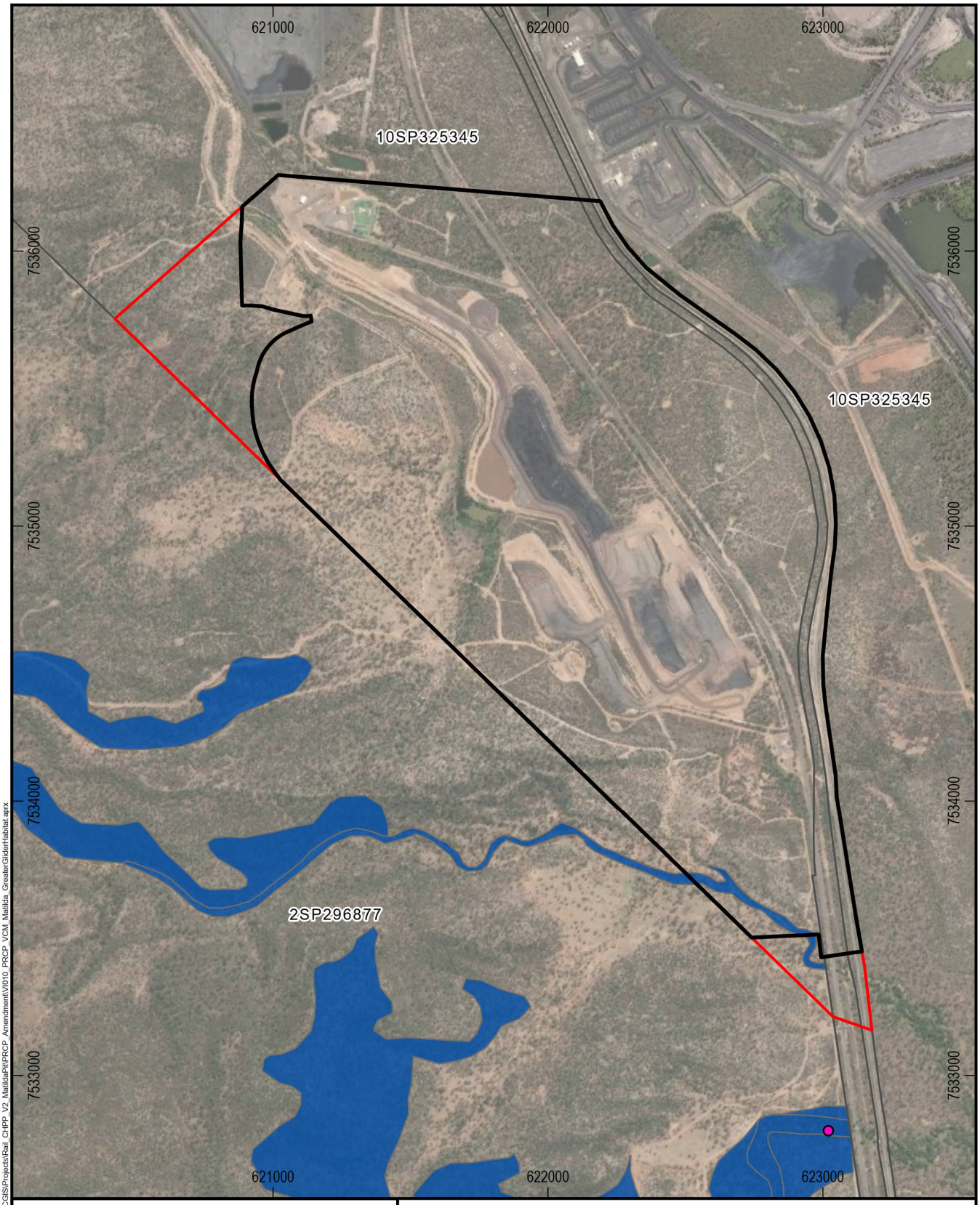
Datum: GDA2020
Projection: MGA55

FIGURE 1-13

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\PRCP_Amendment\VI010_PRCP_VCM_Matilda_SquatterPigeonHabitat.aprx



Legend

- Central Greater Glider Sighting
- Central Greater Glider Habitat
- ML 700060
- VCM Revised Maximum Disturbance
- Property Boundary

Source: Vitrinite 2022, METServe 2020-2022, Maxar.

Vulcan Coal Mine

Central Greater Glider Habitat in the Vicinity of the Project

0 300 600

Meters

Scale: 1:20,000 (A4)

5/01/2023

Datum: GDA2020
Projection: MGA55

FIGURE 1-14

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\PRCP_Amendment\VI010_PRCP_VCM_Matilda_GreaterGliderHabitat.aprx

Table 1-5 Species of national or state environmental significance flagged by databases as being potentially present in the local region

Taxon	Species	Common Name	EPBC status*	NC status†	Habitat requirements	Presence in survey area†	Significant Impact?‡
Bird	*Geophaps scripta scripta*	Squatter Pigeon	V	V	Open grassy woodland with areas of bare ground, on land zones 3, 5 and 7.	C	Y
Mammal	*Phascolarctos cinereus*	Koala	E	E	Vegetation communities containing large food trees (*Eucalyptus* spp.), especially near watercourses.	C	Y
Mammal	*Petauroides armillatus*	Central Greater Glider	E	E	Tall, old-growth eucalypt forest with tree hollows.	C	Y
Mammal	*Tachyglossus aculeatus*	Short-beaked Echidna	-	SL	Cosmopolitan habitat usage; anywhere termites can be found.	C	N
Bird	*Hirundapus caudacutus*	White-throated Needletail	V	V	Airspace containing flying insects, above a diversity of landscapes.	C	N
Bird	*Rhipidura rufifrons*	Rufous Fantail	M	SL	Dense woody vegetation, including vine thickets, paperbark forests and rainforest.	C	N
Bird	*Apus pacificus*	Fork-tailed Swift	M	SL	Almost exclusively aerial, foraging on flying insects above all habitat types.	L	N
Bird	*Gallinago hardwickii*	Latham's Snipe	M	SL	Freshwater wetlands with well-vegetated muddy edges.	L	N
Reptile	*Denisonia maculata*	Ornamental Snake	V	V	Gilgais on heavy clay soil, especially where *Acacia harpophylla* grows.	L	N
Bird	*Rostratula australis*	Australian Painted-snipe	E	V	Freshwater wetlands with well-vegetated muddy edges.	P	N
Reptile	*Acanthophis antarcticus*	Common Death Adder	-	V	Forested areas with deep leaf litter and/or abundant rocks.	P	N
Bird	*Erythrotriorchis radiatus*	Red Goshawk	V	E	Large tracts of undisturbed forest, especially near the ecotone between rainforests, melaleuca swamps and open eucalypt woodlands. Within the survey area, it is most likely in densely forested riparian habitats.	P	N
Reptile	*Egernia rugosa*	Yakka Skink	V	V	Potentially any vegetated habitat with fallen timber or rocks. There are no nearby records, but habitat is available locally.	P	N
Grass	*Aristida annua*	Annual Wiregrass	V	V	Open eucalypt woodlands and pastures ranging from sandy loams to basalt-derived clay. The survey area lies outside the known distribution of the species; the most northern record is 35 km south.	P	N
Bird	*Calidris acuminata*	Sharp-tailed Sandpiper	M	SL	Estuarine and freshwater wetlands with extensive shallow, muddy margins.	P	N

Taxon	Species	Common Name	EPBC status*	NC status†	Habitat requirements	Presence in survey area‡	Significant Impact?‡
Bird	*Cuculus optatus*	Oriental Cuckoo	M	SL	Primarily coastal forest and woodland. Rarely moves inland west of the coastal ranges.	P	N
Bird	*Gelochelidon nilotica*	Gull-billed Tern	M	SL	Primarily a coastal species. Can occur over inland lakes.	P	N
Bird	*Monarcha melanopsis*	Black-faced Monarch	M	SL	Typically associated with rainforest. Migrating individuals may utilise dense riparian vegetation in a transient capacity.	P	N
Bird	*Myiagra cyanoleuca*	Satin Flycatcher	M	SL	Tall wet forests of the coast and nearby ranges. Vagrant individuals may occasionally occur inland, where they are most likely in denser forests (e.g., along waterways).	P	N
Bird	*Plegadis falcinellus*	Glossy Ibis	M	SL	Shallow, marshy edges of large freshwater wetlands.	P	N
Mammal	*Macroderma gigas*	Ghost Bat	V	E	Primarily coastal ranges, where large cave systems occur near extensive forests. The nearest record is 85 km northeast.	P	N
Reptile	*Furina dunmalli*	Dunmall's Snake	V	V	Strongly associated with *Acacia harpophylla* and cracking clay soils. The survey area is outside the known distribution of the species.	P	N
Reptile	*Lerista allanae*	Allan's Lerista	E	E	Inhabits root systems of grass tussocks growing on black clay soils.	P	N
Grass	*Dicanthium queenslandicum*	King Blue-grass	E	V	Grasslands or open woodland on clay soils, with low grazing pressure. Favourable soils within the survey area were subject to high grazing pressure.	P	N
Mammal	*Dasyurus hallucatus*	Northern Quoll	E	LC	Rugged escarpments in wetter forested areas.	P	N
Grass	*Dicanthium setosum*	Bluegrass	V	LC	Grasslands or open woodland on clay soils, with low grazing pressure.	P	N

*Status under the *Environment Protection and Biodiversity Conservation Act 1999*: E = endangered, V = vulnerable, M = migratory. These species constitute MNES.

†Status under the *Nature Conservation Act 1992*: E = endangered, V = vulnerable, SL = special least concern, LC = least concern. Species other than least concern constitute MSES.

‡Presence within the broader survey area encompassing the ML: C = presence confirmed, L = likely to be present, P = possibly present.

‡Is a significant impact likely to arise from the Mine?: Y = yes, N = no (based on a detailed ecological assessment by METServe 2020).

1.2.11 Pre-mining Land Use

The land within the ML is zoned as Rural under the Isaac Regional Council Planning Scheme. The lot containing the Mine (lot 10, SP325345) is a Land Lease with an industrial purpose, and most of the lot contains operational areas of the Peak Downs Mine. The land has an agriculture land class of C2 (land suitable for grazing on native pastures on lower fertility soils) or C3 (land suitable for light grazing on native pastures in accessible areas, and includes steep land), in accordance with the *Guidelines for Agricultural Land Evaluation in Queensland* (DSITI and DNRM 2015). The pre-mining land use is primarily low-intensity cattle grazing. A total of 96% of the mining footprint had been formerly cleared of its natural vegetation; the remaining 4% comprised native remnant vegetation with an understorey that has been highly modified by grazing (see **Section 1.2.9**). The dominant land use adjacent to the Mine (to the north and east) is coal mining.

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

Saraji Road, a public, sealed roadway administered by Isaac Regional Council, passes through the ML. This serves an annual average of 2,270 vehicles per day (as surveyed in 2021: Stantec 2021).

A railway line managed by Aurizon runs immediately inside the eastern boundary of the ML. A flood levee constructed by BHP Billiton/Mitsubishi Alliance (BMA) (owners of the Saraji and Peak Downs Mines) runs through the centre of the ML.

A number of small industrial compounds also existed on the site. These provided supporting infrastructure to a number of commercial operations that utilised small portions of the ML.

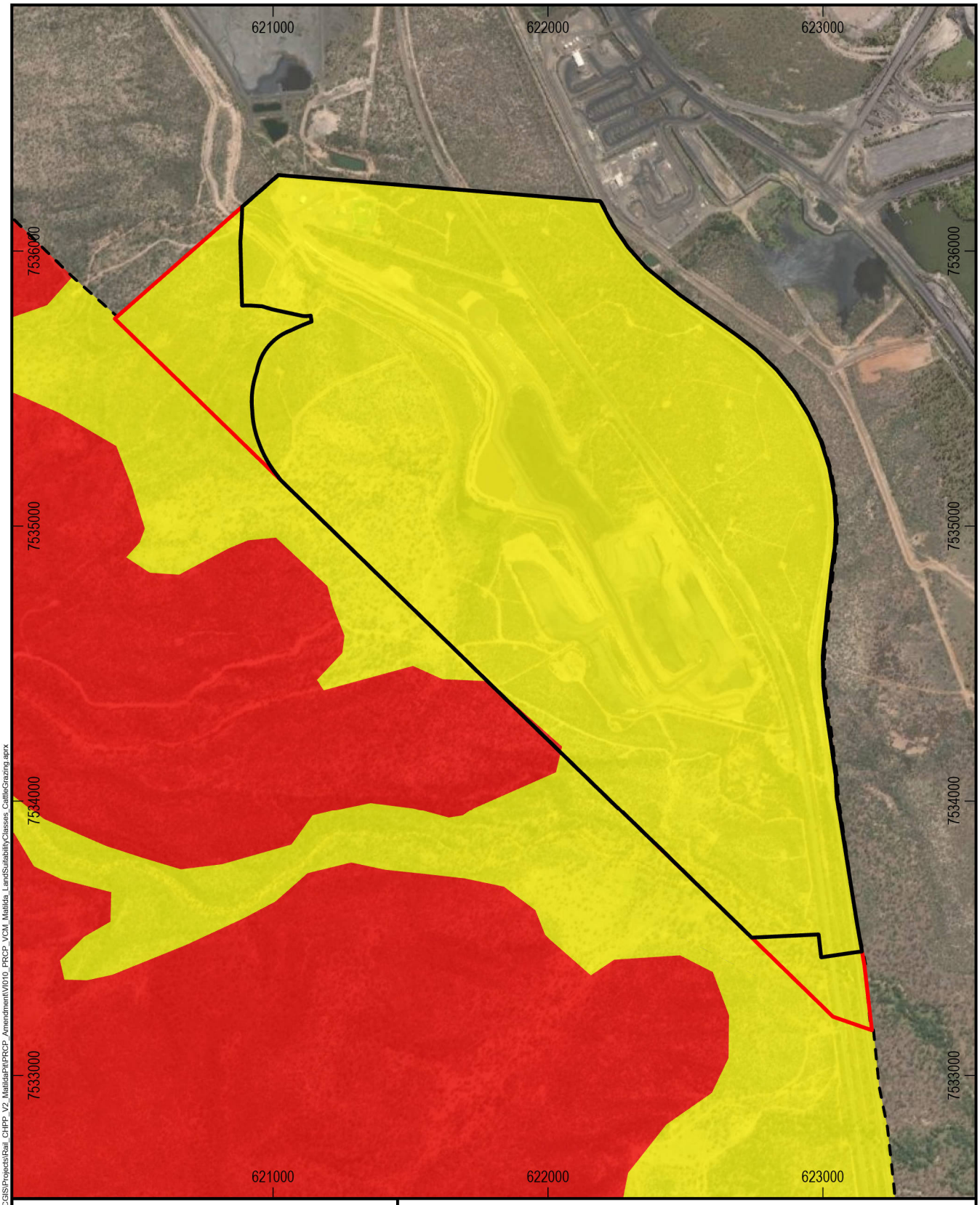
Vitrinite was granted an Environmental Authority (EA0002054) and a Mineral Development Licence (MDL3039) to permit extraction of a bulk sample of coal from within the footprint of the Mine. Prior to commencement of the Mine, Vitrinite extracted approximately 600 kilotonnes (kt) of high-quality coking coal from the bulk sample pit for testing by a number of international coal consumers. The waste rock dump required for the bulk sample phase of the Mine is being developed as an extension of the bulk sample dump. While disturbance resulting from the bulk sample is not considered part of the Mine (as it has previously been approved), rehabilitation of the bulk sample footprint forms part of this PRC Plan, as this footprint is incorporated into the operations of the Mine.

Land Suitability Ratings

An assessment of land suitability for cattle grazing has been undertaken by AARC (**Appendix C**), in accordance with the *Guidelines for Agriculture Land Evaluation in Queensland* (DSITI and DNRM 2015) and *Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland – Land Suitability Assessment Techniques* (DME 1995). This assessment considered water availability, nutrient deficiency, soil physical factors, salinity, rockiness, microrelief, pH, exchangeable sodium percentage, wetness, water erosion, flooding, and vegetation regrowth. The results of this assessment are shown in **Table 1-6**. Sandy soils on the plains (Limpopo and Zambezi) had a land suitability class of 4 (marginal land for grazing). Sandstone escarpment areas of the Crocodile soil management unit had a class of 5 (unsuitable for grazing) (**Figure 1-15**). Class 4 land is categorised as marginal for grazing improved pastures, although it is largely considered suitable for grazing native pastures of variable quality. Class 5 land is unsuitable for any form of pasture improvement and is limited to low productivity grazing of native pastures. Class 5 land may require destocking in poor seasons.

Table 1-6 *Summary of pre-mining land suitability limitations for cattle grazing*

Limitation	Crocodile	Limpopo	Zambezi
Water availability	5	3	4
Nutrient deficiency	4	4	4
Soil physical factors	1	1	1
Salinity	1	1	1
Rockiness	3	1	1
Microrelief	1	1	1
pH	2	2	2
ESP	1	1	1
Wetness	1	2	2
Water erosion	2	1	1
Flooding	1	1	2
Vegetation Regrowth	1	2	2
Overall Suitability Rating	**5**	**4**	**4**



Legend

- ML 700060
- Study Area
- VCM Revised Maximum Disturbance

Land Suitability (Cattle Grazing)

- Class 4
- Class 5

Source: AARC Environmental Solutions 2019-2020, Vitrinite 2022, METServe 2022, Maxar.

Vulcan Coal Mine

Land Suitability Classes for Cattle Grazing

0 200 400 800

Meters

Scale: 1:20,000 (A4)

5/01/2023

Datum: GDA2020
Projection: MGA55

FIGURE 1-15

VITRINITE BRIGHTER COAL

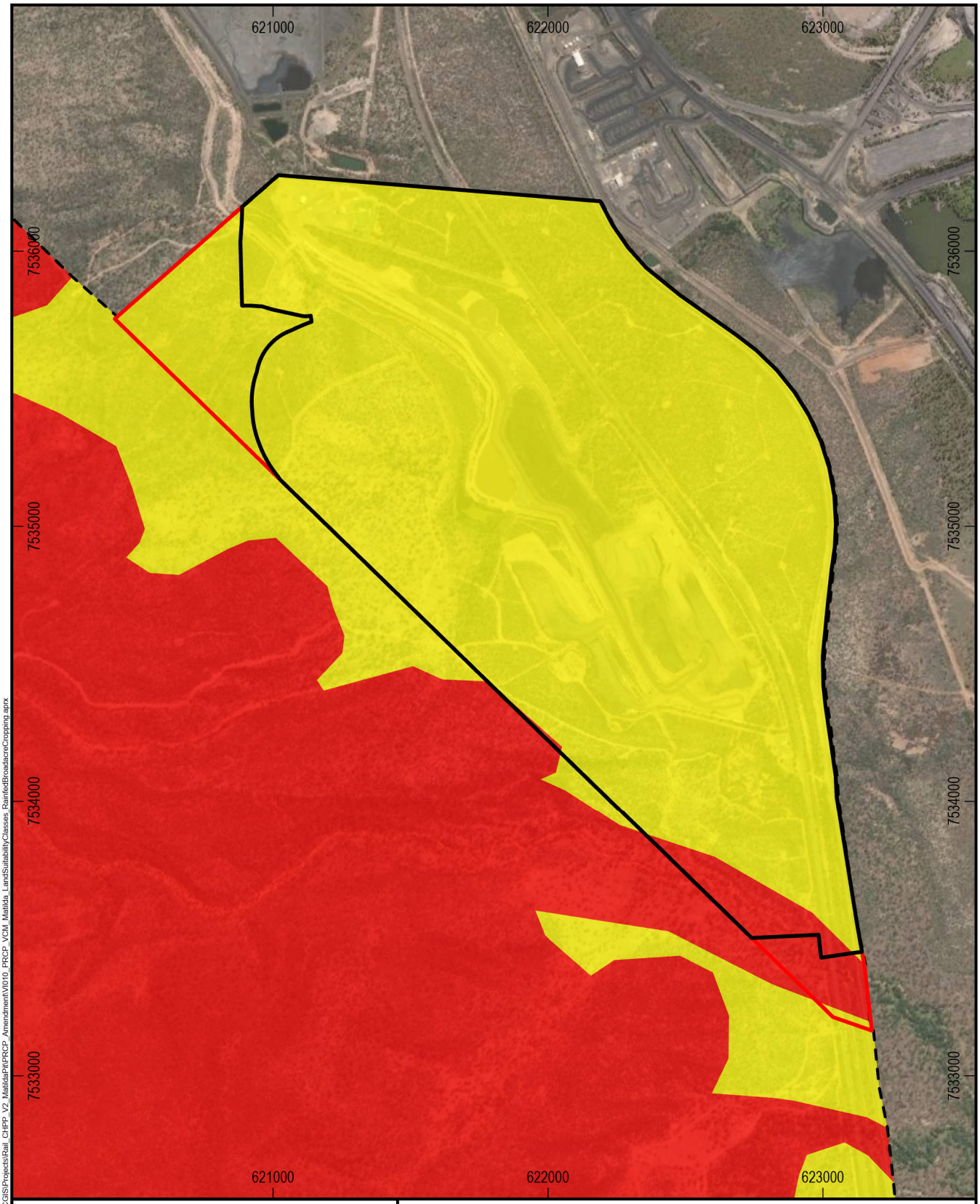
METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\PRCP_Amendment\VI010_PRCP_VCM_Matilda_LandSuitabilityClasses_CattleGrazing.aprx

Although not proposed as a PMLU, a similar land suitability assessment has been undertaken for the land's potential for rain-fed broadacre cropping (**Table 1-7**). This revealed that the majority of the ML has a land suitability class of 4 (unsuitable for rain-fed broadacre cropping with severe limitations) (**Figure 1-16**).

Table 1-7 Summary of land suitability limitations for rain-fed broadacre cropping

Limitation	Crocodile	Limpopo	Zambezi
Water availability	5	4	5
Nutrient deficiency	3	4	4
Soil physical factors	3	1	1
Soil workability	2	1	1
Salinity	1	1	1
Rockiness	3	1	1
Microrelief	1	1	1
Wetness	1	2	3
Topography	4	1	2
Water erosion	5	2	2
Flooding	1	1	3
Overall Suitability Rating	**5**	**4**	**5**



Legend

- ML 700060
- Study Area
- VCM Revised Maximum Disturbance

Land Suitability (Rainfed Broadacre Cropping)

- Class 4
- Class 5

Source: AARC Environmental Solutions 2019-2020, Vitrinite 2022, METServe 2022, Maxar.

Vulcan Coal Mine

Land Suitability Classes for Broadacre Cropping

0 200 400 800

Meters

Scale: 1:20,000 (A4)

5/01/2023

Datum: GDA2020
Projection: MGA55

FIGURE 1-16

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\PRCP_Amendment\VI010_PRCP_VCM_Matilda_LandSuitabilityClasses_RainfedBroadacreCropping.aprx

Based on the land suitability assessments summarised above, the soil management units present on site have been assigned the agricultural land classifications listed in **Table 1-8**.

Table 1-8 Agricultural land classes (AARC 2021)

Soil Management Unit	Land Class	Class Description
Crocodile	C3	Pasture Land – Land suitable for light grazing on native pastures in accessible areas, and includes steep land.
Limpopo	C2	Pasture Land – Land suitable for grazing on native pastures on lower fertility soils.
Zambezi	C3	Pasture Land – Land suitable for light grazing on native pastures in accessible areas, and includes steep land.

1.2.12 Land Holders

Landholders listed in **Table 1-9** currently manage land on which the Mine is to take place.

Table 1-9 Land tenure and real property descriptions for the Mine

Lot/Plan	Land holder	Tenure
Saraji Road	Isaac Regional Council	Road Parcel
Lot 26 on CNS125	Aurizon	Lands Lease
Lot 10 on SP325345	BHP Billiton/Mitsubishi Alliance (BMA)	Lands Lease

1.3 Relevant Activities

1.3.1 Environmentally Relevant Activities

Environmental Authority EA0002912 has been granted for the Mine. The Environmentally Relevant Activities (ERAs) for which this EA has been issued are Mining Black Coal and Ancillary Activities (**Table 1-10**).

Table 1-10 Environmentally Relevant Activities

Activity	Environmentally Relevant Activity	Mine Requirement
Mining Black Coal	Resource Activity, Schedule 3, ERA 13	The Mine will extract up to 6 Mt of coal through an open cut operation.
Crushing, milling, grinding or screening	Ancillary Activity 33: Crushing, grinding, milling or screening more than 5,000 t of material in a year.	The Mine will crush and screen up to 1.95 Mtpa of ROM coal.
Mineral Processing	Resource Activity, Schedule 2, ERA 31 (2) processing, in a year, the following quantities of mineral products , other than coke (b) more than 100,000t	The Mine will process up to 1.95 Mtpa of ROM coal.

1.3.2 Project Description

The VCM is a small-scale coal mine that will extract approximately 6 Mt of run-of-mine (ROM) hard coking coal at a rate of up to 1.95 Mtpa. Coal extraction occurs via the Jupiter and Matilda open-cut pits. Truck-and-shovel mining operations are employed to develop the pit.

The VCM will operate for approximately four years. It has developed from the bulk sample project, which commenced in 2020 and ran for approximately 12 months while the Mine was undergoing environmental authority and mining lease application processes. The Mine will comprise a further four years of mining and a number of years of rehabilitation.

Coal Handling and Preparation Plant

For processing, the VCM will include a modular CHPP (**Figure 1-18**) to process ROM coal into a number of marketable products (coking coal and thermal coal). In summary the CHPP will operate as follows:

- haul trucks will deliver ROM coal from the pit to the ROM hopper. The trucks will dump directly into the ROM hopper or onto the 100 kt ROM stockpile for reclaim by a front end loader.

- the raw coal will be sized before being conveyed to a 300 t raw coal surge bin before being fed to the CHPP at up to 550 t/h.
- the CHPP will be an open steel structure. Coal will be processed through three circuits to produce a primary and secondary product (metallurgical and thermal).
- tailings will be dewatered in a tailings treatment facility to produce a dry tailings product. Recovered water will be recirculated to the process plant fur reuse.
- Coarse, fine and dry tailings will be conveyed to a reject bin, where it will be loaded into trucks for placement within active waste rock dumps (primarily deep within the in-pit dump).
- products will be conveyed and stacked on the product coal stockpiles. Product coal will be reclaimed via dozer push into coal valves and conveyed to the TLO.

The CHPP will operate 24 hours a day, seven days per week and is anticipated to function for the final 2 years of the current approved VCM.

The following chemicals and hydrocarbons will be required for processes in the CHPP, and will be stored on site:

- 215kL of diesel;
- Anionic flocculant (dry powder) 50m^3;
- Cationic flocculant (liquid) 50m^3; and
- Acrylate polymer 10m^3.

Rail Loop

A rail loop will connect to the existing network in the south-east of the ML and will traverse the south-western boundary of the ML. The loop is positioned in the western portion of the ML, between the ML boundary and the existing BMA flood levee that runs north-south through the ML (**Figure 1-18**). The loop will require approximately 4.5 km of rail to be located on the ML. A number of areas of cut and fill will be required along the alignment to facilitate required grades.

Controlled level crossings are proposed where the rail line will cross Saraji Road and connect to the existing Goonyella rail network. Product coal will be railed from the Project rail loop onto the Goonyella Rail network. Export options include Dalrymple Bay to the north and the RG Tanna terminal, in Gladstone, to the south.

Detailed construction plans will be developed prior to the rail loop being developed. Cut and fill requirements for the rail loop are displayed in the figure below. Conceptual plans have determined that cut on the western side of the loop requires 288 kbcm (thousand bank cubic metres) to be removed and the fill on the eastern side of the loop will require 246 klcm (thousand loose cubic metres) to be filled (see **Figure 1-17** below).



Figure 1-17 Matilda pit rail loop cut and fill design

The final landform (post closure) of the rail loop is displayed in cross sections which have been prepared in the Final Landform Drainage Summary Memorandum (WRM 2022b). Cross section XS-5 is taken north-south from the rehabilitated rail loop area through the western backfilled Matilda Pit/in-pit waste rock dump and out to the undisturbed slope to the south. XS-6 is a west east cross section taken from the rehabilitated rail loop area out through the Backfilled Matilda Pit/in-pit waste rock dump. These cross sections are also presented in this PRC Plan (**Figure 6-4** to **Figure 6-7**). Note that the cross sections are conceptual drawings which are not to scale. The cross sections are intended to showcase the key features of the final landforms and design principles which will be used in its detailed design. Specific design elements of the final landform (including final grades, material selection, and final geometries etc.) will be prepared as part of detailed design phase to support relevant rehabilitation reports.

The rail loop is categorised within Rehabilitation Area 3, which has a PMLU of Low-intensity cattle grazing with habitat for threatened fauna. Rehabilitation Milestone 3 (landform development and reshaping/reprofiling) and Rehabilitation Milestone 4 (Surface preparation) criteria will all be achieved by having a final landform which has a similar slope to that of the pre-existing landform. The slopes of the western side of the rail loop will be shaped to a maximum of 15% and will contain surface water management measures to drain water from the landform to the surface water drainage features within the surrounding landscape. The eastern side of the rail loop is expected to have a flatter slope which also incorporates surface water management features (WRM 2022b). Final landform geometry will be surveyed progressively to maintain adherence to the final landform and surface water management design. Sub-soil, rock mulch and topsoil will be spread with bulldozers and will be the subject of depth and distribution survey and quality control monitoring.

Train Loadout

A TLO will be positioned on the eastern side of the loop, on the western side of the existing levee (**Figure 1-18)**. Product coal will be transported by aerial conveyor, across the levee from the product stockpile to the TLO. Appropriate design controls will be incorporated to manage potential impacts on surface water systems from fugitive coal from the overpassing conveyor.

The TLO will link the product stockpiles with the proposed rail loop to load at a rate of 3,500 tph. The train load out facility will be managed via a fully automated system, including overload protection and load veneering. The facility will be positioned over the rail line and will incorporate a suitable under rail spillage pit.

Open Pits

The Jupiter pit is the larger of the two mining pits at the VCM and runs alongside the Saraji Road realignment on the eastern side of the site (**Figure 1-18**). The Jupiter pit will have a maximum depth of 40 m and will target the DLL coal seam which contains moderate to high-ash, good-quality coal.

The Matilda pit will be a small, shallow (maximum depth 40m) open pit within the rail loop alignment (**Figure 1-18**). It will target the Matilda coal seam which underlies the Alex and multiple Dysart Lower coal seams mined in the pit to the east. For the purposes of approval and environmental assessment, it is assumed that the full extent of the rail loop interior is disturbed for mining purposes.

The Matilda pit will be mined concurrently with the Jupiter pit to the east. There is no requirement to increase the production rate or significantly alter project timeframes. This is because further planning work has been completed on the Jupiter pit and the amount of coal to be extracted has reduced from what was originally proposed and approved.

Waste Rock Dumps

A small ex-pit Waste Rock Dump (WRD) has been established prior to commencing in-pit dumping activities which will continue for the life of the operation. The ex-pit WRD has been designed and completed to a maximum height of RL280. This is consistent with the existing topography within the pit bounds that peaks at RL266. The WRD height ranges from 15 to 30m above ground level. Ex-pit WRD rehabilitation activities will include re-contouring of the WRD to a maximum rehabilitation slope of 15 %. The dump has been designed and constructed such that the cut and fill balance allows for an existing levee within the Mine footprint to be maintained undisturbed, to avoid impeding the current water flow throughout this area. A standoff of 10 m from the existing levee has also been utilised to ensure separation and elimination of disturbance of this water course. This remains outside the modelled Q1000 flood extent. The ex-pit WRD will be rehabilitated in-situ.

The Jupiter and Matilda open cut pits will be backfilled with stockpiled waste rock and coal reject material, to create a stable final landform over the former open cut footprints. The final landforms will utilise the waste material to backfill the void via dozer push. This will be re-contoured at a maximum slope of 15 % with fall to existing water courses (for more detail, refer to **Section 6.1**). The location of the in-pit WRD's are consistent with the pre-mining topography such that the dump crest will be in a similar position and at a similar height to the small hill that currently exists in the centre of the proposed pit area.

An assessment of waste rock geochemistry has concluded that the waste rock from the Jupiter pit does not propose a significant risk of generating acidic, saline or metalliferous drainage, and no selective handling and treatment measures are considered required or proposed (RGS 2020). However, subsequent geochemical analysis of the Matilda pit waste rock indicated that it has a low risk of generating AMD, with some deeper Permian waste rock materials being classified as Potentially Acid Forming (PAF) (RGS 2022). In addition, coal reject materials generated from washing the target Matilda seam were classified as PAF.

Saraji Road Realignment

A realignment of the existing Saraji Road and services infrastructure to the eastern boundary of the Mining Lease area, adjacent to the existing rail easement has been completed. The re-alignment occurred on lease; however, the connection back to the existing alignment of Saraji Road to the north will extend off lease and is approved through an alternative process under the Land Act, 1994 (**Figure 1-18**).

Workforce

The construction of the CHPP and rail loop will require a workforce of approximately 130 people for a period of 18 months. The peak operational workforce is anticipated to comprise 80 positions. It is assumed that approximately half the workforce commutes daily from Moranbah, while the other half commutes from Dysart. There are two 12-hour shifts per day, with crews operating on a 7-days-on, 7-days-off roster.

Diversion Channel

Vitrinite proposes to raise a section of the existing BMA diversion levee and undertake earthworks and channel widening along the existing drainage diversion at the northern end of the ML boundary. The proposed works would be undertaken to mitigate flood impacts of the proposed crossing of the existing drainage diversion which connects the rail loop to the haul road on the eastern side of the levee. The levee and channel upgrades were iteratively designed to mitigate the impacts of the crossing and include:

- Raising the northern section of the levee (by up to 1 m);
- Widening the existing drainage diversion channel to a base width of 30 m with a batter slope of 1V:6H on the left bank and 1V:20H on the right bank. The widened channel extends from the ML boundary to the end of the spillway (up to 550 m in length); and
- Extending the existing levee spillway width (spillway height of 253.7 mAHD) from 40 m to 200 m.

Flood Protection Levee

A flood levee is proposed along the western edge of the approved Jupiter pit mining operations to protect the pit from potential floodwater that overflows from the existing drainage diversion. Part of the proposed flood levee may be formed by a haul road that will be located around the western side of the Jupiter pit. The location of the proposed flood levee is shown in **Figure 1-18**.

The Jupiter pit flood protection levee is proposed to cross the existing drainage diversion and associated levee to the west of the pit. Under existing conditions, the existing drainage diversion and levee is overtopped during large flood events. Minor modifications to the existing drainage diversion and associated levee will be undertaken to maintain the existing flow characteristics in the vicinity of the haul road crossings.

Flood levees are also proposed along the western and eastern edges of the proposed Matilda Pit to protect the proposed pit from potential floodwater ingress via the western upstream clean water catchment and overflows from the existing drainage diversion from the east. The proposed Matilda Pit western flood levee may be formed by the drainage diversion used to divert the western clean water catchment around the proposed pit. The location of the proposed Matilda Pit flood levees is shown in **Figure 1-18**.

The Jupiter and Matilda flood protection levees will be regulated structures under the EP Act and will therefore be required to have a crest above the 0.1% annual exceedance probability (AEP) event.

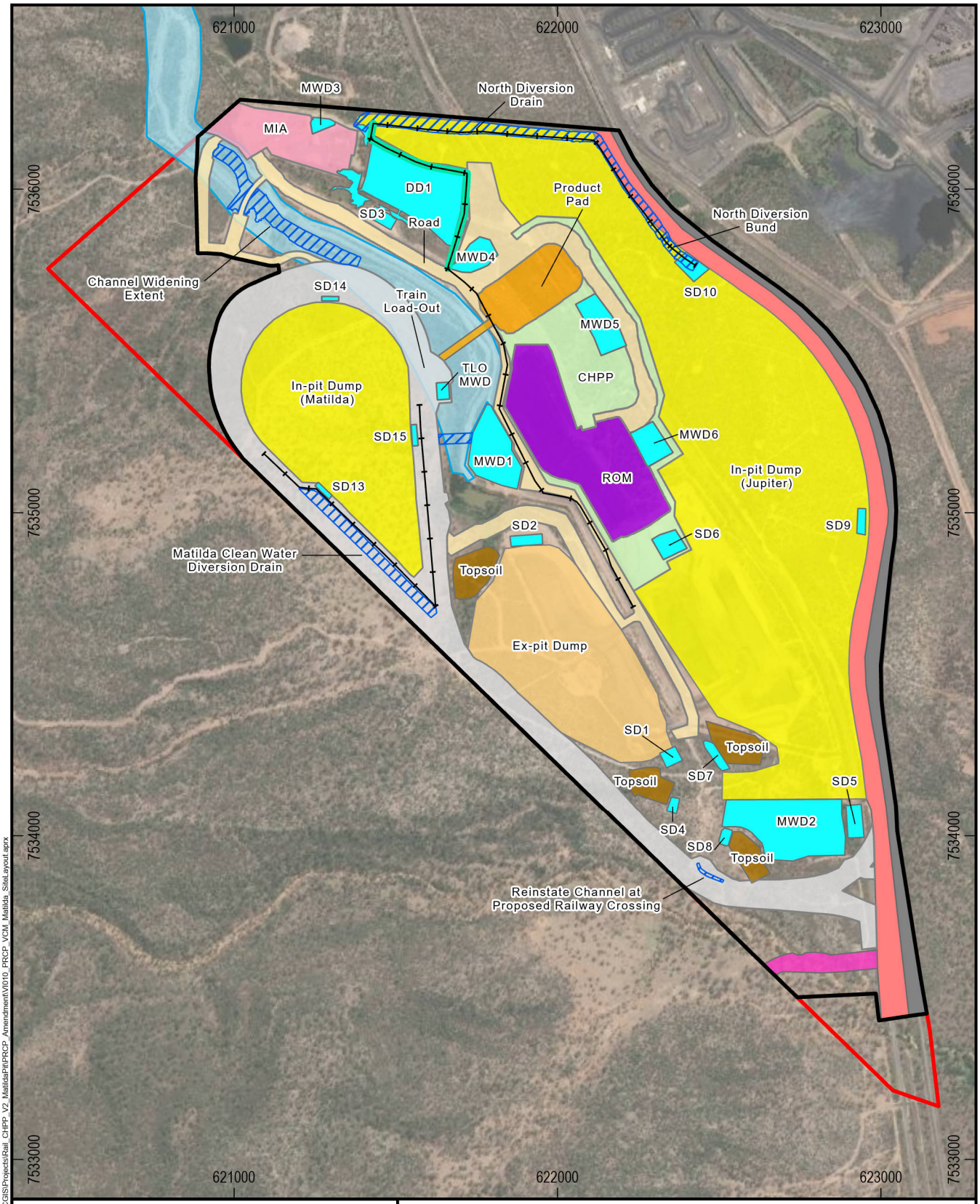
Water Demand, Supply and Management

The addition of the CHPP will increase the site water demand. Vitrinite has secured supply from the Bingegang pipeline which will supply supplementary water demands as required. Vitrinite also has approval to receive mine affected water from neighbouring mine sites.

A key objective of the mine site water management system is to reuse surface water from coal processing and runoff captured within the mine affected water system. Recycling mine water will reduce the required volume of water from external sources.

Explosives Magazine

The existing approved explosives magazine may be developed as a temporary measure; however this area will be required to facilitate construction and operation of the rail loop and Matilda pit. Explosives will continue to be delivered to site on an as-needs basis in the interim period.



Legend

- ML700060 Boundary
- VCM Revised Maximum Disturbance Footprint
- Dam Wall
- Proposed Flood Levee
- Water Pipeline Corridor

Infrastructure

- CHPP
- Ex-pit Dump
- In-pit Dump
- MIA
- Dam
- Existing Rail
- ROM
- Rail Loop
- Road
- Saraji Road
- Stockpile (Topsoil)
- Train Load-Out Product Pad
- Magazine Road
- Water Management Infrastructure

Source: State of Queensland (Department of Resources) 2022, Vitrinite 2021-2022, METServe 2022, Maxar.

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\PRCP_Amendment\VI010_PRCP_VCM_Matilda_SiteLayout.aprx

Vulcan Coal Mine

Site Layout

0 200 400 600

Meters

Scale: 1:17,000 (A4)

5/01/2023

Datum: GDA2020
Projection: MGA55

FIGURE 1-18

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

1.3.3 Water Management

Surface water management infrastructure is established progressively to divert clean water around operational areas and to manage runoff from disturbed areas (**Appendix A**). A series of drains and bunds are established to direct runoff to sediment control structures. Mine water dams are constructed as a water supply for dust suppression. This also receives any accumulated pit water that requires dewatering. Groundwater modelling indicates that the amount of pit dewatering required is expected to be negligible (hydrogeologist.com.au 2022). This is due to the small size and low connectivity of any aquifers intercepted by the open-cut pit. The water management infrastructure in place in and around the final landform once land becomes available for rehabilitation is discussed further in **Section 6.1.7**. This water management infrastructure (refer **Section 5** of **Appendix A**) includes the following:

- diverted water drains to divert runoff from undisturbed catchments around areas disturbed by mining;
- a flood protection levee along the western side of the proposed Jupiter pit that may be formed by a haul road embankment;
- a flood protection levee along the eastern side of the proposed Matilda pit;
- a diversion drain and flood protection levee along the western side of the proposed Matilda pit;
- sediment dams and drains to collect and treat runoff from waste rock emplacement areas;
- mine-affected water drains and dams to store water pumped out of the open cut mining areas and to collect runoff from the infrastructure areas;
- culverts to convey flows through the proposed rail loop and haul road crossings of the existing drainage diversion; and
- minor works to the existing BMA levee (and spillway) and existing drainage diversion in the vicinity of the haul road crossings.

With appropriate storage and disposal of waste rock and coal reject materials on site, it is expected that the risk of potential contamination impacting surface water and groundwater environmental values is low. The chief contaminant that requires management is sediment/turbidity, which is managed via the installation of sediment ponds, fed by drainage lines that gather mine-affected water. Salts are also potentially more elevated in runoff from active mining areas than from natural landscapes (WRM 2022a).

The water management strategy at the Mine is based on the following objectives:

- To maintain separation between up-catchment water and mine-affected water;
- To capture mine-affected runoff (e.g. CHPP, mine industrial area, haul road/ROM pad runoff), and store and reuse this as mine water supply;
- To divert water runoff from upstream catchments around the active mining area;
- To limit external catchment runoff draining into pits;
- To manage sediment from disturbed catchment areas (e.g. ex-pit WRD, cleared/pre-strip areas) by using erosion and sediment control measures prior to release offsite; and
- To manage any mine-affected water releases to the receiving environment in accordance with environmental release conditions.

There are four pathways through which water from the Mine can enter the receiving environment:

- dewatering overflows from sediment dams;
- overflows from mine-affected water dams and the open cut pit;
- runoff from diverted water catchments; and
- runoff from rehabilitated catchments.

A computer-based operational simulation water balance model has been developed for the Mine (**Appendix A**). Due to the changing infrastructure over the Mine's short lifespan, separate models were developed to represent two separate Mine scenarios or stages. These models were used to assess the performance of the water management system. The

models revealed that the combined volumes of the mine-affected water dams are not expected to exceed their full storage volume under the natural range of environmental conditions at the Mine. Some redistribution of water to MWD1 from the other MWDs will be required. Some controlled discharges may be required in wet years (the wettest 5th percentile) in order to empty runoff draining into the open cut pit. Consistent with the IECA guidelines (2008), sediment dams do not provide 100% containment for captured runoff. Hence overflows will occur from sediment dams when rainfall exceeds the design standard. Under median weather conditions, up to 29 ML/yr are expected to be released from sediment dams, whereas in wet years (the wettest 10th percentile), up to 198 ML/yr may be released (WRM 2022a). The release of water within sediment dams is expected to slightly elevate the salt content of Boomerang Creek (downstream) with moderate releases (0.54 ML/d), but have no effect on downstream water with large releases (39 ML/d), due to the greater dilution factor associated with heavier rain events (WRM 2022a). Salinity levels in spilled water are forecast to remain below the low-flow water quality objective for the Isaac River sub-basin as specified in the Environmental Protection (Water and Wetland Biodiversity) Policy 2019.

Overall, the risk and expected harm of releasing mine-affected water to the general environment is low. The downstream receiving waters are heavily modified and have been diverted through the Peak Downs operations. Controlled releases of mine water are not proposed. Furthermore, groundwater assessments predict a negligible need for groundwater management, with dump runoff quality expected to be suitable for release to the receiving waters (following sediment removal). Any potential releases of contaminants to the receiving waters from mine water dams are unlikely to have an adverse effect.

When a sediment dam catchment is successfully rehabilitated, and water quality monitoring of the runoff has established that it is within acceptable limits, the sediment dam and associated drainage infrastructure will be decommissioned. Surface runoff and seepage from the rehabilitated catchment will be allowed to shed directly to the receiving environment. When the drainage corridor is rehabilitated, DD1 will be decommissioned. DD1 will remain until this time to allow in-stream vegetation to establish before receiving upstream catchment flows.

2 LEGISLATIVE REQUIREMENTS AND GUIDELINES

2.1 *Mineral Resources Act 1989*

Resource activities are regulated through a 'resource authority' under the *Mineral Resources Act 1989.* This provides resource companies with the right to enter land and undertake the approved activity. Under section 107(10) of this act, a mining claim can only be surrendered once improvement restoration (i.e., returning the tenement to substantially the same condition it was in before mining) has been carried out and the relevant environmental authority has been surrendered.

2.2 *Environmental Protection Act 1994*

The *Environmental Protection Act 1994* (EP Act) is the principal legislation for protecting environmental values potentially affected by the resource industry in Queensland. The EP Act grants the Queensland Government the power and means to assess, approve and prescribe conditions on proposed mining projects.

The EP Act requires that all areas of disturbed or undisturbed land within the relevant mining tenure be rehabilitated to a post-mining land use (PMLU), or managed as a non-use management area (NUMA). Section 125(1)(n) of the EP Act requires a proposed PRC plan to accompany site-specific EA applications for a mining activity. Sections 126C and 126D stipulate the requirements for PRC plans and PRC Plan schedules, respectively.

Under the EP Act, the Queensland Government is responsible for the issuing of an environmental authority (EA) to carry out a mining activity and approval of a PRC Plan schedule for a PRC plan. Under section 172(4) of the act, if the PRC Plan schedule is refused, the EA application must also be refused. Under sections 426(1) and 431A of the act, an applicant is unable to undertake any relevant activities until an EA with a PRC Plan schedule is approved. The EA and PRC Plan schedule includes all conditions imposed on the authority and schedule. The EP Act also prescribes the requirements for surrendering an EA, including the preparation of final rehabilitation reports and post-mining management reports.

2.3 *Mineral and Energy Resources (Financial Provisioning) Act 2018*

In Queensland, the *Mineral and Energy Resources (Financial Provisioning) Act 2018* regulates a financial provisioning scheme for reducing potential risks to the Government in the event an EA holder fails to meet their environmental and rehabilitation obligations. This act also amended the EP Act to require mining companies to develop PRC plans.

2.4 Progressive Rehabilitation and Closure Plans Guideline

This guideline, prepared by the Queensland Government Department of Environment and Science, contains information to assist applicants in developing a PRC plan as part of a site-specific EA application for a new mining activity. The administering authority must consider this guideline when making a decision about a PRC Plan schedule under section 176A of the EP Act.

2.5 Rehabilitation Requirements for Mining Resource Activities

This guideline has been prepared by the Queensland Government Department of Environment and Science to assist mining companies to propose acceptable rehabilitation outcomes and strategies. The administering authority must consider this guideline when making a decision about a PRC Plan schedule under section 176A of the EP Act.

2.6 *Environment Protection and Biodiversity Conservation Act 1999*

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is the Australian Government's key piece of legislation protecting matters of national environmental significance. Actions that will or are likely to impact matters of national environmental significance require approval from the Environment Minister under the EPBC Act. Any conditions attached to this approval that pertain to rehabilitation of the site after mining must be adhered to under the EPBC Act.

3 STAKEHOLDER ENGAGEMENT

3.1 Stakeholder Consultation Plan

A Stakeholder Engagement Plan that complies with section 126C(1)(c)(iv) of the EP Act was prepared to guide stakeholder engagement activities associated with project planning, the environmental approvals process and the development of the PRC Plan (**Appendix E**). This Stakeholder Engagement Plan has been submitted to DES as part of the site-specific EA application supporting information.

Given that the PMLUs seek to re-establish for the most part, the current site land uses, the key stakeholders for rehabilitation of the site were deemed to be:

- BHP Billiton/Mitsubishi Alliance (BMA), landholder of Lot 10 on SP325345 and manager of the Saraji and Peak Downs Mines;
- Aurizon, manager of the Norwich Park branch railway; and
- Isaac Regional Council, manager of Saraji Road.

For the purposes of the PRC Plan, BMA was considered to be the primary stakeholder as the underlying landholder and downstream neighbour of the Mine. Other stakeholders, including the Department of Environment and Science and the Department of Resources have also been consulted.

In accordance with section 126C(1)(c)(iv) of the EP Act, the Stakeholder Engagement Plan also discusses ongoing stakeholder engagement during progressive rehabilitation and closure.

Given the small scale and short duration of the Mine (all rehabilitation works to be completed within 5 years), and the proposal to return the land to its pre-mine land use, it is considered unlikely that stakeholder perspectives on PMLUs will change significantly during the course of progressive rehabilitation, particularly if the rehabilitation activities are implemented successfully as anticipated.

Vitrinite will provide relevant stakeholders with copies of the annual rehabilitation progress return. Distribution of the annual rehabilitation progress return will be utilised as the mechanism for communication of any proposed changes to the PRC Plan, and to obtain feedback from stakeholders for consideration in ongoing planning and activities. Should significant amendment of the PRC Plan be proposed, stakeholders will be engaged as part of the amendment process.

Further detail regarding the PRC Plan annual reporting mechanism is outlined in **Section 9.1.11.**

3.2 Stakeholder Consultation Register

A stakeholder consultation register that complies with section 126C(1)(c)(iii) of the EP Act is appended to the Project Stakeholder Engagement Plan (SEP) (**Appendix E**).

The stakeholder consultation register is a record of all consultation activities citing: attendees, topics of discussion, outcomes and ongoing commitments for each consultation meeting. The stakeholder consultation register listed details of over 35 consultation meetings that took place over the course of the initial engagement on the Project PMLU's. The previously agreed PMLU's are not proposed to be changed in this update to the PRC Plan.

A second more detailed consultation register was also compiled (appended to the SEP), providing a specific detailed record of all consultation with BMA. BMA is considered one of the primary stakeholders for the purposes of the PRC Plan, as the underlying landholder and downstream neighbour of the Mine.

During the consultation process outlined above, topics of discussion with stakeholders have included the proposed PRC Plan approach, the plan for the mine, PMLUs, areas of disturbance, rehabilitation and management methods, progressive rehabilitation and closure timeframes.

4 POST-MINING LAND USE

The ML hosted five land uses prior to the Mine:

- low-intensity cattle grazing (also provides some habitat for threatened fauna);
- public road;
- railway used for coal transport;
- supporting infrastructure (offices, parking, warehouses) for neighbouring mining operations; and
- flood levee constructed to protect neighbouring coal mines.

BMA has expressed a desire to retain some of the Mine's infrastructure to support their nearby operations.

Most of the ML will have a PMLU of low-intensity cattle grazing. Where supported by available soils, locally native plant species are to be incorporated into the planting mixes where grazing is the PMLU, to create pastoral land that partly restores habitat values for threatened fauna (namely, the Squatter Pigeon and Koala) impacted by the Mine. In accordance with Part 3 of the *Environmental Protection (Rehabilitation Reform) Amendment Regulation 2019*, a PMLU of low-intensity cattle grazing:

- is viable, having regard to the use of land in the surrounding region;
- is consistent with how the land was used before a mining activity was carried out on the land;
- is consistent with a use of the land permitted under the Planning Act; and
- will deliver, or aim to deliver, a beneficial environmental outcome.

The locations of these PMLUs are described within the PRC Plan schedule (**Section 10.1**). Through in-pit dumping of waste rock, no voids will remain on site after mining. No non-use management areas (NUMAs) are proposed.

Based on previous studies, grazing is an achievable PMLU in the Bowen Basin (Bisrat *et al.* 2004). To achieve the PMLU, rehabilitated land should have a land suitability class of at least 4 (marginal land for grazing), which was the land suitability class on site prior to mining (see **Section 1.2.11**).

The Goonyella Aurizon rail line and flood levee PMLUs are existing pre-mine land uses that will not be affected by the Mine and will therefore not be subject to any rehabilitation activities.

As Saraji Road has already been constructed and commissioned, the PMLU of the new road infrastructure is effectively established. Therefore, significant rehabilitation activities to achieve the PMLU are not anticipated. Agreements for the ongoing management and maintenance of the road are in place.

Other PMLUs considered in place of "low-intensity cattle grazing" included "native vegetation communities" (regional ecosystems 11.5.9 and 11.10.3), "forestry" (hardwood *Eucalyptus* plantations) and "agriculture" (dryland cropping), but the limited topsoil materials and high cost of creating a productive growing medium with the materials available limit the feasibility of the latter two options (see **Section 4.3** for an assessment of each option).

4.1 Accordance with Stakeholders' Requests

Through the consultation process undertaken for the development of this PRC Plan, all relevant stakeholders expressed support for the PMLUs.

4.2 Regulatory Constraints

There are relatively few regulatory constraints on the post mining land use on the ML. These are discussed below.

4.2.1 Isaac Regional Planning Scheme

Under the *Isaac Regional Planning Scheme*, the Mine is located in a "Rural" zone. The *Isaac Regional Planning Scheme* defines uses suitable for "Rural" zones as cropping, intensive horticulture, aquaculture, grazing, intensive animal industries, renewable energy facilities and extractive industries. These defined uses are consistent with the PMLUs for the Mine.

4.2.2 Mackay, Isaac and Whitsunday Regional Plan

The Queensland Government, via its *Mackay, Isaac and Whitsunday Regional Plan*, maps the Mine in a "regional landscape and rural production area", which includes land used for agriculture, water catchment, traditional uses, conservation areas and native forests. The PMLUs are consistent with these planned land uses.

The area to the west of the ML is mostly mapped as being of "high ecological significance", while the ML itself mostly lacks ecological significance under the *Mackay, Isaac and Whitsunday Regional Plan*. This plan aims to minimise the impact of development on such areas of high ecological significance, and a PMLU that is compatible with restoring many of the original environmental values is consistent with this regional plan.

4.3 Assessment of Options

A PMLU of "road reserve" is the only reasonable option for the Saraji Road corridor, as it will endure throughout and beyond the Mine life. Likewise, the two pre-existing land-uses that will be undisturbed by the Mine (railway line and flood levee) will remain as PMLUs. A PMLU of "mine-support infrastructure" will be adopted for the area containing infrastructure to be retained by BMA following the completion of the Mine.

However, four potential PMLUs were assessed as part of planning for the remainder of the Mine disturbance area. These included:

1) Low-intensity cattle grazing with habitat for threatened fauna;
2) Native vegetation communities (regional ecosystems 11.5.9 and 11.10.3);
3) Hardwood (e.g., *Corymbia citriodora*) plantation forestry; and
4) Dryland cropping.

These PMLUs were selected because they are land uses consistent with the *Isaac Regional Planning Scheme* and the *Mackay, Isaac and Whitsunday Regional Plan*.

In order to compare the relative merit of each PMLU option, a scoring system was applied across ten cost/benefit criteria, in accordance with the *Progressive Rehabilitation and Closure Plans Guideline* (**Table 4-1**). This awarded a score of 1-5 for each consideration (cost/benefit), with the sum of all scores across considerations used to compare PMLU options. Even though different rehabilitation areas have slightly different rehabilitation methods and milestones, they are assessed together due to their similar constraints.

This assessment revealed that low-intensity cattle grazing was the most appropriate PMLU for the Mine (**Table 4-1**). There are other reasons, not considered in **Table 4-1**, why forestry and cropping are higher risk options for the Mine. In Queensland, plantation forestry is largely limited to coastal regions, and the performance of plantations is untested within the Isaac Regional Council area. Cropping is also considered to be higher risk, given the dispersive subsoils across most of the Mine area (see **Section 1.2.7**). Regular cultivation of the topsoil is likely to expose these subsoils to erosion, with irreversible outcomes.

According to the *Rehabilitation Requirements for Mining Resource Activities v2.01*, optimal PMLUs are those highest up in the following hierarchy:

1) avoid disturbance that will require rehabilitation;
2) reinstate a "natural" ecosystem as similar as possible to the original ecosystem;
3) develop an alternative outcome with a higher economic value than the previous land use;
4) reinstate previous land use (e.g. grazing or cropping);
5) develop lower value land use; or
6) leave the site in an unusable condition or with a potential to generate future pollution or adversely affect environmental values.

The favoured PMLU, low-intensity cattle grazing, falls 4th on this hierarchy. The 2nd and 3rd PMLUs in the hierarchy were assessed as options in **Table 4-1**, but were ranked as slightly less desirable due to a combination of the site's physical and chemical constraints and/or economic benefits.

Table 4-1 Assessment of PMLU options for the Mine

Considerations	PMLU Options*				Justification
	Low-intensity grazing	Native ecosystems	Forestry	Cropping	
Physical constraints	4	4	3	2	Shallow soil, sloping land and a hot/dry climate with limited access to irrigation mean that no land use achieves a score of "5". However, these are relatively minor constraints on re-establishing grazing or native ecosystems. Forestry is largely untested in such a dry climate, so this is awarded a neutral score of "3". Cropping is strongly limited (though not impossible) by the lack of access to irrigation and the thin, sandy soil and is awarded a score of "2".
Chemical constraints	4	4	2	1	Topsoil has poor nutrient-holding capacity, while subsoils are generally dispersive. These attributes largely preclude cropping as an option. They also pose substantial constraints on the performance of forestry, given that stressed trees are less likely to produce a desirable form for milling. While chemical constraints also affect the re-establishment of grazing and native ecosystems, this limitation is relatively minor.
Available materials	4	4	2	1	No land use has a score of "5" due to limited amounts of fresh topsoil that can be directly deposited onto disturbed areas (most soil requires some period of stockpiling, which reduces its quality as a growing medium). Nevertheless, this is expected to be a minor limitation for re-establishing grazing or native ecosystems as land uses. As forestry is an undeveloped industry in this climatic zone, strains of timber trees that perform well in local conditions would need to be investigated and mass-produced, something that is not likely to be achievable in the short timeframe of the Mine. For cropping to be viable, existing soil would need to be overlaid with large quantities of suitable topsoil, to provide a favourable growing medium for crops and protect underlying soils from dispersion/erosion. Such material is unavailable.
Relative cost	4	3	2	1	The scores awarded reflect the costs of obtaining the materials required to instate each land use, and therefore generally reflect the scores awarded for material availability. The reason that grazing is slightly cheaper to instate than native ecosystems is due to the relatively simpler plant communities to be established on pastoral land. Restoring native ecosystems would require a more complex seed mix, which is more costly to collect/obtain.
Economic benefits for the community or landholder	4	1	3	5	Scores were based on the potential gross annual income generated from each land use once each has been instated. It is independent of the relative costs described above.
Environmental benefits	3	5	2	1	Scores were based on the biodiversity of native flora that are likely to coexist with the land use, ranging from 5 = full diversity in native ecosystems, to 1 = no native species in crops. Forestry could vary from 2 to 4, depending on the dominance of weeds vs native species in the understorey. It is assumed that, as few native species are expected to regrow in stockpiled soils without active addition of seed, forestry would most likely create a monoculture of timber trees with few native species below. As a diversity of native grasses and trees will be planted in land used for grazing, biodiversity in this land use will be moderate (3).
Social value (recreation, public amenity, employment)	2	2	3	4	High scores were awarded for land uses dependent on a regular supply chain of materials, machinery or labour (maximising employment, for example cropping and, to a lesser extent, forestry). Moderate scores were also awarded for land uses that provide scenic amenity (forestry, native ecosystems), and/or those compatible with recreational activities such as bushwalking or hunting. Scores tended to be relatively similar across potential land uses, as the land uses providing maximum employment opportunities tended to have fewer recreational or public amenity benefits.
Compatibility with surrounding land uses	5	5	3	3	Grazing, native ecosystems and mining are the predominant surrounding land uses. Therefore, grazing and native ecosystems are fully compatible, while forestry and cropping are neutral. The latter two options will require application of water, fertiliser and/or pesticides, which may impact neighbouring land uses. However, this incompatibility is minor.
The land use before mining commenced	5	5	1	1	Land-uses in place on site prior to mining are awarded "5" and those not in place are awarded "1".
Compatibility with	5	5	5	5	All options are fully compatible with the *Isaac Regional Council Planning*

Considerations	PMLU Options*				Justification
	Low-intensity grazing	Native ecosystems	Forestry	Cropping	
planning instruments under the *Planning Act 2016*					*Scheme* and the *Mackay, Isaac and Whitsunday Regional Plan*.
Total Score	**40**	**38**	**26**	**24**	

*For each consideration, each PMLU option is awarded a relative score (1-5), where 5 is feasible/desirable and 1 is prohibitive/undesirable. The sum of the scores across all considerations was used to compare the favourability of each option.

4.4 Statutory Constraints to be Imposed

Due to the lack of NUMAs and low volumes of reactive waste rock material, and the fact that the final landform will generally resemble the surrounding landscape, few statutory constraints are expected to be imposed on future land managers of the Mine area. Given that vegetation cover will be important to the minimisation of erosion on sloping landforms, limits on stocking rates are considered appropriate. Any restrictions on the future stocking rates are to be described in the Post-mining Management Report (see **Section 9.6**) and imposed through a Site Management Plan, to be adopted by future land managers of the site. This is to be confirmed following pasture development and performance monitoring.

5 REHABILITATION GOALS

Under section 176A(3)(c)(i) of the *Environmental Protection Act 1994*, mined land must be rehabilitated to a stable condition. Land is in a stable condition, as defined in section 111A of the *Environmental Protection Act 1994*, if: (a) the land is safe and structurally stable, (b) there is no environmental harm being caused by anything on or in the land; and (c) the land can sustain a post-mining land use. These three components of stability are the general rehabilitation goals for all areas disturbed by mining in Queensland. They have been developed from the ecologically sustainable development policy framework, especially in relation to intergenerational equity, polluter pays principle, protection of biodiversity, and maintenance of essential ecological processes.

5.1 Rehabilitation Objectives, Indicators and Completion Criteria

A clearly defined set of rehabilitation objectives has been developed for each PMLU for the Mine. For each objective, one or more rehabilitation indicators (measurements of progress towards the rehabilitation objectives) are proposed. These indicators are designed to be auditable against completion criteria, which act as targets for the rehabilitation process. Each completion criterion is applied to the PRCP Schedule as a milestone criterion for the later stages of rehabilitation (**Section 10.3.1**). The full list of rehabilitation objectives, indicators and completion criteria is shown in **Table 5-1**. For details about how each indicator is to be measured, refer to **Section 9**.

Table 5-1 Rehabilitation objectives, indicators and completion criteria

ID	Rehabilitation Objective	Rehabilitation Indicator	Assessment Timing	Completion Criteria	Justification
PMLU A: Low-intensity cattle grazing					
A1	Land is to be stable	a) Indices of Landscape Function Analysis (Tongway and Hindley 2004). b) Depth of active rills and gullies	Sites are to be monitored at the time of planting and then every two years for 10 years after planting.	a) Landscape function analysis scores for soil stability, infiltration/runoff and nutrient cycling have started to plateau, and the plateau values predicted from sigmoidal curves fitted to the data are equivalent to or exceed values at analogue sites. b) No active rill or gully erosion deeper than 25 cm present.	a) This methodology has been widely applied to rehabilitated mine sites across Australia, and is strongly correlated with soil aggregate stability, soil nutrient cycling and water infiltration (Tongway and Hindley 2004). b) Provides a supplementary observational method of early erosion detection and early intervention.
		Percentage cover of rock, woody debris, litter, grasses and herbs within a 10 m × 50 m plot.	Late wet season (February-May), every two years for 10 years after planting.	Grazed land maintains a percentage groundcover of between 50% and 96% on slopes up to 10% and between 70% and 96% on slopes between 10-15%.	A percentage cover of ≥50% protects slopes from erosion (Loch 2000; Waters 2004; Carroll *et al.* 2010). Cover ≥70% is required to achieve background rates of erosion on slopes steeper than 10% (AARC 2021). Excessive groundcover inhibits the recruitment of trees and shrubs, and a maximum value of 96% cover was observed within reference sites in stable, unmined vegetation communities (METServe 2020).
A2	Land is to be non-polluting	Levels of contamination present following remediation efforts that take place after infrastructure decommissioning and removal.	Prior to the commencement of topsoil placement.	A site suitability statement prepared by an approved auditor is to conclude that land is not contaminated and is suitable for the PMLU.	This indicator requires assessment to achieve rehabilitation milestone 2 but does not need to be re-assessed at rehabilitation completion unless a new source of potential contamination occurs (e.g., a hydrocarbon spill).

ID	Rehabilitation Objective	Rehabilitation Indicator	Assessment Timing	Completion Criteria	Justification
		Water quality at permanent monitoring locations downstream of the Mine.	Annually, following rain events.	Surface water in downstream monitoring locations is to remain within site-specific water quality monitoring limits listed in environmental authority EA0002912 (**Table 5-2**)**.**	Site-specific surface water quality triggers are based on baseline surveys undertaken at the site.
		Groundwater quality within permanent monitoring bores.	Quarterly.	Groundwater in downstream monitoring bores remains within site-specific water quality monitoring limits detailed in environmental authority EA0002912 (**Table 5-3**).	Site-specific surface water quality triggers are based on baseline surveys undertaken at the site.
A3	Koala food trees are to have a similar dominance within rehabilitated vegetation communities (except RA1) as they did in vegetation present on site prior to mining.	Proportion of the total basal area of woody vegetation at the site that comprises *Eucalyptus crebra, Eucalyptus populnea* or *Eucalyptus camaldulensis*.	Sites are to be monitored six and ten years after planting.	*Eucalyptus crebra* and/or *Eucalyptus populnea* are to constitute ≥21% of the total basal area of woody vegetation on sand plains. **AND** *Eucalyptus camaldulensis* is to constitute ≥33% of the total basal area of woody vegetation along Ripstone Creek and Drainage Line 2.	Relative dominance of Koala food trees is based on secondary site data gathered from nine sand plain reference sites and three riparian reference sites (METServe 2020).
	Trees are to be sufficiently tall to be used by Koalas and to escape browsing by cattle (except RA1).	Mean height of the tallest ten trees per hectare	Sites are to be monitored six and ten years after planting.	The mean height of the tallest ten trees per hectare is ≥4 m.	The Queensland Environmental Offsets Policy defines non-juvenile Koala habitat trees to be those with a height greater than 4 m (DES 2020). Such trees are also beyond the reach of cattle.
A4	Density of woody vegetation within rehabilitated areas (except RA1) is to be sufficient for Squatter Pigeons.	The mean Normalised Difference Vegetation Index (NDVI) calculated using Landsat imagery captured following at least two months without rain (e.g., late dry season).	Sites are to be monitored at the time of planting and then every two years for 10 years after planting.	Rehabilitated areas have a mean NDVI between 0.1240 and 0.1778	Ecological surveys of the local region found that Squatter Pigeons are confined to vegetation with a density that falls within the range of NDVI values used as the completion criterion (METServe 2020).
A5	Weeds listed under the *Biosecurity Act* are not to exceed densities typically present in unmined, grazed landscapes within the ML and neighbouring areas.	Percentage cover within a 10 m × 50 m plot.	Between February and April, every two years for 10 years after planting.	Rehabilitated areas have ≤0.2% cover of *Parthenium hysterophorus* **AND** rehabilitated areas have ≤0.1% cover of *Harrisia martinii* **AND** Any other weeds listed under the *Biosecurity Act* are to be present in densities of <1 individual per hectare.	Completion criteria are based on the densities of each weed recorded during ecological surveys of the region prior to mining (METServe 2020). As weed densities vary by soil type, only data from soil types present within the ML are incorporated into the completion criteria.
A6	Pasture is to be as productive within rehabilitated areas as in neighbouring unmined areas within the same soil management unit.	Pasture mass (t/ha) of ungrazed plots.	Sites are to be monitored at the end of the growing season (April-May) and end of the dry season (September-November) six and ten years after planting.	Rehabilitated areas have a pasture biomass that is not >10% less than pasture biomass on unmined areas wihin the same soil management unit measured at the same time, as measured under both wet and dry conditions.	Pasture biomass is the standard unit of productivity used widely in the grazing industry (Cayley and Bird 1996).

ID	Rehabilitation Objective	Rehabilitation Indicator	Assessment Timing	Completion Criteria	Justification
	Rehabilitated land is to have the same land suitability class for grazing as pre-mining score.	Land suitability class	Sites are to be monitored six and ten years after planting.	Rehabilitated areas are to have a land suitability class of 4 or lower.	Prior to mining, the land had a suitability class for cattle grazing of 4 (AARC 2021).
PMLU B: Road Reserve					
B1	Design and construction in accordance with agreed conditions.	Isaac Regional Council (IRC) assessment.	At the completion of all works within the realigned road reserve.	IRC has notified Vitrinite that the new road alignment is accepted "off maintenance", in accordance with processes described by the signed compensation agreement between Vitrinite and IRC.	The Saraji Road realignment will be undertaken during the operational phase of the Mine and comprises infrastructure to remain on site after the Mine is completed. As such, there are no specific rehabilitation requirements other than to construct and commission the realigned road infrastructure in accordance with conditions specified in an agreement between Vitrinite and IRC.
PMLU C: Retained Infrastructure					
C1	The infrastructure retained meets the conditions of the signed agreement with BMA.	The types of infrastructure retained, and their condition, as assessed by BMA	At the completion of the operational phase	BMA accepts responsibility for infrastructure in accordance with a formal written agreement.	BMA will ultimately accept ownership and liability of this infrastructure, so this is to be in accordance with the signed agreement.

Table 5-2 Proposed receiving surface waters trigger values

Analyte	Unit	Trigger Value	Source*
pH	pH Units	<6.5 and >8.5	WQO (aquatic ecosystem)
Electrical conductivity	µS/cm	>720 (baseflow) >250 (high flow)	Locally derived
Filtered Metals			
Iron	mg/L	0.72	Locally derived
Lead	mg/L	0.004	MMC (aquatic ecosystem)
Mercury	mg/L	0.0002	MMC (aquatic ecosystem)
Arsenic	mg/L	0.024	WQO (aquatic ecosystem)
Aluminium	mg/L	0.72	Locally derived
Molybdenum	mg/L	0.034	MMC (aquatic ecosystem)
Selenium	mg/L	0.01	MMC (aquatic ecosystem)
Total Metals			
Iron	mg/L	10.44	WQO (irrigation)
Lead	mg/L	0.1	WQO (stock)
Mercury	mg/L	0.002	WQO (aquatic ecosystem)
Arsenic	mg/L	0.5	WQO (stock)
Aluminium	mg/L	8.13	WQO (stock)
Molybdenum	mg/L	0.05	WQO (irrigation)
Selenium	mg/L	0.02	WQO (stock)
Hydrocarbons			
C6-C10 Fraction	mg/L	20	MMC (aquatic ecosystem)
C10-C40 Fraction	mg/L	100	MMC (aquatic ecosystem)
Major Cations and Anions			
Bicarbonate as $CaCO_3$	mg/L	38.40	Locally derived
Sodium	mg/L	30	Locally derived
Carbonate as $CaCO_3$	mg/L	8	Locally derived
Calcium	mg/L	5.8	Locally derived
Chloride	mg/L	31	Locally derived
Potassium	mg/L	7	Locally derived
Magnesium	mg/L	5.4	Locally derived

*MMC: Model Mine Conditions ESR/2016/1936 (DES 2017); WQO: Relevant Water Quality Objective (refer to **Table 1-3**); Locally derived: Interim value based on the 80th percentile of combined dataset.

Table 5-3 Preliminary groundwater quality trigger values

Analyte	Unit	MB05	MB13	MB14	MB15	MB16
pH (field)	pH Units	<5.5 >8.0	<5.5 >8.0	<5.5 >8.0	<5.5 >8.0	<5.5 >8.0
Electrical conductivity (field)	µS/cm	2,818[1]	4,373[1]	12,849[1]	TBD	TBD
SO_4	mg/L	284[1]	577[2]	176[1]	TBD	TBD
Aluminium (total)	mg/L	6.2[1]	6[1]	4.8[1]	TBD	TBD
Arsenic (total)	mg/L	0.013[3]	0.013[3]	0.013[3]	0.013[3]	0.013[3]
Iron (total)	mg/L	2.9[1]	2.8[1]	288[1]	TBD	TBD
Lead (total)	mg/L	0.008[3]	0.008[3]	0.008[3]	0.008[3]	0.008[3]
Mercury (total)	mg/L	0.0006[3]	0.0006[3]	0.0006[3]	0.0006[3]	0.0006[3]
Molybdenum (total)	mg/L	0.034[3]	0.034[3]	0.034[3]	0.034[3]	0.034[3]
Selenium (total)	mg/L	0.005[3]	0.005[3]	0.005[3]	0.005[3]	0.005[3]
Total Recoverable Hydrocarbons C6-C9	µg/L	<20[4]	<20[4]	<20[4]	<20[4]	<20[4]
Total Recoverable Hydrocarbons C10-C36	µg/L	<50[4]	<50[4]	<50[4]	<50[4]	<50[4]

[1] Site specific values using 95th percentiles.
[2] Deep WQO.
[3] ANZG (2018).
[4] Limit of Reporting.

6 REHABILITATION METHODOLOGY

6.1 Landform Design

6.1.1 Overview

The final landform design has sought to limit the Mine's final landform footprint, maximise the usage of open pit disturbance areas and maintain the long-term stability of the final landform. This has resulted in the majority of mine waste being stored in the Jupiter and Matilda in-pit WRDs with a small ex-pit WRD required to facilitate initial mining activities. Due to waste rock swell factors following blasting and handling, the in-pit WRD's will fill the voids and extend to between 20 and 30 m above the pit crests (**Figure 6-1**). The final landforms will be higher than the pre-mining landforms in a localised area; however, the overall landforms will be elevated plateaus (see **Figure 6-1**). The outer batters will be shaped to a maximum of 15% and will contain surface water management measures to drain water from the landform plateau to the surface water drainage features within the surrounding landscape.

The Jupiter and Matilda pits will be backfilled progressively, utilising a combination of paddock dump and end-tipping techniques. Dump lifts are generally anticipated to be low, enhancing rapid material settlement. The shaping and profiling of placed waste will be completed with bulldozers. Final landform geometry will be surveyed progressively to maintain adherence to the final landform and surface water management design. Sub-soil, rock mulch and topsoil will be spread with bulldozers and will be the subject of depth and distribution survey and quality control monitoring, as detailed in **Section 9**.

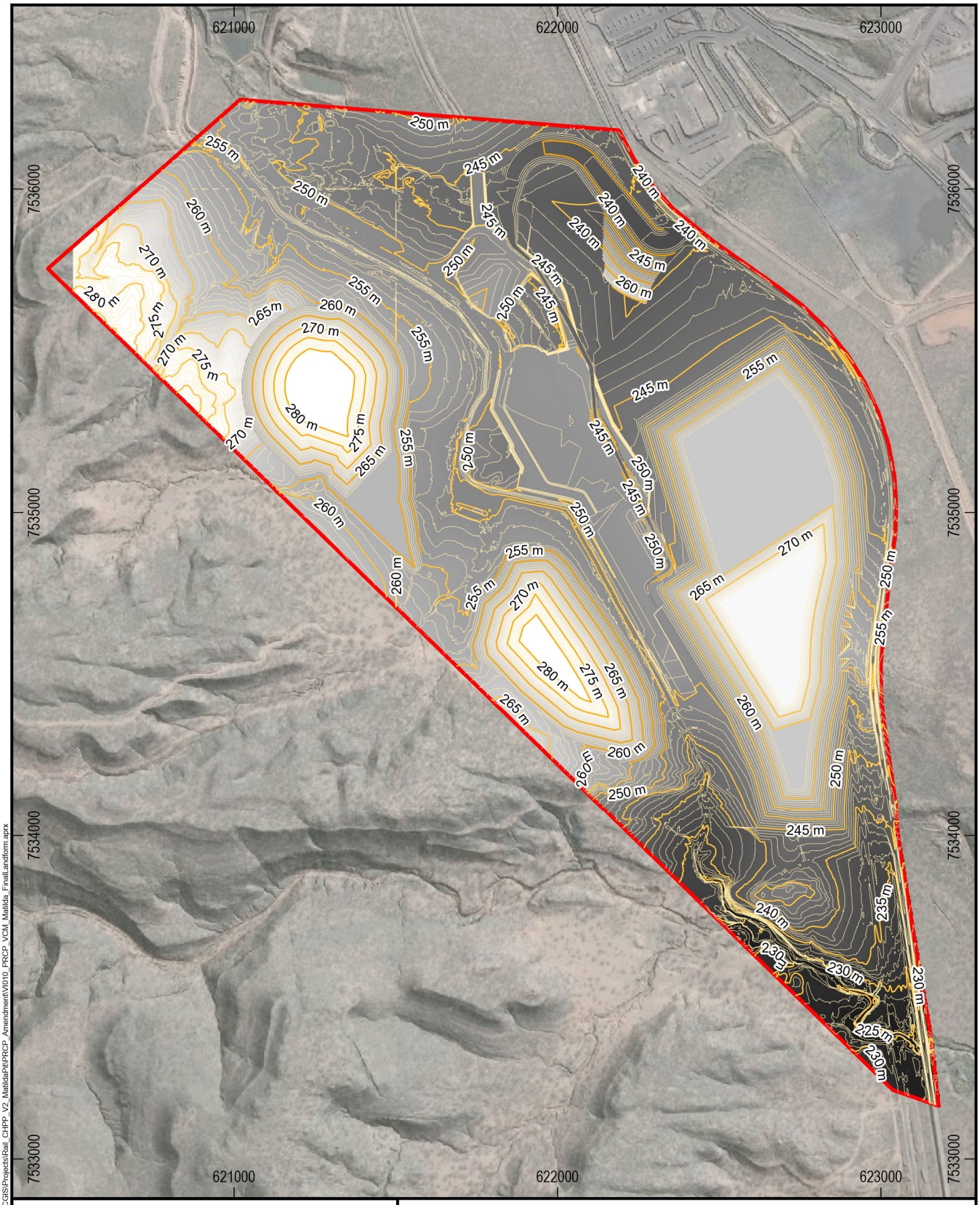
All other mining activities will result in limited change to the pre-mining topography and hence all areas excluding the in-pit WRDs, the ex-pit WRD and the ROM pad will resemble the pre-mining landform. To achieve this, minor shaping or reprofiling works will be undertaken once infrastructure has been removed, in order to smooth the ground surface and merge the landform into the surrounding natural contours.

The CHPP and ROM pad will remain slightly elevated above the original ground level (by 2-5 m), with edges smoothed to merge with surrounding areas. No Non-Use Management Areas (NUMAs) are proposed.

6.1.2 Landform Evolution Modelling

The VCM landform evolution modelling (LEM) assessment was undertaken for the three proposed WRD landforms. The three landforms assessed include the ex-pit WRD, Jupiter in-pit WRD and Matilda in-pit WRD. The LEM assessment involved the analysis of the proposed WRD cover designs and embankment slopes to demonstrate the targeted landform rehabilitation criteria and long-term stability of the landforms would be achieved.

Slope angle, length of slope, and percentage of ground cover are important factors in the control of erosion and have been considered in the landform design to manage erosion characteristics of the final landform. More detailed LEM information is outlined in the provided LEM Assessment Report (**Appendix F**) and in **Section 6.1.10**.



Legend

ML 700060

Contours

1 m

5 m

Final Landform DEM

287.7 m

222.6 m

Source: State of Queensland (Department of Resources) 2022, WRM 2022, Vitrinite 2022, METServe 2022, Maxar.

Vulcan Coal Mine

Final Landform

0 150 300 600

Meters

Scale: 1:17,000 (A4)

5/01/2023

Datum: GDA2020
Projection: MGA55

FIGURE 6-1

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\PRCP_Amendment\VI010_PRCP_VCM_Matilda_FinalLandform.aprx

6.1.3 Design Assumptions and Limitations

The design of the final landform was based on the following limitations and assumptions:

- The footprint of the Jupiter in-pit WRD is constrained by the boundaries of the pit, which is itself constrained by coal availability and the easement of Saraji Road along the eastern boundary of the ML. For logistic reasons, dumped waste rock will have steeper batters than 15%, which are later recontoured to a 15% slope, resulting in a final landform that extends slightly beyond the original boundaries of the pit;
- The footprint of the Matilda in-pit WRD is constrained by the boundaries of the pit, which is itself constrained by the surrounding rail loop. For logistical reasons, dumped waste rock will have steeper batters than 15%, which are later recontoured to a 15% slope, resulting in a final landform that extends slightly beyond the original boundaries of the pit;
- The footprint of the ex-pit WRD is constrained by the flood plain and levee in the north-east (to ensure minimal impact to existing surface water features) and the ML boundary and rail loop in the west;
- In order to produce a final landform that merges with the surrounding landscape, a maximum elevation of 280 m (reduced level (RL) based on the Australian Height Datum) was selected for the ex-pit WRD, to closely match the pre-mining and adjacent topography. Furthermore, a hill that occurred within the footprint of the bulk sample pit previously rose to RL 270 m pre-mining;
- The height of the in-pit WRD is determined by the volume of waste rock to be removed during mining and the amount that can be stored in the ex-pit WRD given the above constraints in height and footprint;
- A swell factor of 30% has been assumed, which can be accommodated within a dump with a maximum elevation of RL 280 m. This swell factor is conservative, as 20-25% is typically observed elsewhere in the Bowen Basin;
- For stability reasons, a maximum slope of 15% was used on the final landforms (based on assessments by AARC 2021: summarised in Section 6.1.9 of this PRC plan) and, where possible, this was reduced further;
- Drainage structures were incorporated into the design of the final landform to further improve long-term stability. Drainage designs were based on recommendations and assessments by WRM (2022b) and have been engineered so that catchment boundaries and flows are as similar as practicable to the pre-mining state;
- The plateau formed by the Jupiter in-pit WRD has a 1% slope to the west, so that surface water is directed away from Saraji Road and into existing drainage systems.

6.1.4 Cover Design

Geochemical characterisation of waste rock and coal rejects has been undertaken to better understand potential risks associated with the storage of this material in final landforms at the Mine (**Appendix I** and **Appendix J**). In terms of material management, it is recommended that fresh waste rock material be backfilled into the open pit and covered with at least 5 m of weathered NAF waste rock material as part of rehabilitation activities (**Appendix I**). Following the return of waste rock to the open cut pit, at least 300 mm of subsoil (removed from the pit footprints prior to mining and stockpiled (**Section 6.2.6**)) is to be spread over the rock (**Figure 6-2**). This will enhance the water-holding capacity of the soil and provide a more favourable growing environment for vegetation. Given the vulnerability of local subsoils to dispersion, some waste rock will be mixed with the subsoil (approximate ratio of rock to subsoil of 1:3), to provide protection from erosion, in the unexpected event that that rock mulch cover and developing grass cover doesn't provide adequate protection, and the overlying topsoil becomes eroded in places.

Topsoil will be spread over the subsoil/rock mix at a depth of 250 mm to provide a favourable medium for plant establishment. Note that this cover design varies slightly between rehabilitation areas due to material availability and rehabilitation requirements (**Table 6-1**). In addition a number of topsoil and subsoil ameliorative measures will be implemented, wherever required, to ameliorate poor soil structure, low moisture retention and low nutrient concentrations that may be encountered with the Limpopo SMU (**Section 1.2.7**).

Amelioration measures that can be utilised where required, include the application of organic matter, fertiliser, rapid establishing cover crops, and hydro mulching. More specific detail on the application of these measures is provided in **Section 6.2.**

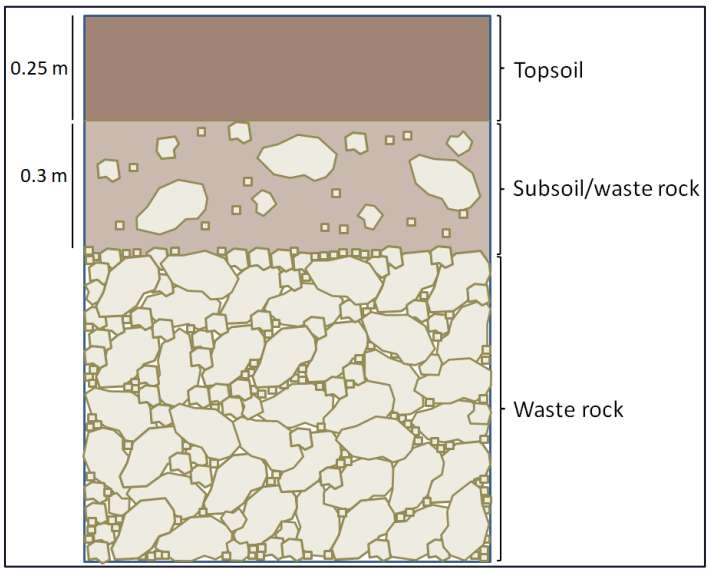


Figure 6-2 Cover design to optimise plant growth

There is strong evidence to support the suitability of the cover design for plant establishment:

- Many independent studies across north-eastern Australia have found that 75-95% of total root biomass within open eucalypt forests and woodlands is contained in the upper 0.5 m of the soil profile (Eamus et al. 2002; Zerihun et al. 2006; Grant et al. 2012), so a soil depth of 55 centimetres (cm) is expected to be suitable for supporting tree growth.
- The cover design is similar to the natural soil profile on the Crocodile soil management unit, which has an average soil depth of 0.62 m above rock (see Section 1.2.7) and supports a dense cover of native vegetation.
- Trials undertaken at the adjacent Saraji Mine compared vegetation establishment on waste rock (spoil) that received 0 cm, 10 cm or 30 cm of topsoil prior to planting (Kopittke et al. 2004). Grass established at higher densities in the topsoil treatments than on the spoil; however, even on spoil, grass achieved 70% cover. Native trees and shrubs established better without topsoil, due to reduced competition with grass, but natural thinning over the first ten years resulted in a final stem density that was equivalent to the topsoil treatments. The spoil at Saraji is more saline than that at the Mine (Kopittke et al. 2004), suggesting that local waste rock is unlikely to pose a barrier to root growth for local vegetation. Based on these trials, the cover system is expected to be ideal for establishing a productive pasture with a moderate density of native woody vegetation.

Table 6-1 Cover variations in each rehabilitation area

Rehabilitation Area	Deviation from standard cover design	Justification
RA1: Ex-Pit Waste Rock Dump	Topsoil is to be placed directly on waste rock without an intermediate layer of subsoil.	Insufficient subsoil material is available at an appropriate stage of mining development to apply this to the ex-pit WRD.
RA2: Open Cut Mining Pits; In-pit Waste Rock Dumps (Jupiter and Matilda)	None	N/A
RA3: Infrastructure- CHPP, Rail Loop, TLO, haul roads, internal tracks, stockpiles, run-of-mine pad	Topsoil is to be placed directly onto prepared disturbed surfaces.	Apart from the rail loop, where deeper incisions may be required for cuttings, no waste rock or subsoil is to be removed from infrastructure areas and therefore these remain intact. For the rail loop, subsoils will be replaced during the backfilling of any excavations which will resemble conditions before subsoil removal.
RA4: Water infrastructure- dams, sediment control drains, ponds and flood protection levees	Land is to be reformed prior to the deposition of topsoil. No waste rock or subsoil is added, beyond what is already contained within the dam walls.	There is to be minimal disturbance to the soil profile at dams once the land has been reformed and topsoil returned.
RA5: Saraji Road	No cover is proposed.	RA5 is to remain an asphalt road in perpetuity.
RA6: Retained Infrastructure	No cover is proposed.	As the infrastructure within RA6 will remain at completion, there is no requirement for cover development.

6.1.5 Mine Waste Geochemistry

Geochemical assessments completed by RGS from 2020 to 2022 represents a program of progressive sampling and characterisation of waste rock and coal reject materials, which is summarised below. The full geochemistry reports are provided in **Appendix I** and **Appendix J**.

An initial assessment of the geochemical characteristics of the waste rock and coal reject materials likely to be generated at the Mine showed that the waste rock at the Jupiter open cut and associated coal reject materials do not pose a significant risk of generating acid, saline, or metalliferous drainage (AMD) (RGS 2020). More recently, an assessment of the geochemical characteristics of waste rock and coal reject materials likely to be generated from the proposed Matilda pit was completed (RGS 2022). The assessment indicated that whilst shallow weathered waste rock at the Matilda pit had a low risk of generating AMD, some deeper Permian waste rock materials were classified as Potentially Acid Forming (PAF) (RGS 2022). In addition, coal reject materials generated from washing the target Matilda seam were classified as PAF.

The initial geochemical assessment of the Jupiter open cut, analysed the concentrations of 22 metals and metalloids (and four other trace elements) within overburden and interburden revealed that no samples were relatively enriched, compared to the mean crustal abundance of each element (RGS 2020). A program of static and kinetic geochemical tests was used to determine the likely geochemical characteristics of the waste rock and coal reject materials (RGS, 2020). The results showed that bulk waste rock materials are likely to have very low sulfur content, excess acid neutralising capacity and are classified as Non-Acid Forming (Barren) (RGS 2020). Similarly, as a bulk material, coal reject (coarse and fine) materials generated from washing coal from the target Alex and Dysart seams at the Jupiter and Vulcan targets are expected to have a relatively low risk of generating AMD and be amenable to preferential co-disposal in in-pit in cells within the much larger volume of waste rock materials that will be generated by planned mining activities (RGS 2020).

The more recent geochemical assessment of materials likely to be generated from the proposed Matilda pit (RGS, 2022) was completed on a total of 52 samples (38 waste rock and 14 coal reject) from seven drill holes within the Matilda pit boundary. The geochemistry assessment results indicated that waste rock materials located within the weathered zone of the stratigraphic profile at the Matilda pit (generally less than 15 m) have a low risk of generating AMD, although some of the deeper fresh Permian waste rock materials are classified as Potentially Acid Forming (PAF). In addition, coal reject materials generated from washing the target Matilda seam are classified as PAF and are likely to require active management measures during operations and at closure (RGS 2022). As a bulk material, coal rejects (coarse and fine)

generated from washing coal from the target Matilda seam at the proposed Matilda pit are expected to have a reduced factor of safety with respect to AMD (RGS 2022).

A variety of management measures are proposed to reduce the risk of acid mine drainage and the likelihood of negative impacts to groundwater and surface water within and adjacent to the project area. During operations, traffic compaction of the in-pit dry coal reject materials is proposed to assist in limiting air entry to the coal rejects to surface diffusion and slow down the overall rate of reaction of the bulk coal reject materials. This outcome will also be favoured using the co-disposal of coarse and fine reject materials whereby fine rejects fill the air gaps in coarse rejects and limit oxygen diffusion into the bulk materials. At the same time the co-disposed coarse rejects provide additional geotechnical stability to the fine rejects. Slowing down the rate of this reaction will hence limit the rate at which acidic materials are formed and reduce the chance of acid mine drainage and deleterious runoff into surface water and groundwater.

In addition, to reduce the likelihood of acid mine drainage, dry coal reject materials will be placed deep into to the open pit profile as backfill and be progressively covered with Non-acid Forming (NAF) waste rock materials. Most of the coarse reject samples have a pH value between 3 and 4 and are already acidic therefore the high ANC waste rock described above may be a useful source of interim covering/neutralising/alkaline materials during the mining and backfilling process. From the above management methods employed in addition to the proposed water management strategies (**Appendix A**), it is expected that potential impacts to surface and groundwater will be adequately managed to meet the EA conditions.

Overall, surface runoff and seepage from the overburden/interburden material is expected to be pH neutral to slightly alkaline and have a low level of salinity if PAF materials are managed appropriately. Dissolved metal and metalloid concentrations in surface runoff and leachate from bulk mining waste materials are expected to be low and unlikely to pose a significant risk to the quality of surface and groundwater resources.

6.1.6 Material Availability

All materials (i.e. topsoils, subsoils, and waste rock) to be used for rehabilitating disturbed land will be sourced from the disturbance footprint and stockpiled during the mining process, until required for rehabilitation. Given that the post-mine landform will be similar but not identical to the pre-mine landform, discrepancies are likely between the quantities of materials obtained from each area and the quantities required to be returned. As can be seen by the materials balance shown in **Table 6-2**, any discrepancies caused by alterations to the landform are expected to be balanced by (a) replacing a slightly thinner layer of topsoil than removed and (b) mixing rock with subsoils. Also note that some stockpiles will be retained in association with retained infrastructure, in order to provide BMA with a resource to rehabilitate this area once no longer required for their operations.

Table 6-2 Materials balance for topsoils and subsoils to be used for rehabilitation

Material	Amount removed from disturbance footprint (m^3)	Amount required for rehabilitation (m^3)	Balance (m^3)
Topsoil*	780,693	599,157	+181,536
Tertiary Subsoil†	499,754	374,815	+124,939
Permian waste rock	16,289,000	47,610^	+16,241,390

*The top 30 cm of topsoil is removed from most disturbed areas prior to mining, while 25 cm is returned to all rehabilitated areas.
†The top 30 cm of subsoil is removed from some disturbed areas (extraction areas and dams) prior to mining, and three parts of this is diluted with one part rock when returned to rehabilitated areas.
^Requirement for one part rock dilution of the Subsoil allocation, and additional requirement of an additional 20 cm of coverage for slopes, batters and drainage areas of the final landform (approximately 40% of final landform surface area).

Drilling conducted by Vitrinite has identified medium to high-strength sandstone resources both above and between coal seams that are likely to be suitable for use in rock mulching. Based on the geological modelling of Vitrinite's coal projects, which locally extends beyond the disturbance footprint of the VCM, this resource is expected to be abundant far beyond the requirements for landform construction.

The available waste rock material will be approximately 16,289,000m^3 (**Table 6-2**). Based on geological drilling logs, there is a high degree of confidence that a significant resource of competent sandstone is present in the waste rock material that will be excavated during mining activities.

The geochemical and geophysical characteristics of waste rock will be assessed to identify the suitable strata for use in landform stabilisation. Once these strata are confirmed, mine scheduling and selective handling will be applied to ensure that adequate suitable material is available for the progressive rehabilitation of landforms. Further information on waste rock testing is provided in **Section 6.2.8.**

6.1.7 Drainage and Surface Water Management

The potential impacts of the final landform on surface water resources will be mitigated through the implementation of a mine site water management system. During closure, the system will revert from the operational water management system, which is designed to control the flow and storage of water of different qualities across the site, to one that primarily seeks to manage drainage from the final landform, control erosion and sediment and divert upstream runoff around the final landform. The relevant elements of the operational surface water monitoring program will be continued in closure to monitor and confirm water management system performance.

Final Landform Drainage

The conceptual final landform drainage is presented in **Figure 6-3** (WRM 2022b Figure A). This presents the drainage principles to be implemented on the final landform. The drainage plan has been developed with the aim of retaining certain water infrastructure constructed during operations, for the management of surface waters during closure. The landform is intended to be free-draining and to discharge water to the receiving environment that is consistent with water quality from surrounding background sites.

The key features and marked cross sections of the final landform that are depicted in **Figure 6-3** (WRM 2022b Figure A) are presented in **Figure 6-4**, **Figure 6-5**, **Figure 6-6** and **Figure 6-7** (WRM 2022b Figure B, Figure C, Figure D and Figure E).

The key drainage features of the final waste rock dump landforms include:

- The final surfaces of the Jupiter and Matilda WRDs will be designed to shed water and avoid concentrated flows. The design of the final landform surface is described in the 'Final landform geometry' section below. Drainage structures will be constructed on the top of the dump, on the batter slopes and at the toe of the dumps, in order to minimise erosion and avoid ponding.
- Plateau drains will collect runoff from the plateau and generally drain them to drop structures and sediment dams. Contour banks on the batter slopes will collect residual runoff not collected in the plateau drains.
- Drop structures will collect runoff from the plateau drains and control the flow down the batter slopes, discharging the flow at the toe of the landform;
- Contour banks will control runoff from the batters;
- Surface water drains will collect runoff at the toe of the dumps and direct it towards sediment dams. These surface water drains will be retained from the operational phase of the Mine;
- Erosion control measures will be used in the construction of the plateau drains, surface water drains, contour banks and drop structures as appropriate. These control measures (shown in **Figure 6-4** to **Figure 6-7**) may include topsoiling and vegetating the drainage structures, incorporating erosion resistant liners (e.g. geotextile liners) and/or rock lining the structures.

A number of dams will be retained or introduced as part of the final landform design:

- Sediment dams SD1 – SD10 will be retained from the operational phase and will collect surface water runoff generated from the dumps and release it to the receiving waters.
- Sediment dams SD11 and SD12 will be constructed as part of the final landform design to collect runoff from the northern side of the eastern in-pit waste rock dump.
- Sediment dams SD13 – SD15 will be retained from the operational phase and will collect surface water runoff generated from the western in-pit waste rock dump and release it to the receiving waters.
- Sediment dam SD16 will be constructed as part of the final landform design of the western in-pit waste rock dump to collect runoff from the east of the dump.

- A catchment runoff dam DD1 will be retained from the operational phase and will collect undisturbed runoff from the northwest of the final landform. It will spill to the proposed drainage corridor. DD1 will be retained until the drainage corridor has been fully established.
- Operational details regarding the dams (including catchment areas and full supply volumes) are outlined in WRM (2022a).

When a sediment dam catchment is completely rehabilitated, and water quality monitoring of the runoff has established that it meets the trigger values listed in **Table 5-2**, the sediment dam and associated drainage infrastructure will be decommissioned. Surface runoff and seepage from the rehabilitated catchment will be allowed to shed directly to the receiving environment.

An existing flood levee and drainage diversion, which drains southward through the Project area between the Jupiter in-pit and out-of-pit dumps (**Figure 6-3**), was constructed in the Project area prior to its commencement. The flood levee may or may not be retained for the final landform. Flooding results presented in WRM (2022a) show Post-closure Conditions assessed against both retaining and removing the existing flood levee.

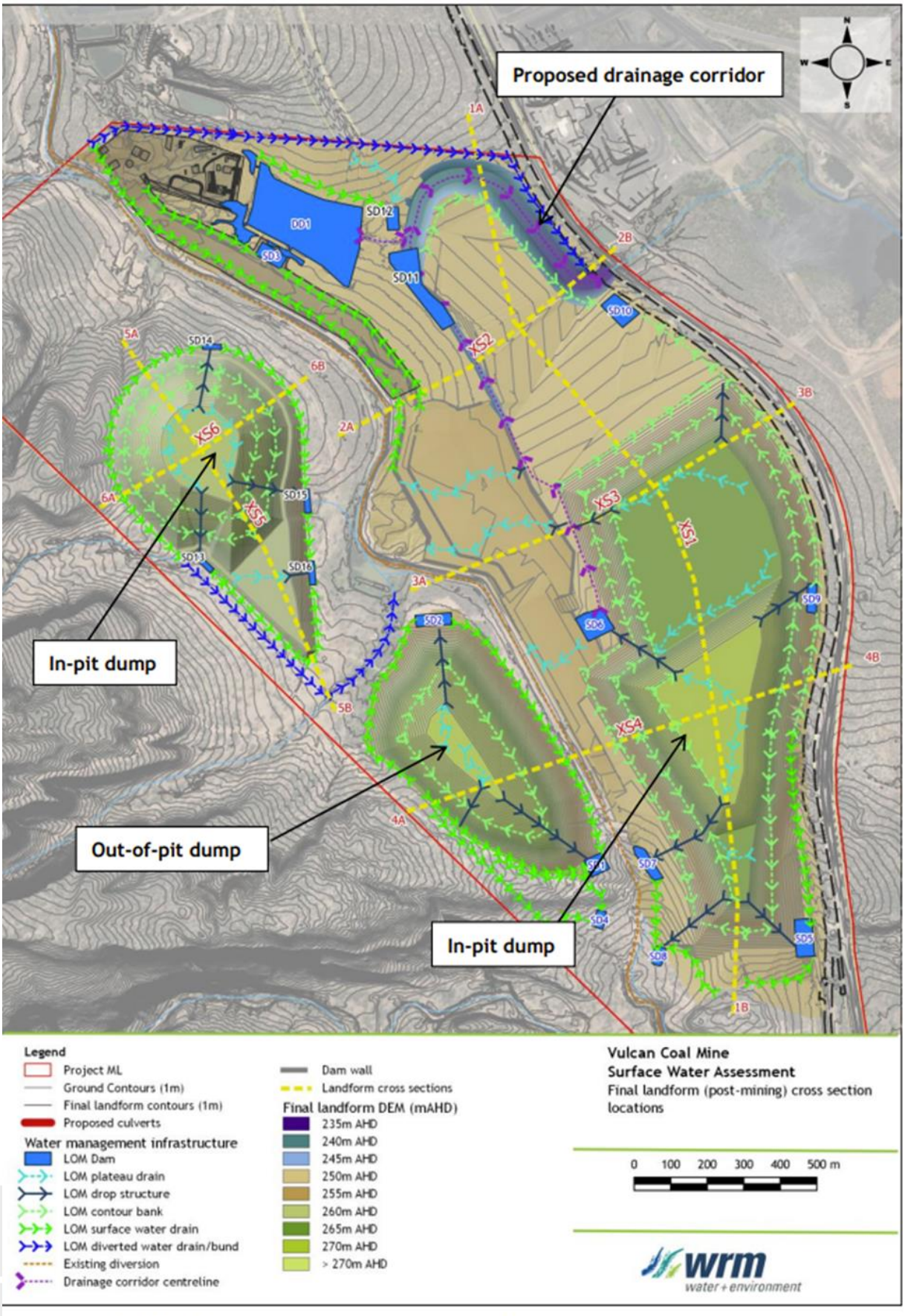


Figure 6-3 Conceptual Final Landform Drainage Plan

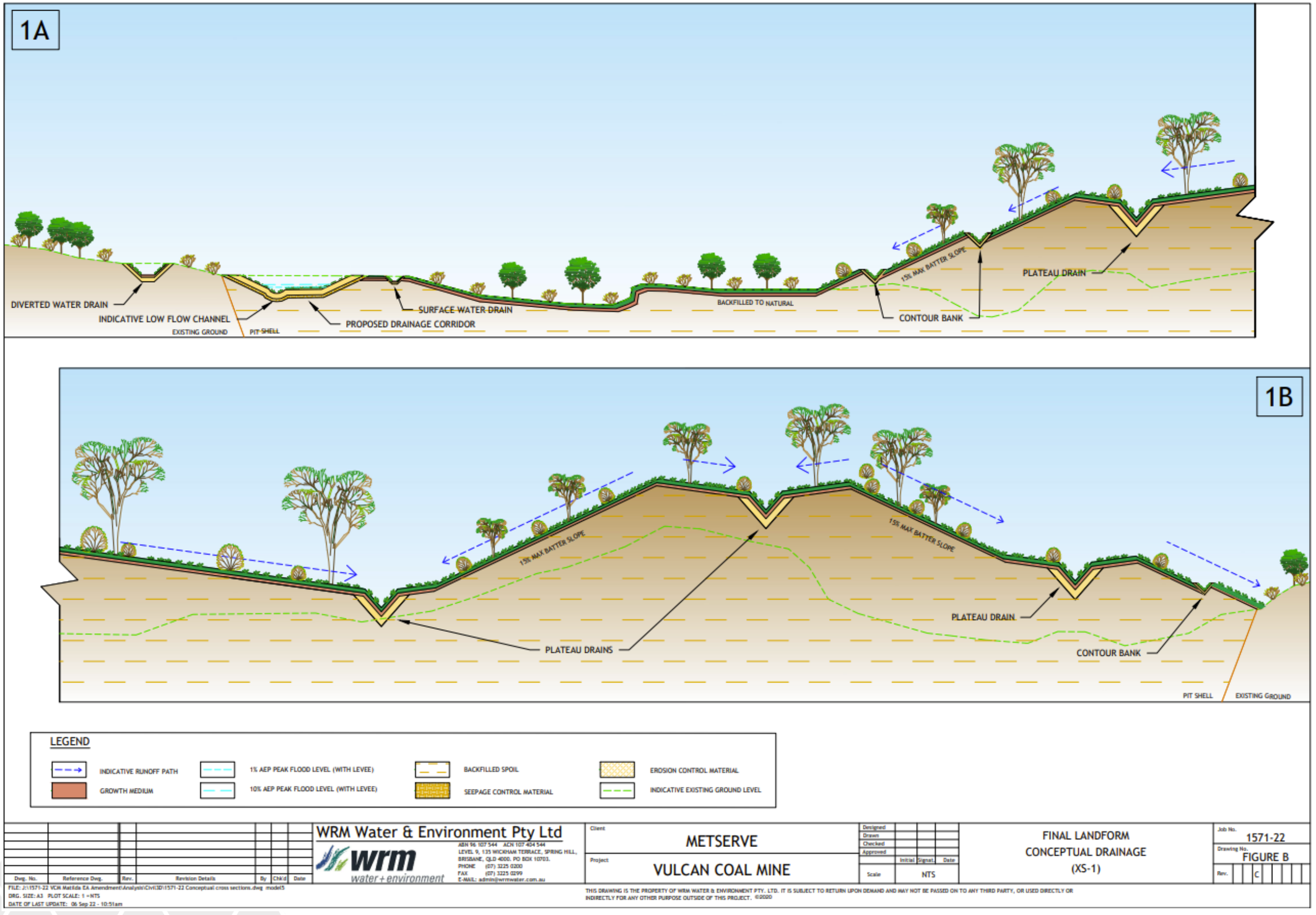


Figure 6-4 Final Landform Drainage XS-1

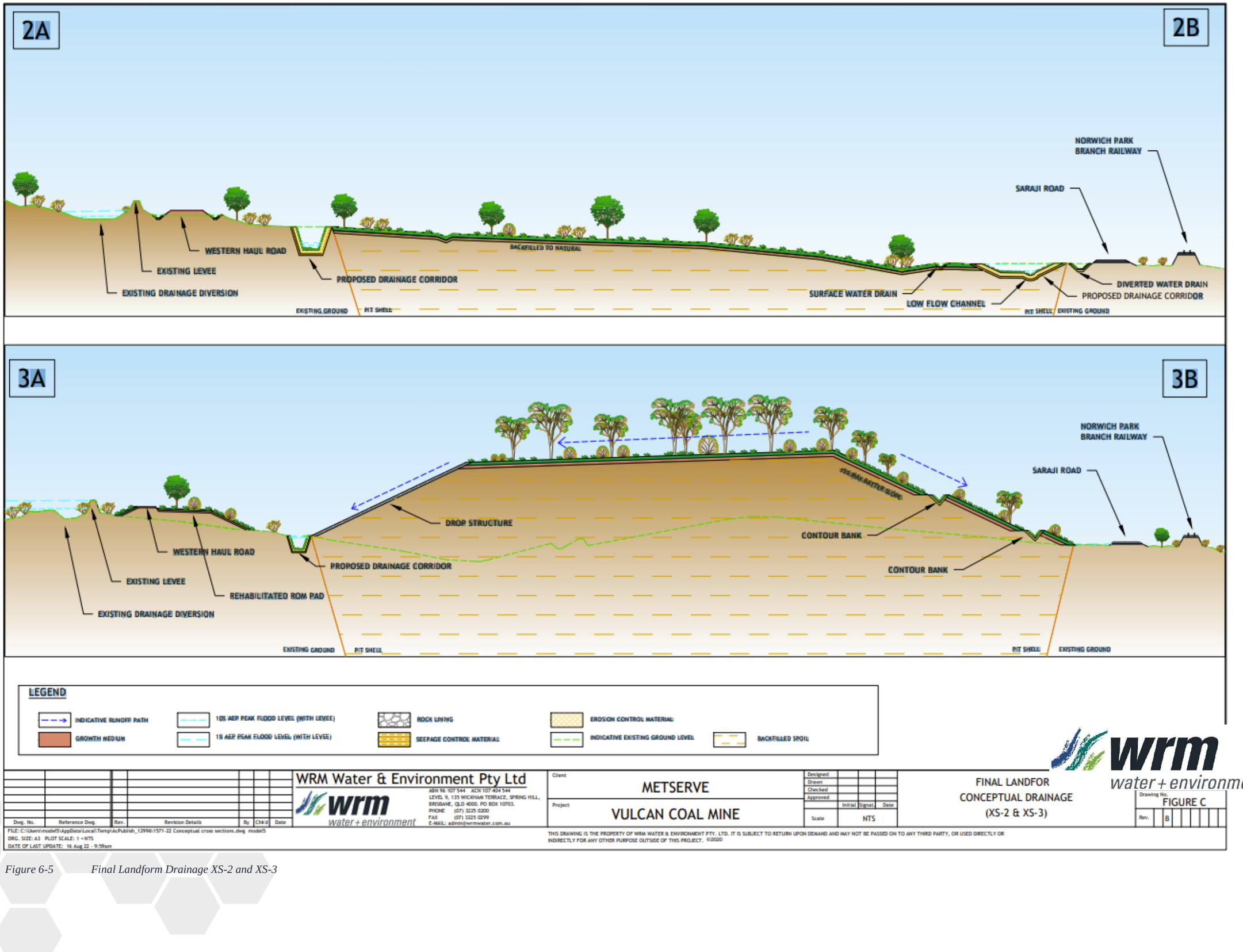


Figure 6-5 Final Landform Drainage XS-2 and XS-3

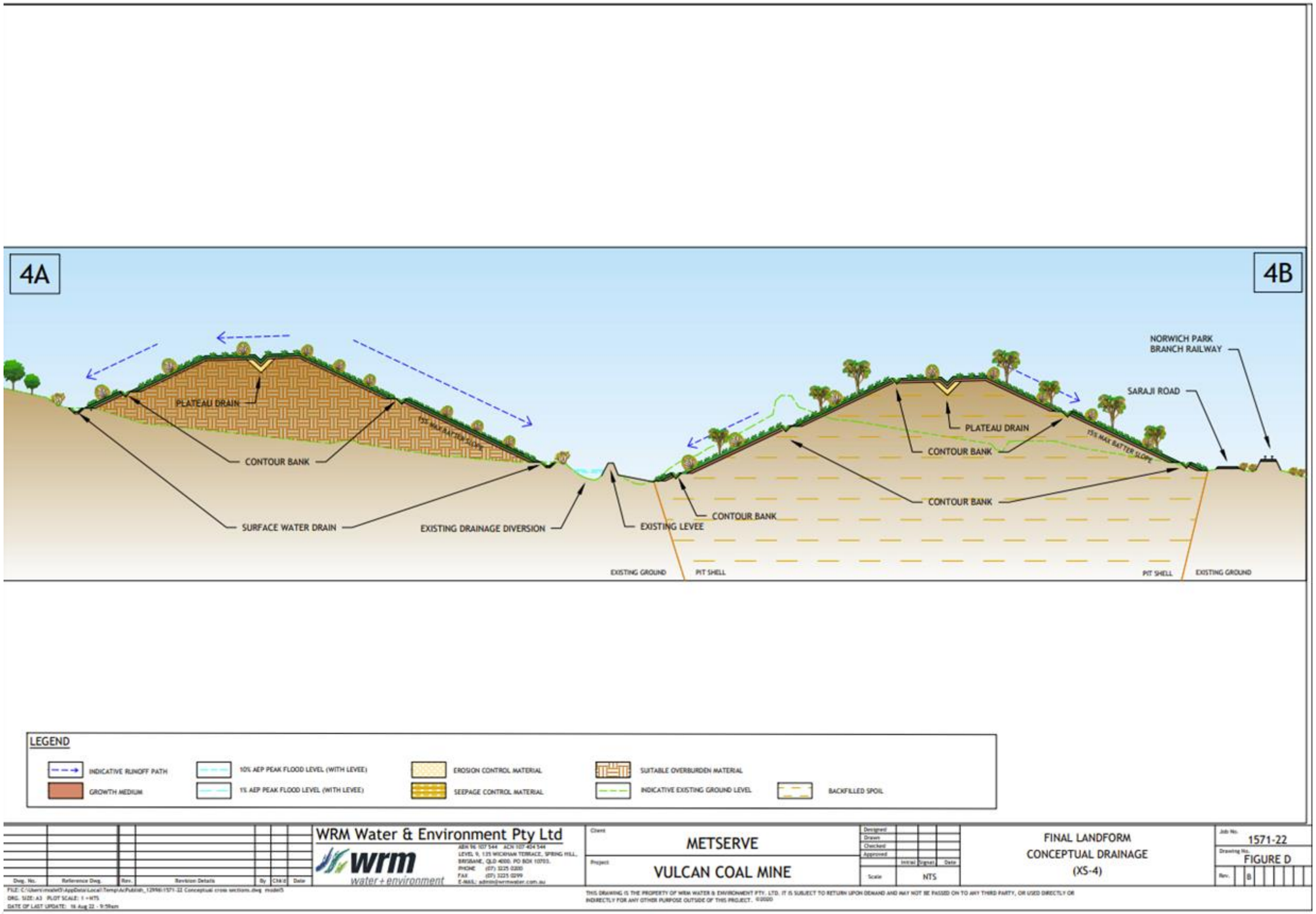


Figure 6-6 Final Landform Drainage XS-4

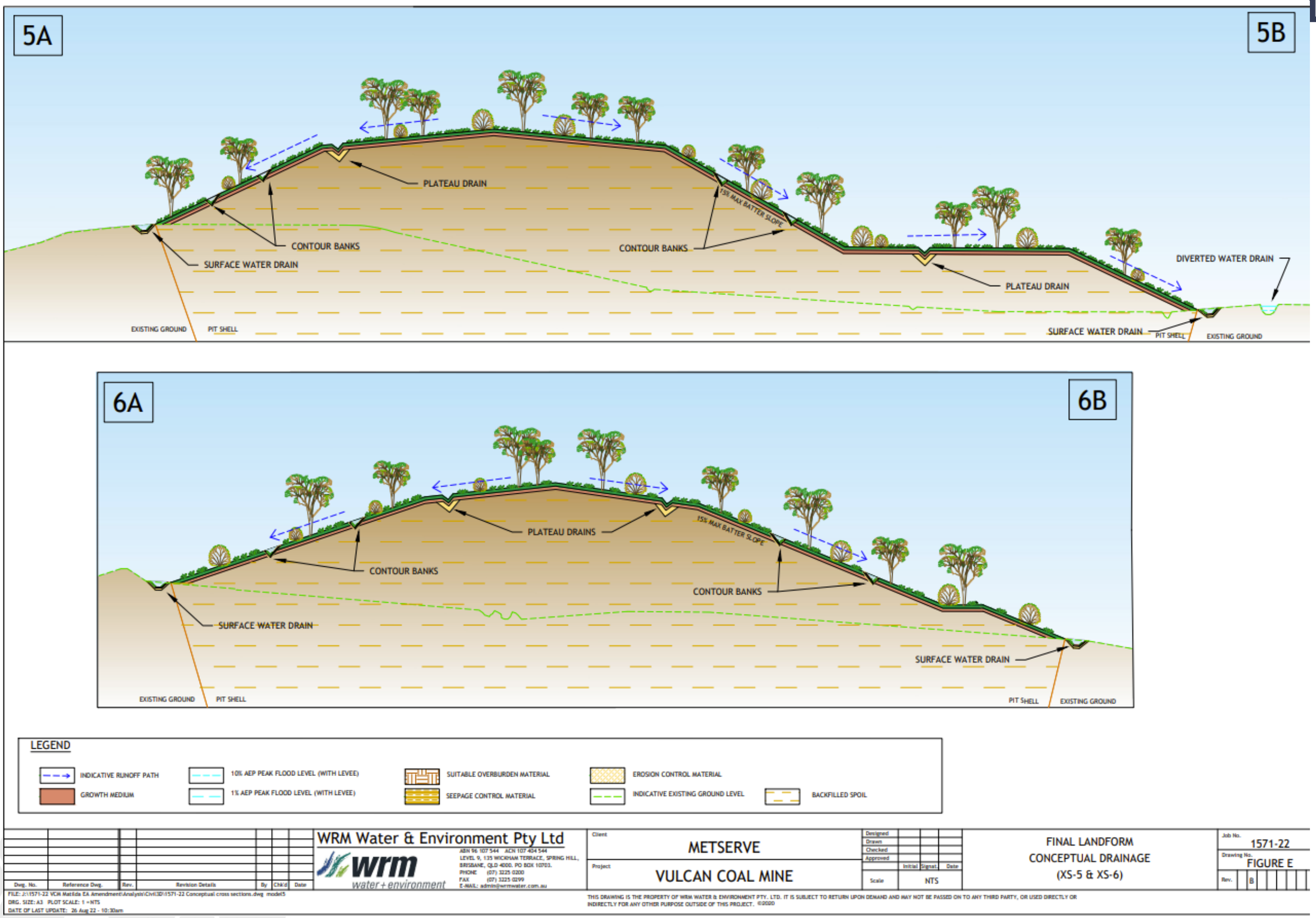


Figure 6-7 Final Landform Drainage (XS-5 &XS-6)

A drainage corridor will divert flows from the western side of the Jupiter WRD out to the east (**Figure 6-3**). The drainage corridor is designed as free-flowing gravity drains. The drainage corridor is a narrow channel on the southwestern side of the Jupiter Pit WRD, commencing at the western edge of the in-pit waste rock dump, draining from SD6 and through SD11. The drainage channel will collect runoff from the drop structures along the western side of the in-pit waste rock dump, as well as undisturbed residual runoff draining from the eastern side of the existing levee. The corridor wraps eastward through the backfilled section of the eastern in-pit dump, joining with a discharge channel from the outlet of DD1. The corridor flows around the northern edge of the backfilled pit, discharging through the existing culverts under the Norwich Park Branch Railway to the east. The corridor is proposed to be approximately 2.2 km in length.

The drainage diversion diverting the western upstream clean water catchment around the Matilda Pit WRD will be formed by the Matilda Pit drainage diversion constructed during operations. The drainage diversion will collect undisturbed upstream runoff and discharges to the existing drainage diversion. The drainage diversion is proposed to be approximately 900 m in length. Cross sections of the proposed Jupiter Pit drainage corridor are shown in **Figure 6-4** (WRM 2022b - Figure B) and **Figure 6-5** (WRM 2022b -Figure C).

WRM (2022a) has produced hydrologic and hydraulic models of flood plains within the ML and surrounding areas to inform the Mine surface water assessment. A flood plain is defined as the same height, or lower than, the water level modelled with a 0.1% annual exceedance probability for a relevant watercourse under the guideline, *Australian Rainfall and Runoff* (Ball *et al.* 2019). Flood maps generated in the surface water assessment indicate the areas of the landform which are inundated during flood events and the impacts when compared against Pre-mining Conditions. The flood figures in **Appendix A** (and summarised in WRM 2022b) indicate:

- Under both 1% and 10% AEP conditions, floodwaters will be confined to the proposed drainage corridor draining around the final landform toe. Retaining the flood levee, flood results indicate peak inundation for the 10% AEP and 1% AEP events will be approximately 1.4 m and 2.6 m respectively within the drainage corridor upstream of the proposed Saraji Road. Without the flood levee, flood results indicate peak inundation for the 10% AEP and 1% AEP events will be approximately 2.8 m and 4.0 m respectively within the drainage corridor upstream of the proposed Saraji Road.
- The results shown in Figures C.3 and C.9 of the SWA (**Appendix A**) that the proposed drainage corridor has sufficient capacity under both levee scenarios to convey flood events up to the 0.1% AEP.
- In addition, the flood assessment presented in the surface water assessment (WRM 2022a) indicate that under 1% AEP conditions, peak velocities within the drainage corridor are up to 1.5 m/s (with levee) and 2.2 m/s (without levee). Under 0.1% AEP conditions, maximum velocities in the drainage corridor are up to 2.5 m/s (with levee) and 2.8 m/s (without levee).
- Under the 10% and 1% AEP conditions, floodwaters will be confined to the proposed drainage diversion around the Matilda Pit final landform. Under 0.1% AEP conditions, the floodplain is inundated within the vicinity of the drainage diversion. The flood results indicate peak inundation for the 10% AEP, 1% AEP and 0.1% AEP events will be approximately 1.2 m, 1.6 m and 2.2 m respectively within the drainage diversion.
- Under the 10% and 1% AEP conditions, floodwaters will be confined to the proposed drainage diversion around the Matilda Pit final landform. Under 0.1% AEP conditions, the floodplain is inundated within the vicinity of the drainage diversion. The flood results indicate peak inundation for the 10% AEP, 1% AEP and 0.1% AEP events will be approximately 1.2 m, 1.6 m and 2.2 m respectively within the drainage diversion.
- Under the 10% AEP, 1% AEP and 0.1% AEP events, maximum velocities in the drainage diversion upstream of the Matilda Pit final landform will be 1.2 m/s, 1.3 m/s and 1.7 m/s respectively. Rock-lining the drainage diversion and/or rock-chute drop structures will be required where the proposed drainage diversion connects with the existing drainage line up to where the drainage diversion discharges to the existing drainage diversion to reduce high velocities and prevent scour and erosion.
- Flooding results in the surface water assessment (WRM, 2022a and 2022b) for the 1% and 10% AEP events retaining the levee have been conceptually represented in **Figure 6-4**, **Figure 6-5**, **Figure 6-6** and **Figure 6-7**.

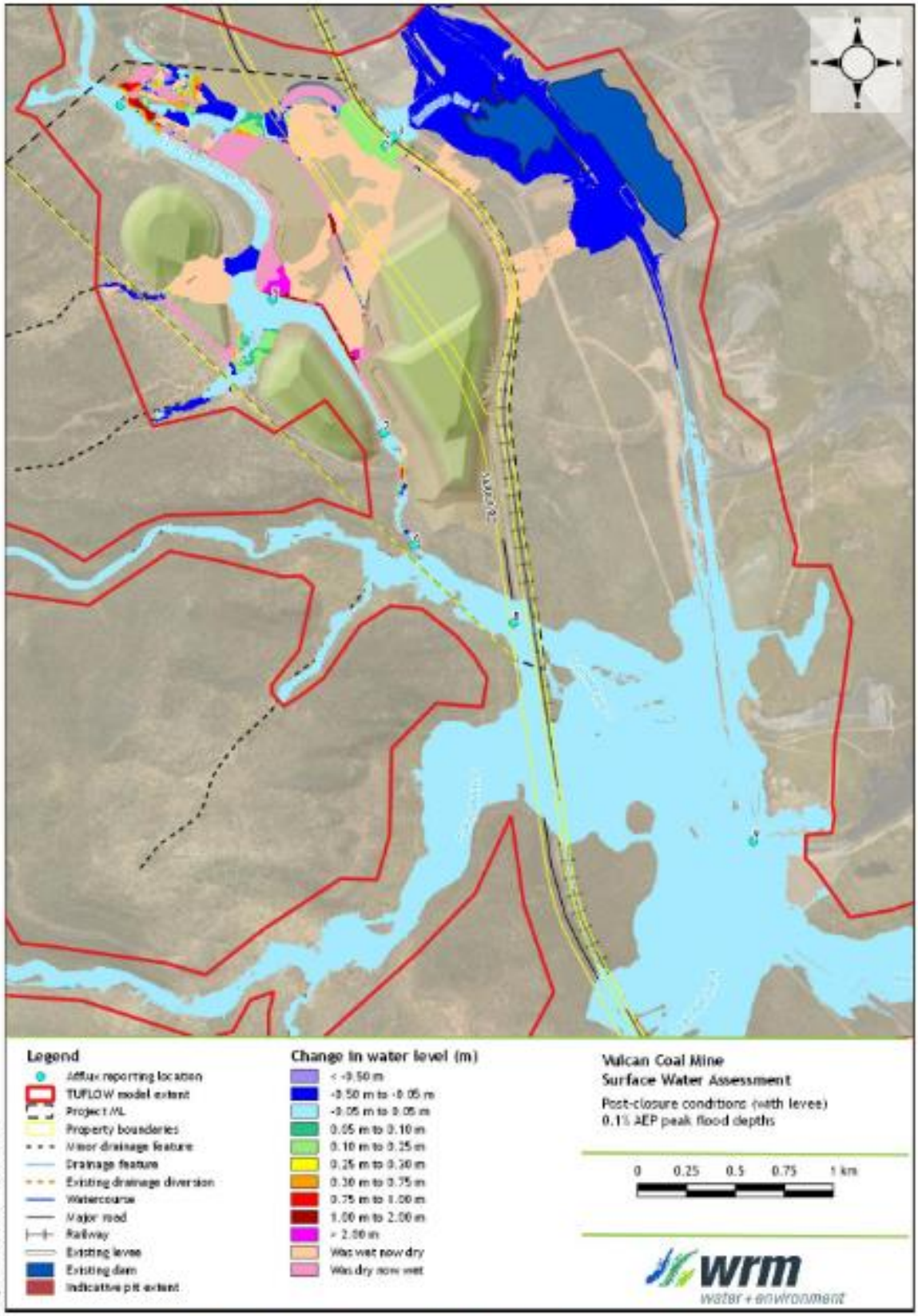


Figure C.3 - 0.1% AEP change in peak water levels - Post-closure Conditions (with levee) impacts

Figure 6-8 Final landform 0.1% AEP flood event (WRM 2022a)

Considering the peak velocities referenced above, erosion and scour protection will be required along the proposed corridor structure around Jupiter Pit, the proposed diversion around Matilda Pit and for the toe of the final landforms, particularly if the existing flood levee is removed post closure. Erosion control measures will need to be carefully considered at the inlet and outlet of the drainage corridor, as well as the downstream culvert crossings. Suitable erosion and sediment control measures will be determined during detailed design. Possible erosion controls include:

- topsoiling and revegetating the drainage corridor;
- rock lining the corridor and landform toe;
- operating DD1 until all erosion controls have been implemented in the channel and/or revegetation is established;
- implementing seepage minimisation measures (such as the addition of a liner along the base of the diversions) to minimise seepage from the corridor to the underlying backfilled material (as shown in **Figure 6-4** and **Figure 6-5**); and
- routine monitoring of erosion and sedimentation along the drainage corridor to ensure the diversion is stable during natural flow events.

When the drainage corridor is rehabilitated, DD1 will be decommissioned. DD1 will remain until this time to allow in-stream vegetation to establish before receiving upstream catchment flows.

The size and configuration of the proposed drainage corridor and the proposed drainage diversion around Matilda Pit will be confirmed during detailed design; however, it is expected that they will be designed to convey at least 0.1% AEP flow event (assuming the existing drainage levee is removed) as they will form part of the permanent landform structure.

The conceptual cross sections in **Figure 6-4** to **Figure 6-7** show the intended profile of the final landform, including across the in-pit and ex-pit WRDs. The conceptual landform surfaces have been developed using the finished level of the dumps supplied from Vitrinite Pty Ltd and have been shaped in order to evenly shed water down the landform in order to minimise erosion.

The key features of the final landform profile are described below:

- cross section XS-1 shows a profile across the in-pit WRD (**Figure 6-4**). As shown, the final landform is intended to be shaped to direct runoff towards the plateau drains situated along the surface. This sloping will ensure that runoff generated along the surface will be collected and controlled through the drainage structures along the surface and minimise uncontrolled flows down the landform batters.
- the surface of the final landform will be topsoiled and will be vegetated consistent with final rehabilitation plans.
- batter slopes (shown in **Figure 6-4** to **Figure 6-6**) will be graded at a maximum of 15% and therefore, will be well below the angle of repose.
- cross section XS-2, XS-3, and XS-4 (shown in **Figure 6-5** and **Figure 6-6**) show a west-east profile across the out-of-pit and eastern in-pit waste rock dump. The dumps are intended to be shaped to grade to the west in order to direct runoff along the western side of the final landform to the planned drainage structures.
- contour banks and plateau drains along the final landform surface are intended to be lightly vegetated and lined with a suitable erosion control material (as shown on **Figure 6-4** to **Figure 6-7**).
- no final voids are proposed. All open cut pits will be backfilled with overburden material.
- when sediment dam catchments are completely rehabilitated, and water quality monitoring of the runoff has established that it is consistent with natural background conditions, the sediment dam and associated drainage infrastructure will be decommissioned.

The materials used in the construction of levees and final landforms will be considered at the time of detailed design.

Impacts on downstream water quality

Preliminary baseline monitoring indicates that water quality in the surrounding environment is of poor quality. Notwithstanding, the water balance modelling indicates that no mine-affected spills are predicted from mining operations. In addition, modelling predicts that spills from the sediment dams will possess electrical conductivity below

the 720 µS/cm Water Quality Objective (WQO) for low flows (**Appendix A**). Baseline salinity exceeds the WQO for high flows.

In consideration of the already-heavily disturbed nature of the surrounding catchment, it is unlikely that Mine releases will have a measurable impact on receiving water quality or environmental values (**Appendix A**).

Receiving Environment Monitoring Program (REMP)

A Receiving Environment Monitoring Program (REMP) has been developed that specifies the monitoring program for the local receiving waters. The REMP will incorporate the historical and monitoring as described in **Section 9.1.8** of this PRC Plan.

The main objective of the REMP is to report against WQOs for local waterways potentially affected by discharge from the Mine and assists in assessing general aquatic ecosystem health.

A set of initial proposed receiving water contaminant triggers levels have been developed, based on conditions at nearby operating coal mines and preliminary baseline results. These trigger levels (see **Table 5-2**) are to be measured at the upstream and downstream water monitoring locations (i.e. VSW1, VSW2, VSW3 and VSW8). Monitoring at these locations will allow for an accurate evaluation of the impact of any releases from the Mine and allow for identification of any upstream influences that are not associated with the Mine.

Contaminant Sources, Pathways and Receptors

As outlined in **Section 6.1.5,** the geochemistry assessment results indicated some waste rock materials have a low risk of generating AMD and some of the deeper waste rock materials are classified as PAF. In addition, coal reject materials generated from washing the target Matilda seam are classified as PAF.

Overall, surface runoff and seepage from the overburden/interburden material is expected to be pH neutral to slightly alkaline and have a low level of salinity if PAF materials are managed appropriately. Dissolved metal and metalloid concentrations in surface runoff and leachate from bulk mining waste materials are expected to be low and unlikely to pose a significant risk to the quality of surface and groundwater resources.

As such, the primary source of contaminant during rehabilitation works and the post-rehabilitation period of the site will be potential increases in sediment load and turbidity of surface water flows. The pathway of any potential elevated sediment load will be the surface water flows across the final landform as outlined in **Section 6.1.7** and **Figure 6-3**. The potential receptors are the downstream catchments and receiving environment, as described in detail in **Section 1.2.5.**

The controls for potential elevated sediment loads and turbidity include revegetation and rock mulch (**Section 6.2**), and water management structures such as contour banks, sediment dams, and plateau drains as detailed in **Section 6.1.7.**

Release contaminant trigger investigation levels

The WQOs for the Mine (**Table 5-2**) will be used as release contaminant trigger investigation levels. Should surface water monitoring show that a release from the Mine are above the WQOs, an investigation will be undertaken into the release. Reporting of the spill will be undertaken in accordance with the EA.

6.1.8 Hydrogeology

A detailed hydrogeological impact assessment has been completed by Hydrogeologist.com.au Pty Ltd for the Mine and is provided in **Appendix B**. The summary below of the hydrogeology has been primarily sourced from the hydrogeological impact assessment.

Hydrogeologist.com.au (2022) has developed a numerical hydrogeological model of all relevant aquifers within the ML and broader region to predict the effects of the Mine on local groundwater levels. This was based on a range of data sources, including an on-site groundwater monitoring network, groundwater assessments from nearby mines, and the Queensland Groundwater Database (DNRME 2019).

An adaptive management strategy is proposed to assist with the management and mitigation of any potential drawdown and water quality impacts on the site. The overall framework for the adaptive management strategy is to undertake a number of ongoing monitoring programs of groundwater level and water quality, and the development of site-specific groundwater trigger levels and contaminant limits.

Drawdown Monitoring

Ongoing monitoring of groundwater levels within the monitoring network will enable natural groundwater level fluctuations (such as responses to rainfall recharge) to be distinguished from potential groundwater level impacts (drawdown) due to dewatering/depressurisation resulting from mining activities. Automatic data loggers are currently installed in the groundwater monitoring network and record daily measurements. These data loggers will be downloaded quarterly to coincide with groundwater quality sampling.

The groundwater monitoring network (**Figure 9-4**) is considered fit for purpose for this assessment, and will form the basis for ongoing drawdown monitoring and management through the life of the Mine (**Appendix B**).

Predicted drawdown due to mining operations is limited to generally less than 2 km from the Jupiter pit and 300 m from the Matilda pit (that is the lateral distance from the pit to the 1 m drawdown contour) (hydrogeologist.com.au 2020; hydrogeologist.com.au 2022). Predicted drawdown is also limited in magnitude (up to 10 m) (hydrogeologist.com.au 2020; hydrogeologist.com.au 2022). This limited drawdown propagation is mainly due to the limited extent of saturation in the Mine area, the low hydraulic conductivities and low storage coefficients. The predicted drawdown extends towards the east, toward Saraji Mine.

Any effects of drawdown will cease soon after the cessation of mining, with no expected residual drawdown post closure (hydrogeologist.com.au 2022). No surface expression of groundwater will occur once the final landform is constructed. Due to this negligible risk, no measures are required or proposed to limit groundwater discharge to the surface (hydrogeologist.com.au 2022). Following recharge, minor groundwater interaction with placed waste material within the former pits are expected. However, based on assessments of the waste material and the current quality of groundwater, this is anticipated to be of limited consequence.

There are no third-party groundwater users within the predicted extent of drawdown and hence impacts on existing users are considered very unlikely. The nearest third party bore (to any of the mine pits) is 700 m from the 1 m predicted drawdown contour line. An uncertainty analysis undertaken by hydrogeologist.com.au (2022) also shows that the maximum probable drawdown does not extend to the nearest third party bore, and that impact to the bore is very unlikely. This is a substantial buffer, and together with the groundwater monitoring program, will ensure that third-party bores are not put at undue risk by the Mine.

Surface- Groundwater interaction

An assessment of the mechanism of recharge from surface water systems in the Mine area was undertaken (Hydrobiology 2022). It was concluded that there was no significant surface-groundwater interaction in the Mine area. It was also determined that impacts on surface waters from groundwater interaction are considered extremely unlikely.

Site-specific Groundwater Quality Parameters

All groundwater sampled to date in or near the ML is brackish to highly saline, being sodic waters of marine origin. Electrical conductivity of groundwater on site ranges between 2.6 to 22.8 dS/m, with a mean value of 6.1 dS/m (hydrogeologist.com.au 202). For context, sea water has an electrical conductivity of approximately 50 dS/m, while drinking water has 0.05–0.5 dS/m. The pH of groundwater on site is generally close to neutral (hydrogeologist.com.au 2022).

Monthly and quarterly groundwater quality monitoring and sampling of the groundwater monitoring network will continue in order to provide longer term baseline data for the formulation of site-specific triggers. The groundwater quality parameters monitored are those outlined in EA0002912.

Trigger values have been developed using water quality data from the groundwater monitoring network through a groundwater quality trigger assessment (hydrogeologist.com.au 2021). The methodology to determine the proposed groundwater level trigger thresholds included:

- determining the pre-mining baseline level for each monitoring bore;
- calculating the seasonal variation in the groundwater levels for each monitoring bore; and
- extracting the predicted groundwater drawdown for each monitoring bore from the numerical model.
- collating the available groundwater quality data from the groundwater monitoring bores;

- analysing the available groundwater data and developing summary statistics for each individual bore listed in the UWMP, and each aquifer or geological formation monitored by the groundwater monitoring bores (i.e., Dysart Lower Lower (DLL) coal seam and the Matilda (MAT) coal seam);
- comparing the summary statistics to published groundwater quality objectives that are designed to protect environmental values associated with the local groundwater regime; and
- developing groundwater quality triggers that address the environmental protection requirements of an EA condition.

The methodology and overall approach to determining site-specific groundwater trigger levels and contaminant limits has been developed to present the most accurate measure of effect on water quality, particularly in the context of the short life of the Mine, the relatively low groundwater values, and the minimal potential for groundwater impacts for the Mine. Given the impact on groundwater quality in the regional context from the many surrounding established, large-scale, long-term operations, monitoring for similar impacts from the relatively small and short-lived mining operation in the same regional context, would likely yield little meaningful result.

6.1.9 Predicted Stability

An extensive review of literature was undertaken to assess the local landscape, extent of protective cover of natural slopes, and previous studies on slope stability in the region (METServe 2020). The result of this review concludes that the final landform is expected to be stable under a post-mining land use of low-intensity cattle grazing.

The following are the main lines of evidence for this:

- the final landform is similar to the topography of surrounding areas; the maximum slope in the final landform is 15%, and 45% of the local landscape comprises grazed slopes that are naturally steeper than this;
- a 30% cover of rock applied to 10-15% gradients will maintain stability until vegetation establishes;
- studies conducted at other mines across the Bowen Basin have found that 15% gradients with only a moderate groundcover of 30-40% have very low erosion rates;
- other Bowen Basin mine sites regularly achieve vegetative cover of 30 to 100% on rehabilitated waste rock, which is more than adequate for maintaining the stability of 15% gradients; and
- even after considering the removal of vegetation expected from cattle grazing, a sufficient cover is expected to be maintained on rehabilitated sites in the long-term.

Further discussion is provided in the subsections below.

The Mine is located on the eastern foothills of the Harrow Range, sandstone ridges and escarpments that rise 100-170 m above the surrounding plains. This range and much of the neighbouring plains support remnant vegetation (open eucalypt forests) that is currently used for low-intensity cattle grazing. The Mine itself is located on cleared pasture and regrowth on relatively low slopes 1 km east of the Harrow Range. Most of the soils on site are sandy and originate from colluvial deposits from the neighbouring range.

The topography of the region is shown in **Figure 6-9** and the range of natural slopes present within 3 km of the Mine is summarised in **Figure 6-10**. As can be seen from these figures, the final landform has slopes comparable to the existing natural topography, which is stable under low-intensity cattle grazing. In summary, 45.2% of the natural landscape within a 3 km radius of the Mine is steeper than the maximum slope for the final landform.

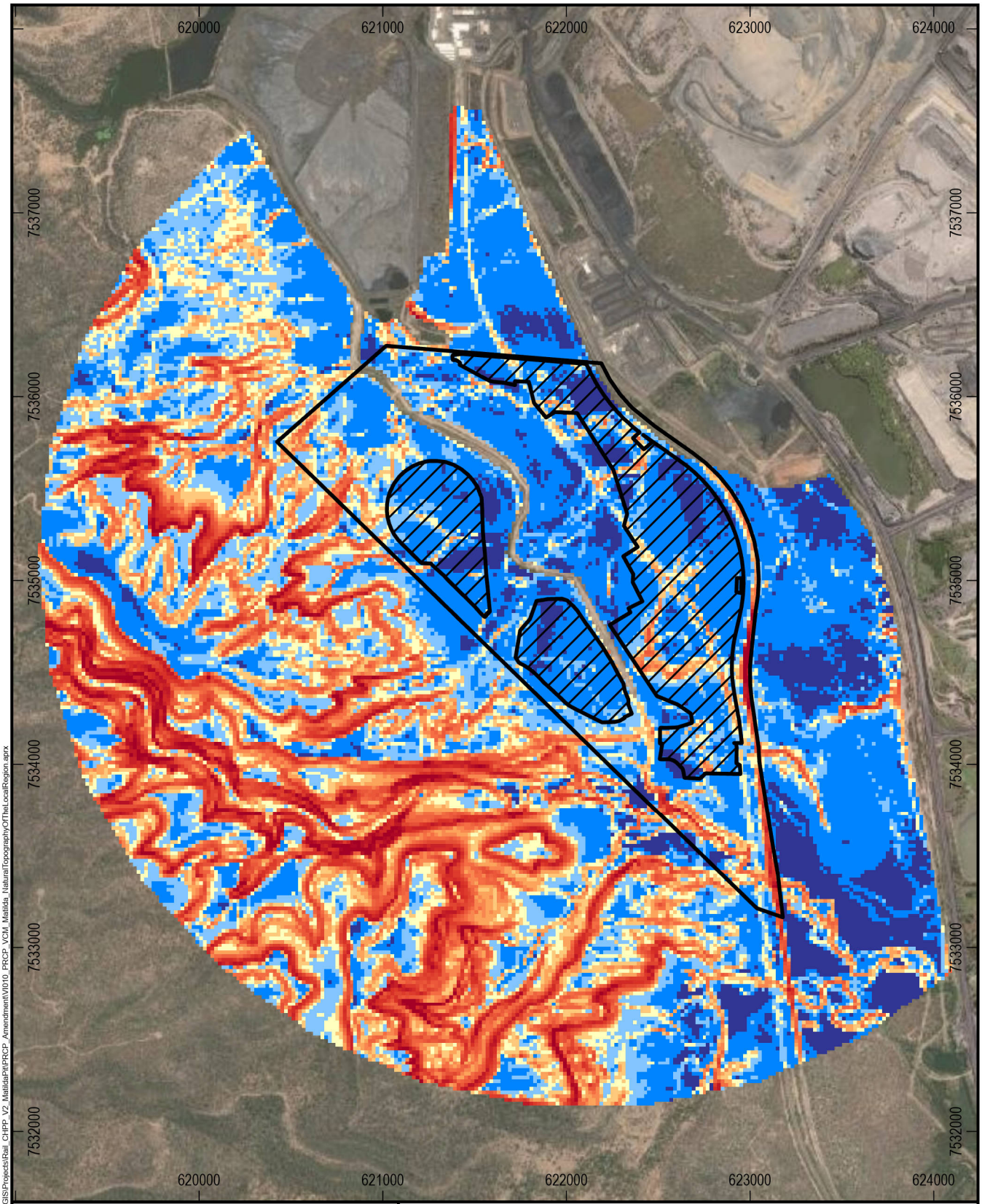
Extent of Protective Cover on Natural Slopes

Many naturally steep slopes in the local region maintain low erodibility via a high cover of rock, vegetation and leaf litter. Ecology surveys undertaken across the area surrounding and including the Mine, measured groundcover and slope across 50 sites. All sites were maintaining stability under low-intensity grazing. This data is plotted in **Figure 6-11** and identifies that when slopes were less than 20% there was no relationship between slope and percentage groundcover. These shallow slopes ranged widely in groundcover, from 40% to 95% (average = 70%). This implies that erosion is not an important force on these shallow slopes. Once slopes have a gradient exceeding 20%, increasing groundcover is required to maintain stability, and all natural sites with a slope greater than 40% had a groundcover exceeding 95%.

This data supports the notion that a final landform with slopes ≤15% will not be at risk of erosion, provided a moderate cover of rock, vegetation and leaf litter can be established and maintained. An approximate 30% cover of rock mulch is

to be applied to gradients of 10-15%. Rock is effective protection against erosion of waste slopes on newly rehabilitated mine sites (Williams 2001; Erskine & Fletcher 2013).

Rock will constitute approximately half of the protective cover required for maintaining long-term stability (based on the natural variation in cover observed in the region), while the remainder will be supplied by developing vegetation.



Legend

- ML 700060
- Waste Rock Dump

Slope Classification

- ≤5%
- 5-10%
- 10-15%
- 15-20%
- 20-25%
- 25-30%
- 30-35%
- 35-40%
- 40-45%
- 45-50%
- 50-55%
- 55-60%
- 60-65%
- 65-70%
- 70-75%
- 75-80%
- 80-85%
- 85-90%
- 90-95%
- ≥95%

Source: Mipela GeoSolutions 2020, Vitrinite 2022, METServe 2022, Maxar.

Vulcan Coal Mine

Natural Topography of the Local Region

0 250 500 1,000

Meters

Scale: 1:30,000 (A4)

6/01/2023

Datum: GDA2020
Projection: MGA55

FIGURE 6-9

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\PRCP_Amendment\VI010_PRCP_VCM_Matilda_NaturalTopographyOfTheLocalRegion.aprx

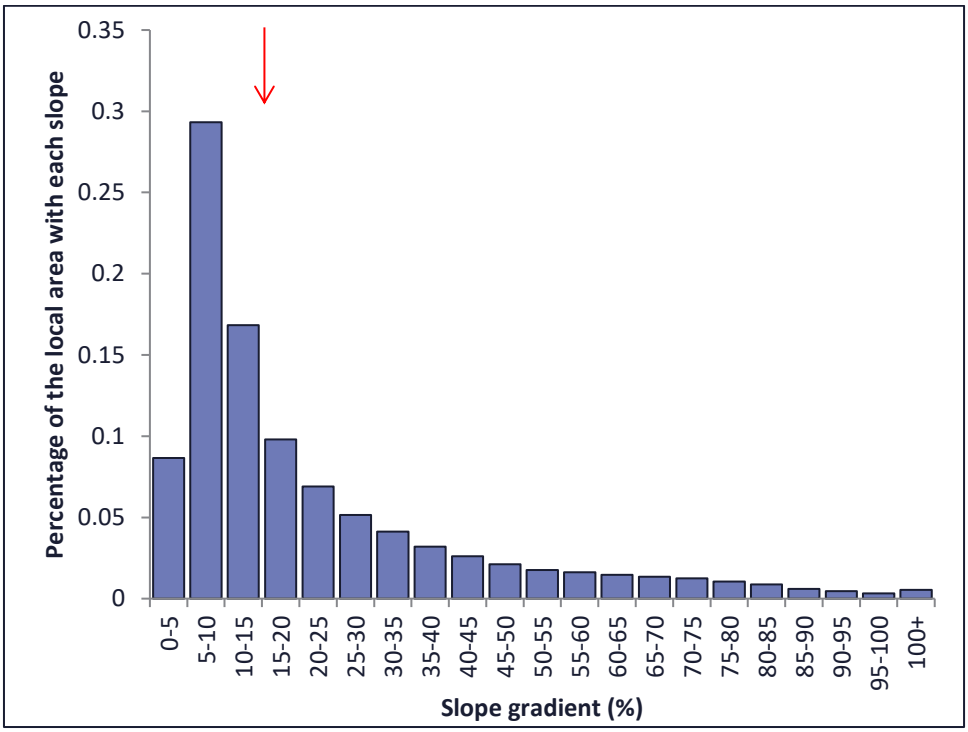


Figure 6-10 *Natural slopes within 3 km of the Vulcan Coal Mine*

The red arrow indicates the maximum slopes for the final landform of the Vulcan Coal Mine.

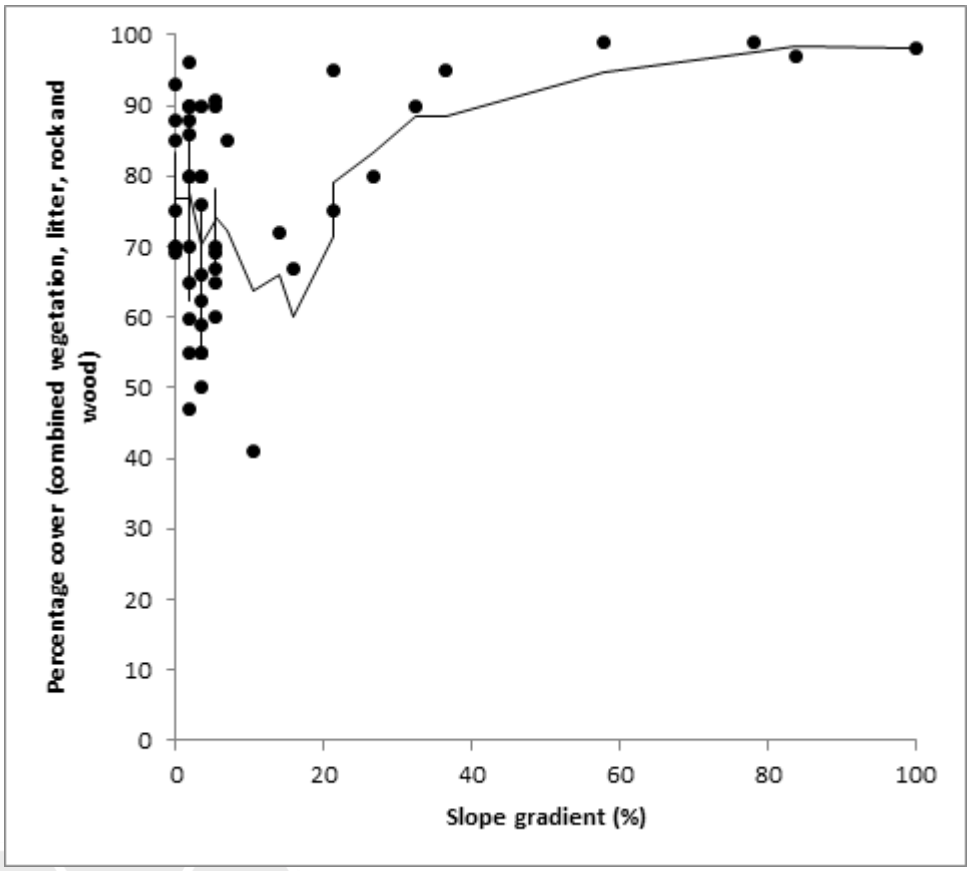


Figure 6-11 *Ground cover and slope relationship at natural vegetation sites assessed across the VCM area*

Previous Studies – Slope Stability

Other studies in central Queensland and elsewhere have investigated the stability of varying slopes on mine waste rock stockpiles and dumps. These are broadly consistent with the inferences about slope stability gained from investigating natural variation in slope and groundcover on the site.

Studies in Queensland demonstrated that any gradient exceeding 3.5%, if not protected by some sort of cover, will erode under average rainfall conditions, and extreme rainfall can erode bare slopes greater than 0.35% (Williams 2001). However, rock or vegetation cover drastically reduces erosion rates (**Figure 6-12**).

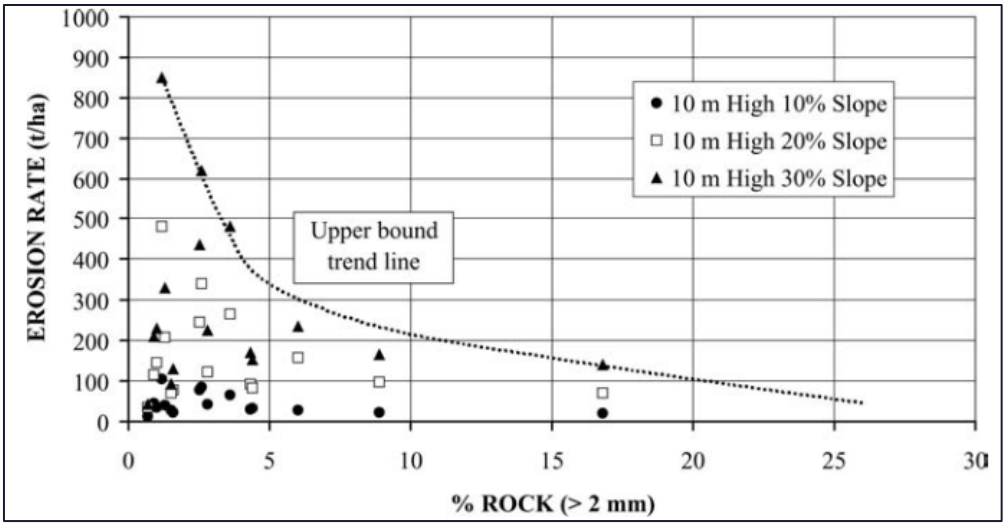


Figure 6-12 Erosion rate versus percentage rock for Bowen Basin soil materials (figure from Williams 2001)

The amount of cover required to protect slopes of various gradients from erosion has been investigated in numerous trials across Central Queensland. Carroll and Tucker (2000) found negligible differences in soil erosion for 10%, 20% and 30% slope gradients once vegetation established (**Figure 6-13**). Both Carroll *et al*. (2010) and Waters (2000) found that maintaining ground cover at 40-60% was sufficient in reducing erosion to negligible levels (<0.5 t/ha), regardless of slope. Likewise, a trial undertaken at Tarong, which simulated a heavy rainfall event on a 15% slope, found that 30-40% ground cover was sufficient to protect against erosion (Loch 2000: **Figure 6-14**).

In light of published data, the approximately 30% rock cover for slope gradients of 10-15% will provide sufficient protection for these slopes during periods of low vegetation cover (e.g., initial phase of rehabilitation, or following fire or drought). An additional vegetation cover of 10-20% (total groundcover of 40-50%) is expected to provide a highly stable landform in the long-term.

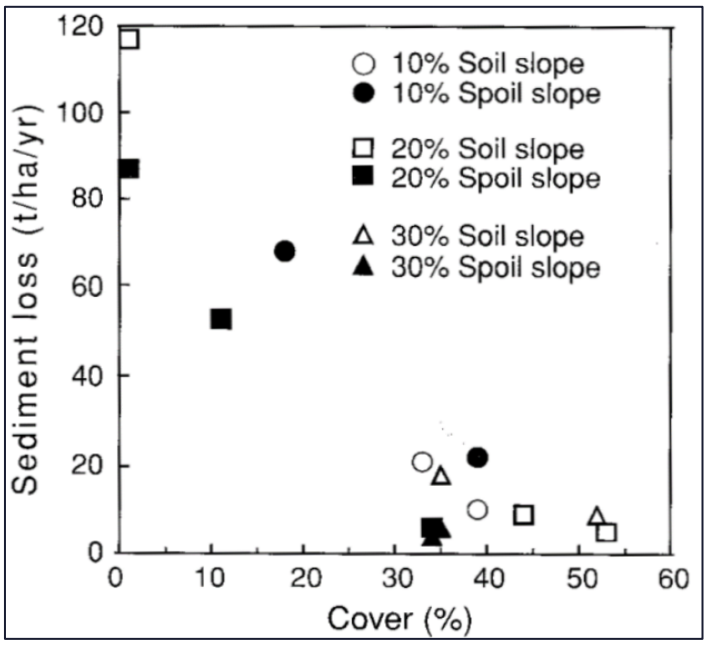


Figure 6-13 Annual sediment loss versus pasture cover on soil and spoil stockpiles at Oaky Creek (Figure from Carroll and Tucker 2000).

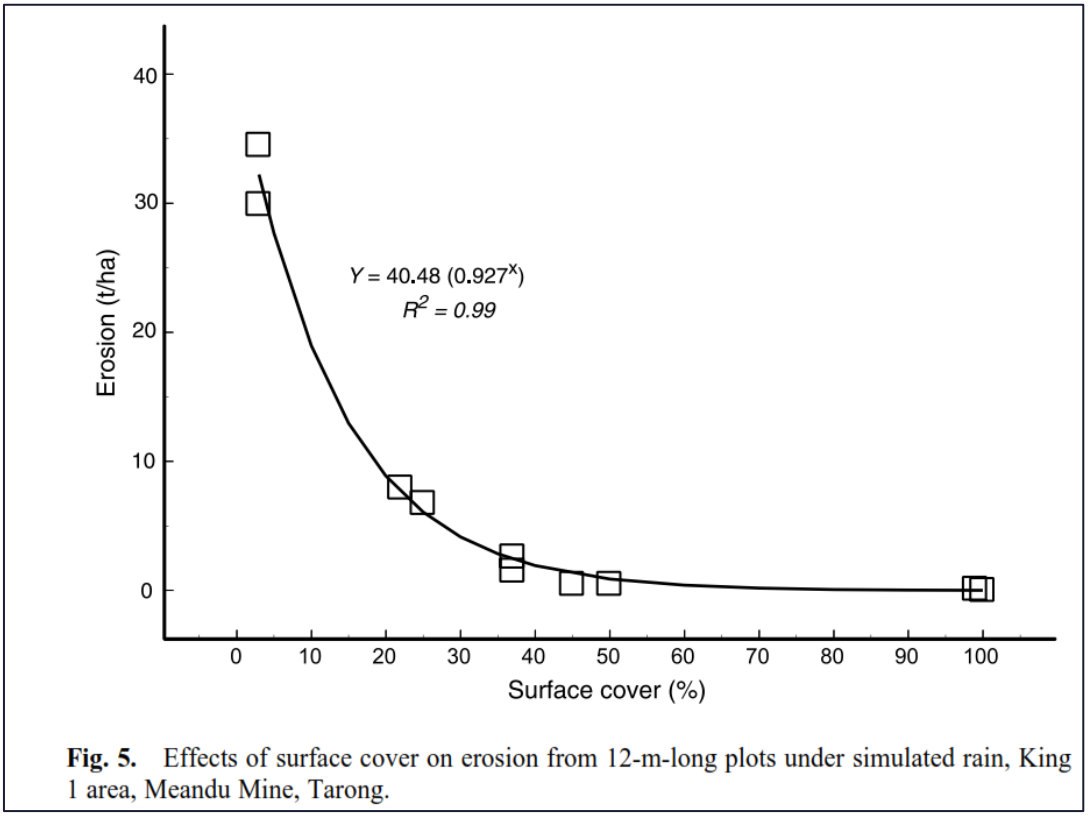


Fig. 5. Effects of surface cover on erosion from 12-m-long plots under simulated rain, King 1 area, Meandu Mine, Tarong.

Figure 6-14 Effect of surface cover on erosion (12-m plots, 15% slope, simulated rain) at Tarong (Figure from Loch 2000).

Previous Studies - Stability of Grazed Slopes

The above review of available data presents a coherent case for the selected final landform designs, having low erodibility provided they have a moderate vegetation cover of 10-20% (in addition to 30% rock cover). However, in order for the landforms to have long-term stability, they must also support the prescribed post-mine land use of low-intensity grazing. Livestock affect landform stability by removing a portion of the vegetation cover and damaging soil surface structure via trampling (Blackburn 1983). For this reason, a review of published data concerning stability of slopes under grazing was undertaken.

Comparisons between adjacent grazed and ungrazed pastures at Charters Towers found that grazing regimes prevalent at the time reduced protective cover (vegetation and leaf litter) by 0–88% (mean of 41%), depending on seasonal conditions (Scanlan *et al*. 1996). Ludwig and Tongway (2002) found this reduction in cover to be less severe; grazing led to an 11% reduction in perennial grass cover and a 29% reduction in canopy cover of trees (correlated with leaf litter cover). Taken together, this data predicts that grazing in central Queensland removes, on average, approximately 1/3 of the vegetative groundcover. When this is taken into account, a target vegetative cover (grass, herbs and leaf litter) of 15-30%, in addition to the 30% rock cover to be added to slopes, will be required in an ungrazed rehabilitated landscape to achieve a target cover of 40-50% once grazing is introduced. Given that other Bowen Basin mine sites regularly achieve vegetative cover of 30 to 100% (Carroll and Tucker 2000; Erskine and Fletcher 2013), a pre-grazing target of 15-30% vegetative cover is highly likely to be achieved at the Mine.

As summarised above, cattle currently graze natural slopes with gradients well in excess of 15% without compromising the stability of these slopes. However, the steepest slopes are somewhat protected from grazing because cattle prefer not to graze such areas (Mueggler 1965; Ganskopp & Vavra 1987). Nevertheless, gradients of 15% are well within the range of slopes utilised by cattle for grazing (Ganskopp & Vavra 1987), and the landform for the Vulcan Coal Mine is consistent with low-intensity cattle grazing.

Erosion Assessment

While the above literature review suggests that the final landform is highly likely to be stable, no trials have been undertaken on the specific soil units to be used for rehabilitation at the Mine. Given the sandy texture and dispersive subsoils, a soil erosion assessment was undertaken by AARC (2021) to investigate the likely erosion rates to be expected on the final landform, in relation to background rates in the local region. The key results of this assessment are described in detail below.

The erosion assessment applied the Revised Universal Soil Loss Equation (RUSLE) to estimate the average annual soil loss caused by hillslope and rill erosion, based on the physical characteristics of the soil, slope and cover. This equation is:

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

Where:

- A is the predicted rate of soil loss in tonnes per hectare per year;
- R is the rainfall erositivity factor, based on the total erosive power of storms during an average eyar and is dependent on local weather conditions;
- K is the soil erodibility factor, which has been specifically derived for the Crocodile, Limpopo and Zambezi soil management units;
- LS is the slope length-gradient factor, which describes the combined effect of slope length and gradient on soil loss;
- C is the cover and management factor, which compares the protective effect of vegetation and other soil covers to a standard fallow plot; and
- P is the conservation or support practice factor, which reflects the effects of management practices such as contouring or strip cropping, compared to straight-row farming up-and-down slope.

The K factor was calculated according to the methodology described by Lu *et al.* (2001), which uses the equation:

$$K = 2.77(100\ P_{125})^{1.14}(10^{-7})\ (12\text{-}20C) + (3.29 \times 10^{-3})\ (PP\text{-}3)$$

Where:

- P125 is the percentage of soil clay, silt and sand particles less than 0.125 mm diameter;
- OC is the organic carbon content; and
- PP is the soil profile permeability class.

An R factor of 1,729.45 MJ/mm per ha/h/y was chosen, based on imput R factor datasets available for use in the RUSLE data, available from the Queensland Spatial Catalogue. A P factor of 0.8 has been adopted, based on undisturbed loose soil to a depth of 0.3 m. Slope characteristics for the pre-mining landscape within each soil management unit were investigated with LiDAR imagery. The 10th percentile, median and 90th percentile slopes, and the corresponding slope lengths were used to determine the LS factor for each soil unit. The C factor was based on field-collected estimates of vegetative, rock and wood debris cover within each soil unit.

Due to the many assumptions and inputs for each of the factors, the erosion estimates are best used for comparative purposes (e.g., comparing different management measures or cover options), rather than for providing absolute estimates of erosion. Likewise, the equation predicts long-term annual soil loss, and erosion rates measures over shorter time scales may vary drastically from the estimates.

The estimated background (pre-mining) erosion rates for the three local soil management units within 3 km of the Vulcan Coal Mine are presented in **Table 6-3.**

Table 6-3 Estimated background erosion rates

Soil Unit (slope percentile)	C	Gradient (%)	A (t/ha.y)
Crocodile: 10th percentile	0.015	4	0.4
Crocodile: median	0.015	12	1.7
Crocodile: 90th percentile	0.015	39	7.2
Limpopo: 10th percentile	0.075	1	0.6
Limpopo: median	0.075	3	1.8
Limpopo: 90th percentile	0.075	14	11.2
Zambezi: 10th percentile	0.005	2	0.2
Zambezi: median	0.005	8	1.2
Zambezi: 90th percentile	0.005	38	9.7

These background erosion rates are lower than those calculated by Lu *et al.* (2003), who found erosion rates of 10-50 t/ha.y for the vicinity of the Mine. Lu acknowledges that their full erosion potential may not be realised for some areas of Queensland and northern Australia because of the high percentage of rock cover and shallow soil depths. As the estimates presented in **Table 6-3** incorporate rock cover as part of the C factor, these are probably more representative than those of Lu.

A similar approach was then applied to the post-mining landform, in order to determine whether the erosion rates are comparable to background levels. K and R factors remained the same as for the background assessments. The P factor was 0.9, based on contour ripping of the slopes. A slope length of 100 m was used for the calculations of LS, and a range of gradients were applied.

The resulting erosion estimates are presented in **Table 6-4**. This reveals that most surfaces of the final landform (gradient ≤ 5%) will have erosion rates resembling background levels provided these possess 50% or more vegetative cover. Batters of the waste rock dumps (with 10-15% gradients) will have erosion rates resembling the 90th percentile of background rates when these have 50% grass cover in addition to 30% rock cover.

When the grass cover increases to 70% (combined with rock cover), erosion rates are expected to be close to, but slightly above, median background levels. Given that these batters will comprise the steepest 15% of the total ML,

comparison with the 90th percentiles of the pre-mining slopes is appropriate. Overall, this erosion assessment confirmed that, provided rehabilitation milestone criteria are achieved, the final landform is expected to erode at a similar rate to the surrounding landscape.

Table 6-4 Predicted soil erosion rates of the Limpopo soil management unit as a factor of slope and cover

Management	C	Gradient (%)	A (t/ha.y)
Bare ground (pre-vegetation)	1	1	10.27
Bare ground (pre-vegetation)	1	5	69.34
Bare ground (pre-vegetation)	1	10	167.96
30% rock mulch (pre-vegetation)	0.325	10	54.59
30% rock mulch (pre-vegetation)	0.325	15	99.58
30% grass cover	0.325	1	3.34
30% grass cover	0.325	5	22.54
30% grass cover	0.325	10	54.59
30% rock mulch with 30% grass cover	0.1	10	16.8
30% rock mulch with 30% grass cover	0.1	15	30.64
50% grass cover	0.15	1	1.54
50% grass cover	0.15	5	10.4
50% grass cover	0.15	10	25.19
30% rock mulch with 50% grass cover	0.05	10	8.4
30% rock mulch with 50% grass cover	0.05	15	15.32
70% grass cover	0.05	1	0.51
70% grass cover	0.05	5	3.47
70% grass cover	0.05	10	8.4
30% rock mulch with 70% grass cover	0.018	10	3.02
30% rock mulch with 70% grass cover	0.018	15	5.52

Rows shaded dark grey possess slopes and covers that meet rehabilitation targets defined by this PRC Plan

Quality Assurance and Control

The final landform will be surveyed following its completion and as-constructed plans drawn, to check compliance with the design plan. These surveys constitute a rehabilitation milestone (**Section 9.1.3**).

Monitoring of the final landform will be integral to the early detection of erosion and will allow for early intervention. **Section 9.1.8** details how erosion and land stability will be monitored.

Geotechnical Assessment

Geotechnical assessments have been carried out by Blackrock Mining Solutions Pty Ltd for the Mine and are provided in **Appendix G** and **Appendix H**. The summary below has been primarily sourced from these geotechnical assessments.

Limit equilibrium analyses were performed to determine the overall slope stability in terms of a Factor of Safety (FoS), which is a commonly employed measure in slope stability analysis to determine the likelihood of slope failure. The FoS is generally a measure of driving forces versus resisting forces in a system. FoS values > 1 are indicative that a system is likely to be stable, while an FoS value of 1.5 is considered to be the generally accepted value for long-term slope design.

The following methodology and criteria were used for the assessment:

- circular failure analyses using the auto-refine search algorithm and the general limit equilibrium method for spoil failures; and
- a basal saturated spoil layer of approximately 5 m thickness was assumed for final landform slope stability assessment.

Limit equilibrium analyses were used in terms of a circular failure mechanism acting through the unsaturated, and saturated Category 2.5 spoil material, for in-pit and ex-pit WRD final landforms, respectively.

Initial analyses returned critical Factor of Safety (FoS) values of 3.88 and 5.10 for the Jupiter in-pit WRD and ex-pit WRD final landforms, respectively. It was concluded from the limit equilibrium analyses that the final landform design exceeds the minimum FoS of 1.5 for long-term stability and is therefore acceptable from a geotechnical perspective. Minor amendment of the height and volume of the ex-pit WRD has since occurred, however the final landform has been assessed as having an insignificant influence on the FoS value, as the slope design has not been altered. Similarly the reconfiguration of the ex-pit WRD is anticipated to be insignificant, and the slope angles and slope lengths have not changed, due to the berm and batter configuration. The Matilda in-pit WRD has similar or identical design geometry and material properties to that of the Jupiter in-pit WRD, therefore Vitrinite is confident that the FoS value for the in-pit and ex-pit WRD landforms remains in excess of the minimum value of 1.5 required for long term landform stability.

6.1.10 Landform Evolution Modelling

The Mine landform evolution modelling (LEM) assessment was undertaken for the three proposed waste rock dump (WRD) landforms. The three landforms assessed included the ex-pit WRD, Jupiter in-pit WRD and Matilda in-pit WRD. The LEM assessment involved the analysis of the proposed WRD cover designs and embankment slopes to demonstrate the targeted landform rehabilitation criteria and long-term stability of the landforms would be achieved.

The assessment used SIBERIA software to simulate erosion behaviour for the three proposed WRD landforms over a 10-year and 100-year timeframe. The results of the SIBERIA erosion modelling highlighted the predicted rilling, gully erosion and sedimentation for each of the potential cover design scenarios which were compared to rehabilitation objectives determined in the PRCP. An erosion risk rating was determined for each of the assessed cover design scenarios based on these rehabilitation objectives. The outcomes of the LEM assessment show that once the proposed WRD landforms have fully established a cover of rock mulch with grass cover, rehabilitation objectives as outlined in the PRCP would be achieved. Erosion objectives achieved with this cover design in place include:

- Erosion depth only affecting uppermost topsoil layer;
- Land is stable, only minor active rills or gully erosion no deeper than 0.25 m;
- Minor risk of sedimentation to downstream waterways; and
- Vegetative cover is considered widely established and effective however may have reduced ability to recover in some areas.

Recommendations of the assessment include incorporation of contour bank structures during detailed design to reduce slope lengths if proposed landform slope lengths exceed 180 m or are steeper than 15% to reduce potential erosion risk ratings. It was also recommended that the proposed WRD rehabilitation areas are monitored up until the sufficient rehabilitation cover management has been fully established and meet milestone criteria, and any rilling or gully erosion up until the target vegetative cover is established is remediated to the proposed landform design.

More detailed LEM information is outlined in the provided LEM Assessment Report (**Appendix F**).

6.1.11 Infrastructure to be Retained

Vitrinite has entered into an agreement with BMA to hand back to BMA most of the infrastructure within the northern infrastructure area of the Mine. Infrastructure contained within this area, which is to be retained for BMA includes:

- field offices;
- workshop;
- warehouse;
- communications tower;
- car parks; and
- access roads.

In addition, one sediment dam, one mine water dam and associated topsoil stockpiles will be retained, because these service the infrastructure to be retained (dams) or provide a valuable resource for potential future rehabilitation of retained infrastructure areas (topsoil stockpiles).

Due to the differing post-mining land use for this northern infrastructure area, compared to the rest of the Mine, it has been assigned its own rehabilitation area (RA6).

Likewise, the following are infrastructure that existed on site prior to the Mine that will remain unaffected by the Mine:

- flood management infrastructure for neighbouring mining operations (levee wall and adjacent farm dam); and
- the railway line along the eastern edge of the ML.

These have only been included within the Mine disturbance footprint to allow for maintenance works, if required. As these will not be rehabilitated, they have not been assigned their own rehabilitation area.

6.2 Revegetation

6.2.1 Revegetation Objectives

The following are the revegetation objectives for the site, consistent with the PMLUs:

- to ensure rapid establishment of vegetation on exposed soil in order to limit erosion over the early stages of rehabilitation;
- to establish a pasture with native and exotic grass species that is sufficiently dense in the long term to protect the soil surface from erosion and support low-intensity cattle grazing;
- to establish a moderate density of locally native trees and shrubs that provide shade for livestock and sufficient cover for the vulnerable Squatter Pigeon;
- to establish a moderate density of Koala and Central Greater Glider food trees; and
- to limit invasion by declared weed species to levels that are similar to those on site prior to mining or representative of adjacent areas.

All the above objectives apply to rehabilitation areas RA2 (the In-pit WRD's), RA3 (infrastructure areas) and RA4 (water management infrastructure areas). However, due to limited subsoil availability, no trees are proposed for RA1 (the Ex-Pit Waste Rock Dump). As a result, the rehabilitation of Squatter Pigeon and Koala habitat is not an objective for rehabilitation area RA1. No revegetation is to take place in rehabilitation areas RA5 (Saraji Road) or RA6 (infrastructure to be retained).

6.2.2 Key Flora Species

The flora species to be planted in disturbed areas vary depending on the topsoil type used at each site. The flora species selected represent the majority of dominant species in regional ecosystems that grow naturally on each soil management unit (**Table 6-5**). The Crocodile Soil Management Unit won't be disturbed as part of the Mine; however, the dominant species that grow on it have been considered for rehabilitation activities on other soil units, where species are known to tolerate alternative soil conditions.

Of the species listed, approximately half are currently commercially available from suppliers such as Nindethana Seed Service and Seed World Australia. It is therefore expected that much of the seed used for rehabilitation efforts on site will require local collection by contractors. This will also have the effect of ensuring a good degree of local provenance of seed stock is utilised in revegetation works.

Table 6-5 Key flora species found pre-mining on each soil management unit

SMU	Reference RE	Dominant Trees	Dominant Midstorey	Dominant Grasses
Crocodile	11.10.3, 11.10.13.	*Acacia shirleyi*, *Corymbia aureola*, *Corymbia citriodora*, *Corymbia trachyphloia*, *Eucalyptus crebra*.	*Acacia bancroftiorum*, *Acacia burdekensis*, *Acacia flavescens*, *Alphitonia excelsa*, *Erythroxylum australe*.	*Alloteropsis cimicina*, *Cleistochloa subjuncea*, *Cymbopogon refractus*, *Digitaria diminuta*, *Eriachne obtusa*, *Melinis repens**, *Paspalidium caespitosum*, *Themeda triandra*, *Urochloa piligera*.
Limpopo	11.5.9, 11.5.3, 11.10.7.	*Corymbia clarksoniana*, *Eucalyptus crebra*, *Eucalyptus melanophloia*, *Eucalyptus populnea*,	*Acacia burdekensis*, *Acacia flavescens*, *Alphitonia excelsa*, *Cassia brewsteri*, *Erythroxylum australe*, *Grevillea parallela*, *Grevillea striata*, *Melaleuca nervosa*, *Petalostigma pubescens*.	*Alloteropsis cimicina*, *Aristida calycina*, *Bothriochloa bladhii*, *Bothriochloa pertusa**, *Cenchrus ciliaris**, *Chrysopogon fallax*, *Eragrostis sororia*, *Eriochloa crebra*, *Heteropogon contortus*, *Perotis rara*, *Setaria surgens*.
Zambezi	11.3.2, 11.3.7, 11.3.25.	*Corymbia clarksoniana*, *Corymbia tessellaris*, *Eucalyptus camaldulensis*, *Eucalyptus crebra*, *Eucalyptus populnea*, *Melaleuca leucadendra*.	*Alphitonia excelsa*, *Bauhinia hookeri*, *Cassia brewsteri*, *Ficus opposita*.	*Bothriochloa ewartiana*, *Bothriochloa pertusa**, *Cenchrus ciliaris**, *Megathyrsus maximus**, *Urochloa mosambicensis**.

*Exotic pasture plants common on each soil prior to mining.

6.2.3 Species of Conservation Significance

Where this is consistent with a PMLU, habitat for threatened fauna inhabiting the Mine area is to be incorporated into the landscape. The following subsections detail how this will be achieved for each species of conservation significance potentially impacted by the Mine.

Koala

Habitat for Koalas can be incorporated into the PMLU of "low-intensity cattle grazing". This will be achieved by ensuring that trees established to provide shade for livestock are also food trees for Koalas. The tree species to be planted (via inclusion in the seed mix) vary by soil type, as shown in **Table 6-6**.

Table 6-6 List of Koala food trees suitable for planting on each soil management unit

Soil Management Unit	Suitable Food Trees
Limpopo	*Eucalyptus populnea*, *Eucalyptus crebra*.
Zambezi	*Eucalyptus camaldulensis* (on creek banks), *Eucalyptus populnea*, *Eucalyptus crebra*.

Squatter Pigeon

Habitat for Squatter Pigeons can be incorporated into the PMLU of "low-intensity cattle grazing" on all soil types contained within the ML, with the exception of the Crocodile soil management unit (rocky, sandstone-derived soils provide unfavourable foraging substrates).

Squatter Pigeons have two chief habitat needs that require restoration in rehabilitation sites: (1) a diversity of native and introduced pasture grasses and herbs (on which to feed) in the understorey; and (2) a minimum tree cover that generates a Normalised Differential Vegetation Index of at least 0.125 (measured across a 1-ha cell in the late dry season). As these habitat features are generally co-located in productive pastures (related to understorey productivity and diversity) and sites with Koala habitat (a moderate tree cover), a PMLU of "low-intensity cattle grazing", with a low-moderate tree cover for livestock shade and Koala habitat is likely to provide habitat for Squatter Pigeons with no additional management inputs.

Central Greater Glider

Habitat for Central Greater Gliders can be incorporated into the PMLU of "low-intensity cattle grazing" through the inclusion of suitable *Eucalyptus* and *Corymbia* spp. Greater glider species feed on the young leaves of *Eucalyptus* and *Corymbia* in a broad range of forests across eastern Australia. They have a preference for tall eucalypt forests with abundant hollows for habitat. *Eucalyptus camaldulensis* (on creek banks) tree species meet this criteria and will be planted to provide shade for livestock. The inclusion of these tree species will provide habitat trees for Central Greater Gliders.

Short-beaked Echidna

Short-beaked Echidnas are habitat generalists that are likely to recolonise rehabilitated mine sites provided these contain (1) sufficient vegetation cover (e.g. pasture, woody vegetation) for protection; and (2) populations of termites and ants. It is expected that these habitat needs will be met by any rehabilitated sites that have a suitably dense and productive pasture cover to fulfil completion criteria pertaining to sustaining a PMLU of "low-intensity cattle grazing". Consequently, no additional management inputs are required to facilitate recolonisation of rehabilitated sites by the Short-beaked Echidna.

6.2.4 Top-Soil Management

Topsoil is the most valuable soil horizon for post-mining rehabilitation. Topsoil contains a seed bank, micro-organisms and nutrients necessary for plant growth. In contrast, many of the subsoils on site are sodic and prone to dispersion if not managed correctly (AARC 2021). The soil characteristics of each soil management units present on site (see **Section 1.2.7**) were examined to determine the maximum depth to which suitable topsoil material should be stripped for stockpiling and/or rehabilitation, and to determine soil management requirements, in order to conserve an optimal growth medium for plants **Table 6-7**).

Table 6-7 Maximum topsoil stripping depths for each soil management unit

Soil Management Unit	Stripping Depth (m)*	Qualities
Crocodile	0.1	The Crocodile SMU is limited in its suitability as a topsoil medium where an improved pasture postmining land use is to be implemented. The land within this SMU has uneven rocky terrain which may introduce accessibility challenges for earth-moving machinery. Given this, the total volume of topsoil able to be sourced from this SMU may be reduced. The soil is very strongly acidic at the surface (pH 5.4) remaining so with depth. pH values such as these have potential to limit soil nutrient content and thus plant growth.
Limpopo	0.3	Topsoil is favourable for plant growth. Topsoil has a low nutrient-holding capacity and will be improved with fertiliser when planting. These sandy soils may be also be prone to erosion and will not be used on slopes exceeding 3% without appropriate measures to manage stability. Subsoils are susceptible to dispersion.
Zambezi	0.3	The Zambezi SMU is suitable for most rehabilitation purposes to a depth of 0.3 m. This surface layer has suitable pH, low salinity and is not sodic. Below this depth, the soil becomes strongly sodic with an ESP of 18.5% and is therefore at high risk of dispersion and subsequent erosion.

*Recommendations from AARC (2021).

Topsoils and subsoils are to be stored separately. Likewise, soils from different soil management units are to be managed separately. Where practicable soils should be directly placed in prepared rehabilitation areas rather than stockpiled. This conserves a viable seedbank, promotes revegetation and limits rehandling.

Topsoil Stockpiling

Where stockpiling of topsoil is required, the following measures for soil management will be implemented where relevant and practicable, to reduce the risk of soil degradation and improve the chances of rehabilitation success:

- topsoil stockpiles are to be less than 2 m high and be contoured and positioned in a manner that encourages water drainage and discourages erosion. Grass and herbaceous plants germinating from the soil seed bank are to be maintained as a protective cover for stockpiles;

- if stockpiles fail to develop a natural grass cover, they are to be seeded with a fast-growing, non-invasive, commercially available sterile grass species. Recommended species are listed in Appendix 4 of the Soil Conservation Guidelines for Queensland (DSITI 2015);
- if there is a risk of a grass cover not establishing voluntarily, stockpiles will need to be ripped and seeded with a quick establishment pasture. Topsoil should ideally be stockpiled for the minimum time. Studies have shown that most deterioration occurs within the first year (Keipert et al. 2005);
- topsoil should be stockpiled for the minimum time practicable. Studies in the Hunter Valley have shown that the majority of deterioration occurs within the first year (Keipert et al. 2005);
- stockpiles are to be monitored annually for weeds and control measures implemented to prevent weed colonisation on the stockpiles;
- where soil must be stockpiled for extended periods (>2 years), soil testing will be considered before use for rehabilitation purposes; and
- topsoil stockpiles are to be located in areas fenced to exclude livestock.

Topsoil Placement

The disturbance area within the Mine area suggests that the topsoil resource will be sourced predominantly from the Limpopo SMU. The Limpopo SMU is characterised as having moderate organic matter content and a high sand content and may therefore be at risk of erosion-induced movement (AARC 2021). For this SMU, establishing a sufficient vegetative cover to mitigate erosion risk is important, particularly as rehabilitated slopes increase. To create a favourable environment for vegetation growth, topsoil from the Limpopo SMU will require application of one or more of the amelioration measures outlined in the following sub-sections.

Where possible, placement of topsoil at a minimum thickness of 0.25 m will be undertaken for rehabilitation areas to create a growth medium of sufficient depth to hold water and support revegetation. For all rehabilitated areas, contour ripping and/or ploughing of the landform after topsoil placement will be undertaken to key the topsoil and subsoil layers together, and to improve seed germination conditions. Placement of armour rock or mulch cover to assist in stabilising the landform and reducing topsoil loss should be considered for slopes above 10%.

Topsoil amelioration

Organic matter application

Sandy soils such as the Limpopo SMU, usually have poor soil structure, low moisture retention and low available nutrient concentrations. The addition of organic matter to such soils helps to bind soil aggregates together and resist physical breakdown, improving soil structure; in turn increasing soil moisture retention and re-incorporating nutrients back into the soil. Where possible, topsoil should be stripped with its existing ground cover vegetation and, if subject to stockpiling, relocated with its cover crop vegetation.

Depending on availability, additional organic matter (such as mulches, manures, or compost), may be incorporated into the topsoil. Organic materials incorporated into the topsoil will increase organic carbon levels, providing more exchange sites for necessary cations, increase water holding capacity, and ensure less organic matter is oxidised into carbon dioxide and nitrous oxide or reduced into methane (Smith *et. al*. 2018).

Application rates will vary depending on mulch type. Straw mulch should be applied at a rate of 5 t/ha (NSW Government 2015). Note that fresh mulch should not be used in acidic soils. Manure should be incorporated at rates of 5-30 t/ha (depending on the type of manure) (MLA n.d.). If available, compost can be applied at 70-150 t/ha (Kelly 2006).

Fertiliser application

Fertilisers may be utilised to increase nutrient concentrations in soil. As the Limpopo SMU is moderately acidic (pH of 5.5) care must be taken when fertilising, as some fertilisers (such as ammonium-based fertilisers) can have an acidifying effect on the soil. Were this to occur, lime applications would be required to mitigate the fertiliser's acidifying effects.

A calcium nitrate-based fertiliser such as calcium ammonium nitrate (15 to 27% N) is suitable for this application as it has near neutral effect on soil pH and can be used to increase both nitrogen and calcium levels in the soil. An application rate of 25-50 kg N/ha should be sufficient for successful vegetation establishment (CRDC 2020). This could

be complemented with an application of sulphate of potash (41 % K) to increase potassium levels in the soil. This fertiliser would also increase sulphur and can be drilled with seeds (unlike other potassium fertilisers such as muriate of potash which can damage seed germination). Typical application rates of potassium for pastures in light soils are of around 20 kg K/ha (Department of Primary Industries n.d.).

Alternatively, urea (46.7% N) may be applied as a nitrogen fertiliser (usually the most economical nitrogen fertiliser), but this would need to be applied in combination with lime (calcium carbonate), to overcome the acidifying effects of urea. A rate of 150 kg/ha of urea is recommended for soils in low rainfall areas where soil nitrate content is below 3 mg/kg. Limestone application rates should be around 1 t/ha of lime.

It is expected that 1 t/ha of lime (incorporated in the first 10 cm of soil) will increase the pH of sandy soils by 0.57 units (Department of Primary Industries n.d.). Follow up pH testing will be undertaken to evaluate the need to add more lime – lime would be added initially at small doses and then at gradually increasing application rates as necessary.

Phosphorus application rates would be carefully determined, as many Australian native species are adapted to low phosphorus concentrations in the soil. Application rates of 10-20 kg P/ha have been suggested for grazing pastures (Victoria Government 2013) and mine restoration (Daws *et al.* 2013). To achieve this, single superphosphate (8.8% P) could be applied, which would also supply sulphate. Note this fertiliser should not be blended with urea.

After application, soil ameliorants will be incorporated into the soil to approximately 0.3 m (for example by using a scarifier or ripper tynes) so they are not lost by wind or washed away by rainfall. Ideally, after vegetation establishment (after 6 to 12 months since sowing) soils will be re-tested to determine if any follow-up application of ameliorants is required.

Besides using fertilisers, incorporating native leguminous forbs such as *Rhynchosia minima* (Rhynchosia) and *Glycine tomentella* (Hairy Glycine) to the seed mix is a natural method of increasing soil nitrogen levels due to the nitrogen fixing capabilities of legume species. This could establish natural nitrogen cycling within the topsoil resulting in long-term improvements in soil fertility and self-sustaining vegetation.

6.2.5 Subsoil Management

Most subsoils within the Mine area (with the exception of the Crocodile SMU) are dispersive and must be managed carefully to reduce the risk of erosion and sedimentation of downstream waterways. Most of these subsoils do not provide a favourable substrate for plant establishment, excluding the use of grass covers as an erosion protection measure. Instead, the following actions, where practicable, are to be taken to manage the storage of subsoils:

- subsoil to be directly placed into its final position rather than stockpiled as a priority;
- subsoil stockpiles to be contained, to ensure that any eroded material is retained within the pits and not released into waterways;
- Subsoil stockpiles should not to be placed on slopes greater than 3%, and the stockpile surface should be levelled to reduce the speed of any run-off; and
- Sediment control infrastructure is to be constructed around any stockpile areas.

Where dispersive subsoil material is to be utilised in rehabilitation works, it will be tested and, if required, treated with gypsum (calcium sulphate) prior to sowing/planting.

Dispersive soils generally have low porosity, low air movement and therefore low oxygen availability for plants. They also have slow water infiltration, which can lead to waterlogging. Gypsum application rates for moderately to severely dispersive soils usually range from 2.5 to 5 t/ha depending on site-specific characteristics (DPIRD 2020).

Given the high exchangeable sodium percentage (21.5%) and low pH present in the Limpopo subsoil, an application of 5 t/ha of gypsum is recommended (AARC 2021). Gypsum will cause soil particles to flocculate, thereby improving soil structure, increasing water and plant root penetration into the soil. Irrigation will also be important where required.

These soils should be well irrigated so that sodium is leached down the soil profile. In contrast, low amounts of water in the soil can result in sodium moving up the soil profile by evaporation.

Outside of the Mine area, the subsoil characteristics of the Crocodile and Kei SMUs do represent an opportunity for use as a soil resource, given their non-sodic nature throughout the depth profile.

If available as a soil resource, consideration will be given to incorporating ameliorants to address the pH limitations of these materials and improve their potential to support a rapid and successful rehabilitation outcome.

6.2.6 Revegetation Approach

Soil Spreading

A growing medium of approximately 250 mm of topsoil will be placed over the deposited and shaped subsoil/waste-rock (see **Section 6.1.4**). Organic material harvested from the mine footprint will be incorporated into the topsoil, where practicable.

Following the spreading of topsoil, rehabilitated areas are to be ripped to a depth of 0.4 to 0.5 m. Ripping reduces compaction from heavy machinery, encourages the infiltration of water and reduces the risk of erosion.

Spread and ripped soil should have a rough surface with abundant troughs and banks, which help to resist erosion, improve infiltration and retain leaf litter. In accordance with the results of trials elsewhere in the Bowen Basin (Williams 2001), a rock cover (sourced from waste rock) is to be placed upon topsoil on slopes greater than 10% (equivalent to 6°). This rock is to constitute approximately 30% of the soil cover, to convey optimal erosion protection during the initial stages of vegetation establishment (Williams 2001). Further detail on the use of rock cover and establishment of grass cover is outlined in **Section 6.1.9**.

Where practicable, topsoil placement will occur in October-November, shortly before the commencement of the wet season. Soil operations are to be undertaken when the soil is dry or damp, but not saturated. Manual handling of wet soils is logistically difficult, damages the soil's structure and leads to compaction.

Fertiliser and Soil Amelioration

Most of the topsoils within the Mine area are nutrient-deficient, and the addition of an initial fertiliser application at the time of planting will facilitate plant establishment and growth. A controlled-release fertiliser with the following nutrient concentrations is to be applied at the time of seeding as required:

- Nitrogen: 7.0-25.0%;
- Phosphorus: 0.3-2.0%; and
- Potassium: 4.0-15.0%.

Application rates should follow the manufacturer's guidelines, but are expected to be 100-500 kg/ha, depending on nutrient concentrations. Further detail on specific application rates of fertilisers if required for amelioration of different anticipated conditions is also outlined above.

Seeding

Seeding operations shall not take place until the prepared area has been constructed in accordance with the specified requirements. Ideally, sowing should take place within one week of topsoil placement and ripping. Rainfall between cultivation and sowing results in the partial collapse of furrows and crusting of the soil surface. Sites may need to be re-ripped prior to sowing if rain occurs following the initial treatment. Seeding operations are not to be undertaken on days:

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

The seed mix to be applied varies by soil management unit (**Section 6.2.7**). However, all seed mixes are to include a combination of sterile grass varieties (e.g., Silk Sorghum *Sorghum* spp. and/or Japanese Millet *Echinochloa esculenta*)—which act as cover crops—native species and pasture species.

A fast-establishing sterile annual cover crop is recommended to be included in the seed mix. This will help to rapidly establish ground cover and minimise topsoil loss. This approach will also help to supress weeds and assist in restarting biological processes in the soil, creating a favourable micro-environment for the germination and emergence of the native seeds.

Considering the sandy nature of the Limpopo topsoil, it is recommended that a cover crop is sown at a high seed density, of approximately 30 kg/ha. This should provide a rapid ground cover and assist in achieving soil stabilisation. The seed mix is to be uniformly blended with a bulking agent such as dry sand or dry, fine sawdust at a rate of 1 part seed to 5 parts bulking agent by volume. This mix is then combined with fertiliser on the day of planting and distributed evenly across the planting area. Seed may be pre-mixed and stored with the bulking agent for several months; however, fertiliser should not be stored with seed for longer than necessary.

Hydromulching

Where deemed appropriate on the steepest banks that are more disposed to potential erosion, Hydromulching will be implemented. Hydromulching will be undertaken with a slurry of water, seed, fertiliser, mulch and a binder to contribute to ideal growing conditions and rapid vegetation through the stabilisation of the landform, incorporation of organic matter and nutrient addition.

Planting of Container Stock

Some species of trees and shrubs (especially those with fleshy fruits, such as *Erythroxylum australe* and *Carissa ovata*) recolonise poorly from directly sown seed, and are best reared in a nursery environment and planted as one-year-old tube stock. Monitoring of previous years progressive rehabilitation on site (i.e. detecting the failure of certain species to germinate in situ) will inform which species should be prioritised for container stock in ongoing rehabilitation campaigns.

Container stock is to be hand-planted in clusters of 5-10 individuals, each seedling spaced approximately 2 m apart. The planting of container stock is to take place within five days of heavy rain (>40 mm over a 24 hr period), when soil moisture levels are high. The spacing between clusters will depend on the density of other species that successfully germinate, but planting densities of up to 100 trees per hectare may be required where seed germination is particularly poor.

All container stock is to be sun-hardened for at least one month prior to planting.

Planting holes are to be excavated to a minimum diameter equivalent to twice the diameter of the plant container and to a depth equivalent to the height of the plant container. The material at the bottom of the hole is to be broken up to a depth of 50 mm. The sides of the hole are to be roughened. The top of the plant's root ball is to be level with the surrounding ground. The topsoil is to be tamped down to create a slightly depressed basin surrounding the plant, without exposing the root system.

Fencing

Livestock-proof fencing is to be installed around all revegetated areas at or prior to the completion of seeding and planting. Rehabilitated areas are to be maintained free of livestock until these sites are sufficiently established for the commencement of grazing.

6.2.7 Seed Mix

Seed is to be sourced from a combination of local collections and commercial suppliers. Local seed collections will begin at least two years prior to the commencement of revegetation, to allow for the potential of unfavourable weather to cause the failure of seed production in any one year. Seed is to be stored for a maximum of five years prior to use, and regular collections/purchases will be required throughout the Mine.

The preliminary seed mixes that have been planned for each soil management unit are shown in **Table 6-8**. These have been developed based on the dominant species of trees, shrubs and grasses present within each soil management unit

within the Mine area prior to mining. Adjustments to these seed mixes will be made, pending seed availability and the performance of the earliest rehabilitation efforts on site. It is expected that some of the species listed will display poor recruitment via direct seeding, and such species will be removed from the seed mixes and planted as container stock instead.

The value of Buffel Grass (*Cenchrus ciliaris*) for mine rehabilitation in Queensland is debated. This exotic pasture species is a rapid coloniser of disturbed ground and is effective for controlling erosion. Among earlier rehabilitation efforts in the Bowen Basin, Buffel Grass was the dominant pasture species planted (Grice *et al.* 2012). However, it is only moderately palatable to cattle and aggressively outcompetes other plant species, including more valuable pastures (Grice *et al.* 2012; Erskine and Fletcher 2013). Buffel Grass is considered the likely cause of a marked decline in species diversity over time at other mine rehabilitation areas within the Bowen Basin (Erskine and Fletcher 2013). This declining diversity jeopardises the stability and functionality of the rehabilitated landforms.

Due to the risks associated with Buffel Grass (*Cenchrus ciliaris*) and the likelihood that it will establish naturally, it is not included within seed mixes applied at the Mine, despite being dominant on some soil management units pre-mining. This approach aims to replicate the pastures occurring on site prior to mining and establish a diverse mix of native and exotic pasture species that have high pasture productivity and environmental value (i.e., can sustain the PMLUs).

Table 6-8 Seed mixes for each Soil Management Unit (SMU) for low-intensity cattle grazing PLMU

SMU	Trees and shrubs	Rate (kg/ ha)	Pasture grasses and legumes	Rate (kg/ ha)	Sterile cover crop	Rate (kg/ ha)	Total Rate (kg/ha)
Limpopo*	*Acacia burdekensis*	0.1	*Alloteropsis cimicina*	1	Japanese Millet - sterile	15	
	Acacia flavescens	0.05	*Aristida calycina*	1	Silk Sorghum	15	
	Alphitonia excelsa	0.1	*Bothriochloa bladhii*	1			
	Cassia brewsteri	0.05	*Bothriochloa pertusa*	1			
	Corymbia clarksoniana	0.2	*Chrysopogon fallax*	1			
	Eucalyptus crebra	0.15	*Eragrostis sororia*	0.5			
	Eucalyptus melanophloia	0.15	*Eriochloa crebra*	0.5			
	Eucalyptus populnea	0.15	*Heteropogon contortus*	1.5			
	Grevillea parallela	0.05	*Perotis rara*	0.3			
	Grevillea striata	0.05	*Setaria surgens*	1			
	Melaleuca nervosa	0.05	*Stylosanthes scabra*	0.5			
	Petalostigma pubescens	0.1	*Glycine tomentella*	0.2			
	TOTAL	**1.2**		**9.5**		**30**	**40.7**
Zambezi	*Alphitonia excelsa*	0.1	*Bothriochloa bladhii*	3	Japanese Millet - sterile	15	
	Bauhinia hookeri	0.2	*Bothriochloa ewartiana*	2	Silk Sorghum	15	
	Cassia brewsteri	0.1	*Bothriochloa pertusa*	0.3			
	Corymbia clarksoniana	0.3	*Megathyrsus maximus*	1			
	Corymbia tessellaris	0.3	*Urochloa mosambicensis*	1			
	Eucalyptus camaldulensis	0.5	*Stylosanthes scabra*	0.5			
	Eucalyptus crebra	0.4	*Glycine tomentella*	0.2			
	Eucalyptus populnea	0.4					
	Ficus opposita	0.1					
	Melaleuca leucadendra	0.2					
	TOTAL	**2.7**		**8**		**30**	**40.7**

*In the RA1 rehabilitation area, no trees and shrubs are to be included in the seed mix.

6.2.8 Rehabilitation Trials

In accordance with the *Progressive Rehabilitation and Closure Plans Guideline*, rehabilitation trials are not to result in the delay of rehabilitation. They should also take place in locations that have been or will be disturbed for other components of the Mine, so as to not unnecessarily enlarge the total disturbance footprint of the Mine.

The short duration of the life of Mine, the narrow window of time until the first rehabilitation commences and the lack of suitable locations to undertake trials precludes rehabilitation trials from being a useful tool for refining the rehabilitation methodology. Instead, the rehabilitation methodology has been informed by rehabilitation trials elsewhere in the Bowen Basin, as well as reference data gathered during ecological surveys of the site prior to mining. The rehabilitation methodology (e.g., seed mixes, relative contribution of tubestock, timing of planting, soil management and amelioration) will also be progressively refined following the early outcome of each year's progressive rehabilitation efforts.

The Geochemical Assessments which have been undertaken outline appropriate management practices to be undertaken throughout the construction, operations, rehabilitation and decommissioning phase of the Mine (RGS 2022). High ANC (acid consuming) material will be used as part of the operational backfilling of the in-pit WRD's to assist in managing PAF material. Coal rejects will be co-disposed, traffic compacted, and covered with 5 m of NAF waste rock material to manage the risk of acid generation potentially impacting the surrounding environment. It is a recommendation of the report (RGS 2022) that additional sampling be undertaken to confirm geochemistry and to aid in best management of materials during progressive rehabilitation.

To this end, a geochemical and geophysical sampling and resting trial will be undertaken to focus on collecting representative samples of waste rock (i.e. spoil) materials planned to be used at the surface of final landforms to supplement any existing subsoil and topsoil salvaged re-used in revegetation and rehabilitation activities. Testing will also include a suite of typical parameters including pH, EC, exchangeable cations, organic matter, total organic carbon, Emerson Aggregate, particle size distribution, and nutrients (including available K, P, S, as well as Nitrogen (N) species (TKN, TN, Nitrite and Nitrate).

Testing will also include geophysical kinetic tests of sandstone waste rock material, to assess long-term weathering characteristics and competency of waste rock material potentially to be used as rock mulch.

In the unlikely circumstance that the available sandstone material not be sufficient, either in available volume, or on the basis of its geophysical or geochemical characteristics, Vitrinite commits to obtaining a substitute material that achieves the landform stability requirements of the Mine.

Similarly, in the event that waste rock material is identified as having negative geophysical characteristics (i.e. is more susceptible to dispersion or instability), appropriate amelioration techniques and selective handing processes will be applied to maintain the integrity of the final landform.

7 SURRENDER OF THE ENVIRONMENTAL AUTHORITY

A surrender application must comply with requirements contained in section 262 of the *Environmental Protection Act 1994*. This application must be accompanied by a final rehabilitation report, a post-mining management report and a compliance statement for the EA and PRC Plan schedule.

The final rehabilitation report is to contain an environmental risk assessment and information on any proposed costs related to residual risks remaining at the site. The environmental risk assessment must be completed using a methodology agreed to by the administering authority. The risk assessment is a key step before the calculation of any residual risk costs for the site. The calculation of costs could include consideration of the present value of the future costs of likely repairs, necessary monitoring and maintenance costs and the ongoing management costs of rehabilitated land.

There is a payment as a pre-condition of the surrender of an EA in order to allow the government to address residual risks associated with a site at surrender. Residual risks may include the possibility that rehabilitation works and engineered structures may fail or the ongoing costs of monitoring and maintenance after surrender.

The residual risk requirements do not remove or change the obligations of an EA holder to complete rehabilitation to required standards. The residual risk framework enables companies to relinquish the tenure and surrender an EA whilst ensuring the State understands any remaining risks on site and is resourced to manage the risks, including possible financial consequences of future environment harm.

8 RISK ASSESSMENT

In accordance with section 126C(1)(f) of the EP Act, **Table 8-2** assesses the risks of a stable PMLU not being achieved, and how these risks will be managed or minimised. Risks specific to each rehabilitation milestone are identified. Both inherent risks (in the absence of risk treatments) and residual risks (once controls are in place) are identified and assessed for each hazard. Risks are scored based on definitions in **Table 8-1**.

Table 8-1 Scoring system used to assess risks

			Likelihood				
			1 Rare	**2 Unlikely**	**3 Possible**	**4 Likely**	**5 Almost Certain**
			Unlikely to occur in a lifetime; or very unlikely to occur; or no known occurrences in broader worldwide community.	Could occur about once during a lifetime; or more likely not to occur than to occur; or has occurred at least once in the broader worldwide industry.	Could occur more than once during a lifetime; or as likely to occur as not to occur; or has occurred at least once in the mining/ commodities trading industry.	May occur about once per year; or more likely to occur than not occur; or has occurred at least once on a mine site in the Bowen Basin.	May occur several times per year; or expected to occur; or has occurred several times on a mine site in the Bowen Basin.
Consequence	**5 Catastrophic**	Unconfined and widespread environmental damage; impacts reaching into surrounding areas; major remediation measures required.	**15**	**19**	**22**	**24**	**25**
	4 Major	Long-term (2-10 years) impact; major remediation measures required.	**10**	**14**	**18**	**21**	**23**
	3 Moderate	Medium-term (<2 years) impact; requires moderate intervention.	**6**	**9**	**13**	**17**	**20**
	2 Minor	Short-term impact; requires minor remediation or intervention.	**3**	**5**	**8**	**12**	**16**
	1 Negligible	No lasting impact; requires minor or no remediation; minor management intervention mat be required.	**1**	**2**	**3**	**7**	**11**

Table 8-2 Risk assessment for rehabilitation of the Mine

Milestone	Hazard	Impact	Inherent Risk			Rehabilitation actions	Justification of treatment option	Resource requirements	Performance measures	Reporting and monitoring	Residual Risk		
			Likelihood	Consequence	Risk Ranking						Likelihood	Consequence	Risk Rating
1: Infrastructure decommissioning and removal.	Schedule for infrastructure decommissioning and removal inadequately communicated among management and work teams.	• Failure to remove all infrastructure in accordance with the PRC Plan Schedule. • Achievement of Milestone 1 delayed.	2	3	9	• Infrastructure decommission schedule to be incorporated into annual mine planning. • Monthly progress meetings are to take place between management (i.e., responsible personnel) and work crews regarding infrastructure decommissioning and removal. • A register of infrastructure is to track which structures exist in each rehabilitation area and which have been removed.	The actions will allow the early identification of potential deviations from the PRC Plan Schedule, affording ample opportunity to adjust work rates to ensure that scheduled works are completed by the reporting date of 10 December.	Adequate time allocated for planning and progress meetings.	Refer to **Section 5.1**	Refer to **Section 9.1.1**	1	3	6
	Infrastructure decommissioning and removal takes longer than planned.	• Achievement of Milestone 1 delayed.	2	2	5	• Monthly progress meetings are to take place between management (i.e., responsible personnel) and work crews regarding infrastructure decommissioning and removal. • Additional work team resourcing may be sought in the event that the completion of scheduled works is otherwise unlikely by the annual reporting date.	The actions will allow the early identification of potential deviations from the PRC Plan Schedule, affording ample opportunity to adjust work rates to ensure that scheduled works are completed by the reporting date of 10 December.	Adequate time allocated for planning and progress meetings; funding for supplementary contractors, if required.			1	2	3
2: Remediation of Contaminated Land	Previously unidentified contamination source discovered.	• Achievement of milestone 2 delayed. • Financial cost of remediation.	2	3	9	• Records are to be kept of all spills, leaks and other incidents occurring at the Mine that might result in contamination. These incidents are to be recorded in an Incident Register, and information about relevant incidents are to be provided to an approved auditor prior to their site visit/testing. • Employees and contractors are to be made aware of their reporting obligations through a Site Induction. • Initial consultation with an approved auditor to identify contamination targets for remediation or removal.	To be suitable for a PMLU of low-intensity cattle grazing, contaminated land must be removed from the Contaminated Land Register or the Environmental Management Register and declared suitable for any use. These works must be approved by a suitably qualified person and an approved auditor (under the *Environmental Protection Act 1999* Act).	Adequate time per shift for reporting; funding for audits.	Refer to **Section 5.1**	Refer to **Section 9.1.2**	1	3	6
	Remediation work not completed to schedule.	• Achievement of milestone 2 delayed, stalling later phrases of rehabilitation.	2	3	9	• Decontamination works are to be incorporated into annual mine planning. • Monthly progress meetings are to take place between management (i.e., responsible personnel) and work crews regarding de-contamination works. • Compliance with the PRC Plan schedule is to be overseen by responsible personnel.	Decontamination works must be completed to allow sufficient time for milestones 3 and 4 to be accomplished prior to the wet-season, or milestone 5 will be delayed by an additional year.	Adequate time allocated for planning and progress meetings.			1	3	6
	Waste rock is more reactive than anticipated.	• Potential for acid mine drainage, neutral metalliferous mine drainage or saline mine drainage to reduce water quality in groundwater and surface water. • High cost of remediation.	2	4	14	• Ongoing waste characterisation throughout operations. • Ongoing testing of mine-affected water throughout operations. • Should waste rock material with more reactive chemistry than anticipated be identified during operations: – Extraction is to cease until the situation can be resolved; and – Geochemical specialists are to be consulted to advise about appropriate handling and management of the material.	Ongoing testing of waste material and mine-affected water is a standard practice in QLD mining operations. It will provide an early detection system for mischaracterisation of rock. A response procedure will aim to prevent further removal of reactive material until appropriate infrastructure can be designed and constructed to manage the material.	Adequate budget for geochemical testing.			1	4	10
3: Landform Development and Reshaping/Reprofiling	Heavy rain prior to surface preparation and revegetation (milestones 4 and 5).	• Sedimentation of downstream waterways.	3	3	13	• Slope designed with shallow gradient. • Earthworks timed to coincide with dry-season. • Sediment management systems (drains and sediment dams) to be operational during construction of final landform.	The planned low slope gradient limits the capacity for water to carry material. Heavy downpours are unlikely between the months of June and October. Sediment management systems trap eroded material before it can enter local waterways. This system has been designed in accordance with the *Best Practice Erosion and Sediment Control* (IECA 2008) guidelines.	The sediment management system has been already designed for the planning and approval stages of the Mine. Appropriate time and personnel are required for construction of this system.	Refer to **Section 5.1**	Refer to **Section 9.1.3**	2	3	9
	Timing and design specifications for final landform not adequately implemented.	• Achievement of milestone 3 delayed. • Reduced safety and/or stability of final landform.	2	3	9	• Annual audits are to confirm agreement between as-constructed landforms and approved designs. • Monthly progress meetings are to take place between management (i.e., responsible personnel) and work crews regarding landform construction.	Early detection of inconsistencies between constructed landforms and approved designs will allow adequate opportunity for modifications to be completed by the reporting date of 10 December.	Adequate time allocated for planning and progress meetings; funding for auditors.			1	2	3
3: Landform Development and Reshaping/Reprofiling (cont.)	Mining schedule changes.	• The final landform is not achieved.	3	2	8	• Detailed mine planning based on robust resource model • Short term project – less susceptible to significant influencing factors • Ability to modify designs through PRC Plan amendment possible – although undesirable.	A larger landform is not possible without approval and PRC Plan amendments. As such this Hazard is associated with a smaller scale landform. Given the progressive backfill of the pit, it is unlikely that such a landform would result in significantly different environmental outcomes, albeit of a smaller scale.	Mine planning, scheduling, surveying.	Refer to **Section 5.1**	Refer to **Section 9.1.3**	2	2	5

Milestone	Hazard	Impact	Inherent Risk			Rehabilitation actions	Justification of treatment option	Resource requirements	Performance measures	Reporting and monitoring	Residual Risk		
			Likelihood	Consequence	Risk Ranking						Likelihood	Consequence	Risk Rating
	Predicted waste rock swell factor overestimates volume of material available for preparation of final landform.	• The final landform is not achieved.	3	2	8	• Detailed mine planning based on robust geological model of well understood geological features. • Early monitoring of blasting and mining activities will inform ongoing scheduling and planning.	Industry standard swell factors have been applied. Significant deviations from this are unlikely. Minor deviations are considered unlikely to affect ability to achieve PMLU's and if lower may result in better outcome (lower final in-pit WRD).	Mine planning, scheduling, surveying.			2	2	5
4: Surface preparation	Inappropriate topsoil and subsoil management whilst stockpiled.	• Reduced viability of topsoil, limiting plant establishment at rehabilitated sites. • Topsoil infested with weed propagules, which will invade rehabilitated sites.	4	4	21	• Spatial segregation of topsoil and subsoil, with signage installed at each stockpile to denote soil type. • Topsoil stockpiles to be managed in strict accordance with practices described in **Section 6.2.6.**	By minimising stockpile heights, preventing the mixing of subsoils and topsoil, maintaining a vegetative cover on stockpiles and controlling weed populations on stockpiles before they become dominant, soil health will be maintained.	Adequate signage, herbicides and personnel are required.	Refer to **Section 5.1**	Refer to **Section 9.1.4**	2	3	9
	Inadequate topsoil cover.	• Exposure of dispersive subsoils to rain. • Gully erosion. • Cost of repeating landform reshaping and surface preparation.	3	4	18	• A minimum of 25 cm of topsoil is to be placed on all exposed subsoil. • 30% rock cover applied to topsoil on slopes. • Subsoils are to be mixed with 25% rock. • Rapidly establishing grasses to be included in seed-mixes. • Sediment management systems (drains and sediment dams) to be operational during surface preparation and revegetation.	Dispersive subsoils across the local region often naturally have a cover of only 10-20 cm of stable topsoil, and 25 cm is considered sufficient to protect the subsoil from exposure to erosional forces. A review of studies elsewhere in the Bowen Basin (refer **Section 6.1**) indicates that the measures in place at the Mine will sufficiently limit the risk of erosion.	Adequate waste rock set aside for a protective cover; seed for pioneer grasses; appropriate time and personnel are required for construction of the sediment management system and final landform according to designs.			2	3	9
	Vehicles contaminated with weed seeds used for earthworks.	• Weeds invading rehabilitated sites, inhibiting the establishment of desirable species and preventing achievement of milestones 6, 7 and 8.	3	4	18	• Strict vehicle wash-down practices for vehicles entering the site from contaminated areas. • Annual weed monitoring program, to allow the early detection and treatment of new weed infestations.	Prevention of introduction and early treatment of new infestations are central to the successful and cost-effective management of weeds on site.	Adequate time and budget for wash-downs, monitoring and weed control.			2	3	9
	Heavy rainfall occurring prior to establishment of vegetative cover.	• Loss of topsoil from slopes. • Siltation of downstream waterways. • Failure of vegetation to establish on eroded surfaces. • Cost of reapplying topsoil to eroded surfaces.	4	3	17	• Low slope gradient in landform design to limit capacity for sediment loss. • Surface preparation immediately prior to seeding to limit time that bare slopes are exposed to rain events. • 30% rock cover applied to slopes. • Rapidly establishing grasses to be included in seed-mixes. • Sediment management systems (drains and sediment dams) to be operational during surface preparation and revegetation.	A review of studies elsewhere in the Bowen Basin (refer **Section 6.1**) indicates that the measures in place at the Mine will sufficiently limit the risk of erosion.	Adequate waste rock set aside for a protective cover; seed for pioneer grasses; appropriate time and personnel are required for construction of the sediment management system and final landform according to designs.			2	3	9
5: Revegetation	Seed unavailable.	• Lack of seed of certain species can lead to long-term effects on the composition of the eventual plant communities that establish.	4	3	17	• Seed collection and procurement is to commence at the start of the Mine , so that supplies are available when revegetation begins. • A store of seed is to be maintained on site. • Woody species unavailable at the time of sowing are to be added to rehabilitated sites as tubestock in the following wet season.	Approximately half of the species to be used are not currently stocked by commercial seed suppliers and therefore require local collection. Collecting over two years prior to revegetation allows for certain species to seed poorly in any one year.	Funding for seed collection/purchase must be available from the start of the Mine.	Refer to **Section 5.1**	Refer to **Section 9.1.5**	2	2	5
	Heavy rain immediately after sowing.	• Loss of topsoil from slopes. • Siltation of downstream waterways. • Failure of vegetation to establish on eroded surfaces. • Cost of reapplying topsoil to eroded surfaces.	4	3	17	• Low slope gradient in landform design to limit capacity for sediment loss. • Surface preparation and sowing is not to take place if heavy rain (>40 mm) is forecast over any one day within the next fortnight. • 30% rock cover applied to slopes during surface preparation. • Rapidly establishing grasses to be included in seed-mixes. • Sediment management systems (drains and sediment dams) to be operational during surface preparation and revegetation.	A review of studies elsewhere in the Bowen Basin (refer **Section 6.1**) indicates that the measures in place at the Mine will sufficiently limit the risk of erosion.	Adequate waste rock set aside for a protective cover; seed for pioneer grasses; appropriate time and personnel are required for construction of the sediment management system and final landform according to designs.			2	3	9
	Inappropriate quantity of grass seed used in the seed mix.	• Tree and shrub establishment inhibited by high grass cover. • Insufficient protective cover of grass increasing the risk of erosion.	3	3	13	• Seed mixes have been based on other mine sites across north-eastern Australia. • Grass seed application rates are to be modified pending the outcome of the initial rounds of rehabilitation. • In sites with excessive grass densities, tubestock of trees and shrubs are to be planted within circles (1 m radius) of grass that have been killed using herbicide. • In sites with insufficient grass cover, there is to be supplementary sowing and/or fertilising in bare patches to encourage grass growth.	Studies elsewhere in the Bowen Basin indicate that dense grass can inhibit vegetation development (Erskine and Fletcher 2013). Early identification of issues and amendments of seed mixes will reduce overall costs associated with remediating over- or under-dense grass swards.	Adequate time for reviewing the revegetation methodology on an annual basis.			2	2	5

Milestone	Hazard	Impact	Inherent Risk			Rehabilitation actions	Justification of treatment option	Resource requirements	Performance measures	Reporting and monitoring	Residual Risk		
			Likelihood	Consequence	Risk Ranking						Likelihood	Consequence	Risk Rating
	Inappropriate quantity of tree and shrub seed used in the seed mix.	• Insufficient or excessive canopy cover can cause the eventual vegetative communities to fail to achieve milestones 6 and 7.	3	3	13	• Seed mixes have been based on other mine sites across north-eastern Australia. • Seed application rates are to be modified pending the outcome of the initial rounds of rehabilitation. • Supplementary planting of tubestock or thinning of established seedlings may be required to correct for inappropriate tree densities.	A minimum tree and shrub density is required to achieve completion criteria pertaining to the Koala and Squatter Pigeon. However, excessive tree and shrub densities limit pasture development, jeopardising the achievement of the desired PMLU. Early identification of issues and amendments of seed mixes will reduce overall costs associated with remediating over- or under-dense grass swards.	Adequate time for reviewing the revegetation methodology on an annual basis.			2	2	5
	Drought over the first months after planting.	• Poor seedling survival and establishment.	3	3	13	• Planting is to take place in the early wet season, when probability of further rain during seedling establishment is high. • Supplementary planting (seed or tubestock) may be required following exceptionally dry years.	Long dry periods soon after germination can result in widespread mortality of seedlings. The actions reduce the risk of this occurring and propose remedial actions in the event it does occur.	Adequate time and budget allocated for planting in years following drought.			3	2	8
	Vehicles and/or footwear contaminated with weed seeds.	• Weeds invading rehabilitated sites, inhibiting the establishment of desirable species and preventing achievement of milestones 6 and 7.	3	4	18	• Strict vehicle wash-down practices for vehicles entering the site from contaminated areas. • Annual weed monitoring program, to allow the early detection and treatment of new weed infestations.	Prevention of introduction and early treatment of new infestations are central to the successful and cost-effective management of weeds on site.	Adequate time and budget for wash-downs, monitoring and weed control.			2	3	9
	Intruding livestock.	• Premature grazing could lead to poor seedling establishment.	4	3	17	• Cattle-proof fencing surrounding each rehabilitation area is to be installed prior to seeding. • Fences are to be inspected monthly, faults immediately repaired and livestock immediately removed.	Rehabilitated areas are to be maintained free of livestock until vegetation is adequately established (at least five years).	Fencing materials and personnel for construction and inspection.			1	1	1
6: Commencement of Grazing	Poor pasture development	• Insufficient pasture density to meet completion criteria. • Insufficient species richness of grasses to meet completion criteria. • Increased risk of erosion.	3	3	13	• Seed mixes have been based on other mine sites across north-eastern Australia. • Grass seed application rates are to be modified pending the outcome of the initial rounds of rehabilitation. • In sites with insufficient grass cover, there is to be supplementary sowing and/or fertilising in bare patches to encourage grass growth.	Early identification of issues and amendments of seed mixes will reduce overall costs associated with remediating over- or under-dense grass swards.	Adequate time for reviewing the revegetation methodology on an annual basis; additional seed stocks and fertiliser, as required.	Refer to **Section 5.1**	Refer to **Section 9.1.6**	2	2	5
	Weeds	• Weeds invading rehabilitated sites, inhibiting the establishment of desirable species and preventing achievement of milestones 6, 7 and 8.	3	4	18	• Strict vehicle wash-down practices for vehicles entering the site from contaminated areas. • Annual weed monitoring program, to allow the early detection and treatment of new weed infestations.	Prevention of introduction and early treatment of new infestations are central to the successful and cost-effective management of weeds on site.	Adequate time and budget for wash-downs, monitoring and weed control.			2	3	9
	Excessive density of trees and shrubs	• Pasture species become shaded out. • Failure to achieve targets of rehabilitation completion criteria.	3	2	8	• Seed mixes have been based on other mine sites across north-eastern Australia. • Seed application rates are to be modified pending the outcome of the initial rounds of rehabilitation. • Thinning of woody vegetation (using machinery or fire) may be required at sites with excessive shrub and tree densities.	Early refinements of the seed mixes will reduce the need for later interventions. Vegetation thinning is widely implemented in Queensland's pastoral landscapes to increase pasture production in densely forested situations.	Adequate time for reviewing the revegetation methodology on an annual basis; machinery to undertake thinning of trees and shrubs, if required.			1	2	3
7: Establishment of target vegetation type	Poor pasture development.	• Insufficient pasture density to meet completion criteria. • Insufficient species richness of grasses to meet completion criteria. • Increased risk of erosion.	3	3	13	• Seed mixes have been based on other mine sites across north-eastern Australia. • Grass seed application rates are to be modified pending the outcome of the initial rounds of rehabilitation. • In sites with insufficient grass cover, there is to be supplementary sowing and/or fertilising in bare patches to encourage grass growth.	Early identification of issues and amendments of seed mixes will reduce overall costs associated with remediating over- or under-dense grass swards.	Adequate time for reviewing the revegetation methodology on an annual basis; additional seed stocks and fertiliser, as required.	Refer to **Section 5.1**	Refer to **Section 9.1.7**	2	2	5
	Poor development of Koala and Central Greater Glider food trees.	• Insufficient density of food trees to allow use of rehabilitated areas by the Koala and Central Greater Glider. • Failure to achieve targets of completion criteria.	2	4	14	• Seed mixes have been based on other mine sites across north-eastern Australia. • Seed application rates are to be modified pending the outcome of the initial rounds of rehabilitation. • Regular monitoring aims for the early detection of sites with inadequate seedling establishment. • Sites with insufficient density of food trees developing over the first two years will undergo supplementary planting of tubestock.	Early refinements of the seed mixes will reduce the need for later interventions. Tubestock is a superior method for adding trees to existing pastures, as tree seeds often fail to germinate/establish among competitive understorey species.	Adequate time for reviewing the revegetation methodology on an annual basis; a nursery facility to rear tubestock OR contracts with commercial nurseries to rear stock.			2	2	5
	Excessive density of trees and shrubs.	• Pasture species become shaded out. • Habitat becomes unsuitable for the Squatter Pigeon. • Failure to achieve targets of rehabilitation completion criteria.	3	2	8	• Seed mixes have been based on other mine sites across north-eastern Australia. • Seed application rates are to be modified pending the outcome of the initial rounds of rehabilitation. • Thinning of woody vegetation (using machinery or fire) may be required at sites with excessive shrub and tree densities.	Early refinements of the seed mixes will reduce the need for later interventions. Vegetation thinning is widely implemented in Queensland's pastoral landscapes to increase pasture production in densely forested situations.	Adequate time for reviewing the revegetation methodology on an annual basis; machinery to undertake thinning of trees and shrubs, if required.			1	2	3

Milestone	Hazard	Impact	Inherent Risk			Rehabilitation actions	Justification of treatment option	Resource requirements	Performance measures	Reporting and monitoring	Residual Risk		
			Likelihood	Consequence	Risk Ranking						Likelihood	Consequence	Risk Rating
	Insufficient density of trees and shrubs.	• Habitat is unsuitable for the Koala and Squatter Pigeon. • Failure to achieve targets of rehabilitation completion criteria.	3	4	18	• Seed mixes have been based on other mine sites across north-eastern Australia. • Seed application rates are to be modified pending the outcome of the initial rounds of rehabilitation. • Regular monitoring aims for the early detection of sites with inadequate seedling establishment. • Sites with insufficient density of trees and shrubs developing over the first two years will undergo supplementary planting of tubestock.	Early refinements of the seed mixes will reduce the need for later interventions. Tubestock is a superior method for adding trees to existing pastures, as tree seeds often fail to germinate/establish among competitive understorey species.	Adequate time for reviewing the revegetation methodology on an annual basis; a nursery facility to rear tubestock OR contracts with commercial nurseries to rear stock.			2	2	5
	Weeds.	• Weeds could invade via wind, vehicles or footwear during vegetation development. • Weeds can inhibit the establishment of desirable species and preventing achievement of milestones 6, 7 and 8.	2	4	14	• Strict vehicle wash-down practices for vehicles entering the site from contaminated areas. • Annual weed monitoring program, to allow the early detection and treatment of new weed infestations.	Prevention of introduction and early treatment of new infestations are central to the successful and cost-effective management of weeds on site. Weed risk is highest during topsoil stockpiling, surface preparation and planting, rather than during the development of the vegetation communities post-planting. However, weed management practices are to remain in place throughout the duration of rehabilitation.	Adequate time and budget for wash-downs, monitoring and weed control.			2	3	9
7: Establishment of target vegetation type	Fire.	• A fire during early stages of vegetation establishment could kill developing trees and shrubs prior to their establishment, leading to a failure to achieve rehabilitation completion criteria pertaining to tree cover.	2	3	9	• A fire break will be maintained along the western boundary of the Mine, to minimise the risk of fires originating within bushland areas of the Harrow Range. • An Emergency Response Plan describes processes in place to control fires that originate on site.	Damaging fires are most likely to spread from the west, due to the large tracts of bushland present there and the hot, dry westerly winds typically associated with periods of high fire risk. Close proximity of the in-pit WRD to Saraji Road precludes the installation of fire breaks along the eastern boundary of rehabilitated land (maintaining a strip of bare ground on the foot-slopes of the in-pit WRD poses too high an erosion risk).	Personnel and machinery required to build and maintain fire breaks.	Refer to **Section 5.1**	Refer to **Section 9.1.7**	1	3	6
	Intruding livestock.	• Premature grazing could damage developing trees and shrubs and impair pasture development.	4	3	17	• Fences are to be inspected monthly, faults immediately repaired and livestock immediately removed.	Rehabilitated areas are to be maintained free of livestock until vegetation is adequately established (at least five years).	Personnel for inspections and repairs; tools and equipment for fencing.			1	1	1
8: Achievement of stable PMLU	Low pasture productivity.	• Failure to support economically viable cattle grazing.	2	3	9	• Seed mixes have been based on other mine sites across north-eastern Australia. • Grass seed application rates are to be modified pending the outcome of the initial rounds of rehabilitation. • In sites with insufficient grass cover, there is to be supplementary sowing and/or fertilising in bare patches to encourage grass growth.	Early identification of issues and amendments of seed mixes will reduce overall costs associated with remediating inadequate grass cover.	Personnel/contractors required for regular monitoring; adequate time for reviewing the revegetation methodology on an annual basis; additional seed stocks and fertiliser, as required.	Refer to **Section 5.1**	Refer to **Section 9.1.8**	2	2	5
	Low pasture diversity.	• Over-dominance of one or few pasture species increases the vulnerability of the pasture to extreme environmental events (flood, fire, drought, insect plagues). • Low pasture diversity is associated with reduced nutrient cycling and ecosystem stability. • Failure to sustain cattle grazing in the long-term.	4	4	23	• A multitude of local pasture species are to be included in seed-mixes. • Non-native grasses known to suppress other species (e.g., Buffel Grass) are to be sown at very low rates. • Regular monitoring (every two years) of rehabilitated sites will track pasture diversity and allow for an early modification of seed mixes and/or other interventions.	Over-dominance of Buffel Grass limits rehabilitation success and stability at other Bowen Basin mines (Erskine and Fletcher 2013). It is important to allow less aggressive grass species time to establish prior to Buffel Grass becoming too dense. A diversity of grasses improves ecosystem stability and protects against fluctuations in environmental conditions.				2	4	14
	Poor landscape function.	• Failure of sites to develop adequate sediment and leaf litter capture by groundcover features. • Formation of a dysfunctional landscape that results in a loss of resources (nutrients, water, sediment) over the long term. • Failure to achieve rehabilitation completion criteria pertaining to landscape function.	2	3	9	• Low slope gradient in landform design to limit capacity for sediment loss. • 30% rock cover applied to slopes during surface preparation. • Inclusion of a diversity of grass, trees and shrubs in seed mixes. • Topsoil storage and handling are to be in accordance with practices described in **Section 6.2.6.**	Landscape function analysis is a widely implemented framework for managing and monitoring landscape stability. A review of studies elsewhere in the Bowen Basin (refer **Section 6.1**) indicates that the measures in place at the Mine will lead to a stable landform with low erodibility.				2	2	5

Milestone	Hazard	Impact	Inherent Risk			Rehabilitation actions	Justification of treatment option	Resource requirements	Performance measures	Reporting and monitoring	Residual Risk		
			Likelihood	Consequence	Risk Ranking						Likelihood	Consequence	Risk Rating
	Significant erosion of placed soils on final landform	• Failure to establish vegetative cover and therefore stable PMLU • Loss of topsoil • Loss of sediment control structure performance • Water quality impacts	4	3	17	• Low slope gradient in landform design to limit capacity for sediment loss. • Surface preparation and sowing is not to take place if heavy rain (>40 mm) is forecast over any one day within the next fortnight. • 30% rock cover applied to slopes during surface preparation. • Rapidly establishing grasses to be included in seed-mixes. • Sediment management systems (drains and sediment dams) to be operational during surface preparation and revegetation. • Amelioration measures to assist with soil retention, including addition of: o fertiliser; and o organic mulch.	A review of studies elsewhere in the Bowen Basin (refer **Section 6.1**) indicates that the measures in place at the Mine will sufficiently limit the risk of erosion. Further amelioration measures are provided to enhance early establishment of vegetation and to support a sustainable and productive vegetative cover.	Adequate waste rock set aside for a protective cover; seed for pioneer grasses; amelioration materials and labour; appropriate time and personnel are required for construction of the sediment management system and final landform according to designs.			2	3	9
9: Acceptance of Saraji Road by Isaac Regional Council	The Saraji Road realignment does not meet the requirements of IRC and will not be accepted.	• Cost of repairs • Delays to the commencement of mining at the VCM, due to the retention of the old road until the new one is accepted.	3	4	18	• Adherence to a legal agreement with IRC outlining the requirements and responsibilities of all parties to facilitate the construction, maintenance and eventual handover of the road realignment. • Road inspections at the direction of IRC. • Ability of IRC to direct Vitrinite to undertake remediation in a timely fashion. • Security held by IRC for the purpose of undertaking any remediation that Vitrinite fails to complete. • Requirement of a Certificate of Practical Completion prior to return of the Road to IRC. • A 12-month Defects Period during which Vitrinite remains responsible for any remediation that is required prior to IRC assuming maintenance responsibility.	As a functioning council road that is intended to remain in place in perpetuity, Saraji Road must meet regional council requirements in its construction and maintenance. The construction and maintenance of the Saraji Road Realignment is the only rehabilitation that is appropriate to this area as a piece of remaining infrastructure.	Provision of security and any associated management documents to IRC for approval prior to commencement. Resources appropriate to road maintenance and all other aspects of the agreement with IRC until such time that the agreement is ended	Refer to **Section 5.1**	Refer to **Section 9.1.9**	2	3	9
10. Acceptance of retained infrastructure by BMA	The retained infrastructure does not meet the agreement between BMA and Vitrinite	• Cost of improvements to the condition of infrastructure or its removal; • Delays to the relinquishment of the ML	3	3	13	• Adherence to a legal agreement with BMA outlining the infrastructure to be retained and its condition at handover. • BMA to inspect remaining infrastructure at least six months prior to anticipating handover, to allow time for improvements/removals, if required.	Provided infrastructure meet the conditions if the signed agreement, there is little risk of completing this milestone.	Time allocated to inspections and liaising with BMA in the six months approaching handover.	Refer to **Section 5.1**	Refer to **Section 9.1.10**	2	2	5

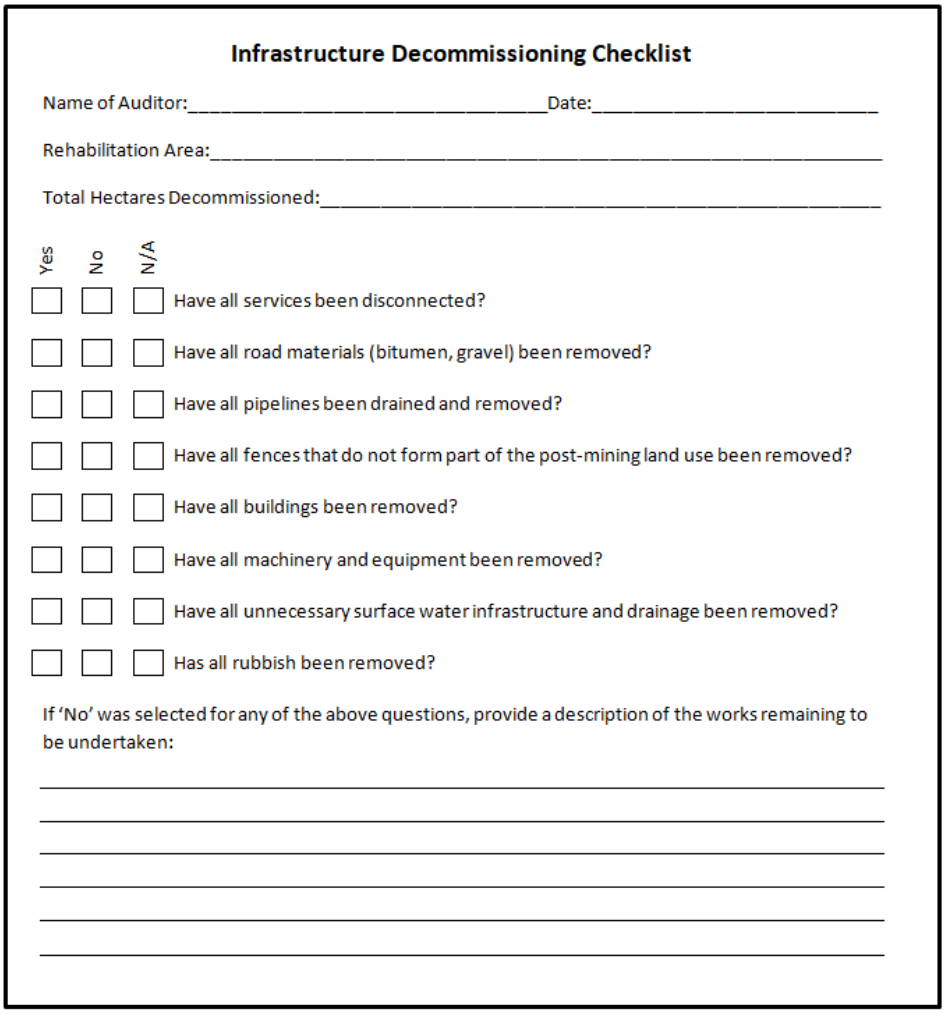
9 MONITORING

9.1 Milestone Monitoring

Ten rehabilitation milestones are described in **Section 10.3** (PRC Plan Schedule). A monitoring program has been developed to determine whether milestone criteria have been achieved. This program is described below, with respect to each of the rehabilitation milestones. Where milestones are only relevant to some rehabilitation areas, this is stated.

9.1.1 Rehabilitation Milestone 1: Infrastructure Decommissioning and Removal

Following the disconnection of services and removal of all buildings and mine infrastructure, an Infrastructure Decommissioning Checklist is to be completed. Failure of a site to meet all items on the checklist will trigger remedial works to remove outstanding infrastructure. This rehabilitation milestone monitoring is applicable to rehabilitation areas RA3 (Infrastructure) and RA4 (Water management infrastructure). An example checklist is provided below in **Figure 9-1.** Further detail on the milestone criteria set for the decommissioning and removal of infrastructure is provided in **Section 10.3.1** and **Table 10-3**. This includes a list identifying how infrastructure will be decommissioned.



Infrastructure Decommissioning Checklist

Name of Auditor:_____Date:_____

Rehabilitation Area:_____

Total Hectares Decommissioned:_____

Yes	No	N/A	
☐	☐	☐	Have all services been disconnected?
☐	☐	☐	Have all road materials (bitumen, gravel) been removed?
☐	☐	☐	Have all pipelines been drained and removed?
☐	☐	☐	Have all fences that do not form part of the post-mining land use been removed?
☐	☐	☐	Have all buildings been removed?
☐	☐	☐	Have all machinery and equipment been removed?
☐	☐	☐	Have all unnecessary surface water infrastructure and drainage been removed?
☐	☐	☐	Has all rubbish been removed?

If 'No' was selected for any of the above questions, provide a description of the works remaining to be undertaken:

_____

_____

_____

_____

_____

_____

Figure 9-1 *Example Infrastructure Decommissioning Checklist for each Rehabilitation Area*

9.1.2 Rehabilitation Milestone 2: Remediation of Contaminated Land

A contaminated land investigation document is to be prepared by an approved auditor, which is to contain the following components:

- a site investigation report, scientifically assessing whether contamination exists;
- a validation report, describing works undertaken to remediate any contamination; and
- a site suitability statement, stating that land is not contaminated and is suitable for the relevant post-mining landuse.

Rehabilitation areas for which this milestone may be relevant include RA3 (Infrastructure), RA4 (Water management infrastructure) and RA6 (Infrastructure to be retained).

9.1.3 Rehabilitation Milestone 3: Landform Development and Reshaping/Reprofiling

Following landform development and reprofiling, survey, inspection and reporting is required to provide assurance that rehabilitation activities occurred in accordance with approved designs. Upon the completion of physical works, all landform works must have 'as-constructed' plans prepared. Deviations between design and construction are to be identified and highlighted. A database of design and 'as-constructed' plans for any engineering works associated with the mine rehabilitation is to be maintained.

Rehabilitation areas requiring landform development include RA1 (Ex-pit WRD), RA2 (In-pit WRD's) and RA4 (Water management infrastructure).

9.1.4 Rehabilitation Milestone 4: Surface Preparation

Soil assessments of stockpiled topsoil are to be undertaken within the six months prior to spreading. Soil is to be sampled at various depths of each stockpile. These tests are to be carried out by an appropriately qualified person to confirm that soil is suitable for target vegetation establishment.

As a record of milestone completion, GIS files should be kept that record:

- the boundaries of each area that had topsoil applied in each year (areas with different soil management units or topsoil spreading methodology are to be mapped separately);
- the date on which topsoil spreading occurred in each area;
- depth of topsoil applied in each area;
- the soil management unit of the topsoil applied in each area; and
- whether a rock mulch was applied.

These records are to be kept wherever topsoil is spread, including in rehabilitation areas RA1 (Ex-pit WRD), RA2 (In-pit WRD's), RA3 (Infrastructure) and RA4 (Water management infrastructure).

9.1.5 Rehabilitation Milestone 5: Revegetation

All areas in which seeding and planting have been carried out are to be entered into a GIS database that includes the following details:

- the boundaries of each area rehabilitated (areas with different soil management units, seed mixes or dates of planting are to be mapped separately);
- the soil management unit of the topsoil applied in each area;
- the seed mix applied to each area;
- the date the seed mix was applied to each area;
- the number and species of tubestock planted in each area; and
- the date tubestock was planted.

These records are to be kept wherever planting takes place, including in rehabilitation areas RA1 (Ex-pit Dump), RA2 (In-pit WRD's), RA3 (Infrastructure) and RA4 (Water management infrastructure). While this rehabilitation milestone applies to RA1 (Ex-pit WRD), no tubestock will be planted there and the seed mix applied there will not contain trees.

9.1.6 Rehabilitation Milestone 6: Land Suitable for the Commencement of Grazing

Monitoring of milestone RM6 involves a combination of field surveys and satellite imagery analysis. Methodologies for each are described below.

Erosion

In-field erosion monitoring will be undertaken at permanent monitoring transects (50 m in length) established across the landform in conjunction with the Landscape Function Analysis (LFA) monitoring sites (**Section 9.1.8**), to provide a basis for temporal assessments.

Visual observations will be taken whilst traversing transects on foot and recording the number and average depth of any erosion features, rill lines or gullies. Visual assessments should identify any evidence of excessive sediment movement, including the formation of rills, removal of soil around the base of plants and accumulation of loose sediment at the base of slopes. In-field erosion monitoring will be accompanied by assessment of the water quality of run-off water released from the catchment of given rehabilitation areas (**Section 6.1.7**).

Rills are gullies are defined as "active" when (1) they have an average depth >25 cm, and (2) there is evidence of erosion during the most recent rain event (e.g., loose sediment is present, vegetation has not established within the rill/gully, and/or there has been an increase in depth or width of the rill/gully since the previous monitoring event).

Ground Cover

An accurate measurement is required to assess the rehabilitation completion criteria that "grazed land maintains a percentage ground cover of between 50% and 96%". While this criterion relates specifically to rehabilitation areas to which cattle have been introduced (at advanced stages of rehabilitation development), it is prudent to commence this monitoring prior to the introduction of cattle. This data can then be used to calculate the effect of grazing on percentage cover, and thereby predict the groundcover expected at ungrazed sites following cattle introduction. This in turn will be useful for adjusting stocking rates, if required.

Ground cover is to be calculated by running a 50 m measuring tape along the length of each vegetation monitoring transect. Observations of the type of cover (limited to the cover present below 1 m above ground level) are made at point intercepts along the centre line of the 50 m transect at 0.5 m intervals. Cover types include (a) vegetation (including all live vegetation and standing senescent vegetation that is still attached to the main plant and is not in intimate contact with the soil); (b) leaf litter and woody debris; (c) rock or (d) bare ground. The cover type that is intercepted directly below each point is recorded. The intercept point is to be assessed by viewing the ground through a small observation hole (in a piece of stiff card or plastic) or tube. Preferably, this should contain a cross hair, although this is not obligatory. A total of 100 observations are made per transect, and the sum of each cover type equates to its percentage cover.

Percentage cover is to be assessed at rehabilitation sites only (reference site data is not required). Monitoring is to be undertaken concurrently with assessments of landscape function and vegetation surveys in the late wet season.

Pasture Productivity

Pasture productivity within rehabilitated sites is to be equivalent to nearby unmined sites on the same soil types. Pasture productivity is to be assessed via one of two methods:

1) **Manual measurements of pasture mass at specific moments in time.** An electronic dry matter capacitance meter (e.g., Grassmaster Pro) can be used to estimate pasture dry mass (kg/ha) at points within rehabilitation areas. This technique is superior to traditional plate meters on stony ground, such as will be found on sloping rehabilitation areas. The exact number of replicate points required per rehabilitation area is dictated by the variation observed between points and the need to meet the conditions of the completion criteria, namely that pasture mass is not significantly different from unmined areas, with adequate sampling to detect ≥10% difference between groups. An appropriate sample size (n) is based on the following formula:

$$n = 15.68*\sigma^2 / d^2,$$

where σ^2 is the population variance, and d is the minimum difference required to be detected. This formula is based on a standard 95% confidence interval and 80% power. It is anticipated that several hundred point-readings are likely to be required per rehabilitation area and reference paddock. Data from the first 100 readings can be used to calculate n for a d value that represents 10% of the mean dry mass at the reference site. Reference and rehabilitation areas are to be assessed concurrently, under at least two seasonal conditions: 1) at the end of the growing season (February-May), and 2) at the end of prolonged dry weather (i.e., after at least three consecutive months with no more than 10 mm of rain falling per 24-hour period).

2) **Satellite estimation of pasture growth rate.** The CSIRO is in the process of developing their "Pastures from Space" website, which uses satellite imagery to provide real-time data on pasture growth rates at fine spatial scales. This technique has been optimised for temperate Australian pastures, but its applicability to the tropics and subtropics remains unclear. With further development and optimisation, this tool could provide a highly efficient method for comparing pasture productivity between rehabilitation and reference areas, without the need to undertake labour-intensive field studies. It is expected that this tool may be available by the time pasture productivity monitoring is to commence at the Mine (i.e., 2031, six years after the first planting).

Tree Height

In rehabilitation areas where tree cover is to be established (all but RA1), trees must be at least 4 m tall before cattle are first introduced. This is to prevent damage by browsing stock and to ensure that trees are sufficiently tall to begin being utilised by Koalas.

Tree height of the tallest ten trees within a 100 m × 100 m area is to be measured using a laser rangefinder. An average of one monitoring site is to be installed per 10 ha of rehabilitated land. The same monitoring locations are to be used as for groundcover assessments and landscape function analysis, although the size of the plot is larger for assessing tree height.

Land Suitability Assessment

Land suitability assessments are to be undertaken by a suitably qualified person in accordance with the *Guidelines for Agricultural Land Evaluation in Queensland* (DSITI and DNRM 2015). Criteria and thresholds for the environmental limitations of grazing land are to be based on Table 2-2 of the Land Suitability Assessment Techniques, located in Part B of the *Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland* (DME 1995). Land suitability assessments, and the soil tests that inform these, are to be undertaken six and ten years after revegetation (rehabilitation milestone 5) is complete.

9.1.7 Rehabilitation Milestone 7: Establishment of Target Vegetation Type

Monitoring of milestone RM7 involves a combination of field surveys and satellite imagery analysis. Methodologies for each are described below.

Field Surveys

Field surveys are to monitor the following attributes of rehabilitation areas:

- Relative dominance of Koala and Central Greater Glider food trees (all rehabilitation areas except for RA1);
- Percentage cover of declared weeds; and
- Species composition of the pasture.

These attributes are to be measured within a 10 m × 50 m belt transect installed within rehabilitation areas.

Basal area of woody vegetation is to be measured using a Bitterlich gauge. Each species of tree/shrub is to be measured separately. Each site is to be assessed using two 360° sweeps of the gauge (one at each end of the transect, 50 m apart), and the basal area of each woody species is the average from the two sweeps. The proportion of the total basal area of all woody vegetation that comprises Koala food trees (*Eucalyptus crebra, Eucalyptus populnea* and *Eucalyptus camaldulensis*) and Central Greater Glider food trees (*Eucalyptus camaldulensis* and *Corymbia Citriodora*) is used to assess the success of rehabilitation. As tree establishment is not a goal in RA1, basal area of woody vegetation is not monitored there.

The entire belt transect is to be searched, and all species of forbs and grasses contained within it are to be recorded. Percentage ground cover of each species is to be estimated to the nearest 0.1%, with 0.1% cover being equivalent to 0.5 m^2 total cover within the transect. From this data, milestone completion criteria pertaining to weed cover can be assessed.

Field surveys are to be undertaken in the late wet season (February-May), to coincide with maximum growth of grasses and forbs. Permanent monitoring sites are to be installed within all rehabilitation areas, and each end of each transect is to be marked with a star picket. An average of one monitoring site is to be installed per 10 ha of rehabilitated land.

NDVI

Rehabilitation areas for which the PMLU includes habitat for the Squatter Pigeon, Koala and Central Greater Glider (i.e. RA2, RA3 and RA4) are to undergo monitoring of woody vegetation density six years and ten years after the revegetation milestone is achieved. Woody vegetation density is measured using the Normalised Difference Vegetation Index (NDVI). The following approach is to be adopted:

1) The entire rehabilitation area is divided into 1ha cells.
2) Landsat satellite imagery is to be downloaded from an appropriately dry time of year:
    - following at least two months in which no more than 10 mm of rain fell in a single 24-hour period; and
    - following at least one week with no rain.
3) Using mapping software, the mean NDVI value for each 1-ha cell is to be calculated.

By using imagery captured during dry periods, when grass is dry, the NDVI (an index of greenness) reflects the density of woody vegetation cover. The months of July-September are usually appropriate, but in unusually wet winters, other months may need to be considered.

All cells fully contained within the relevant rehabilitation area are to have NDVI values between 0.1240 and 0.1778 in order to satisfy the completion criteria for threatened fauna. One-hectare cells within parts of the ML in which no disturbance has occurred and in which woody vegetation density is likely to have remained relatively stable over time (e.g., remnant vegetation) are to be used as reference points for NDVI. NDVI values of reference cells within the focal year should closely resemble values of the same cells calculated from Landsat imagery collected in August 2018 (on which completion criteria were based). If this is not the case, imagery from a different time of year should be used or, if this is unavailable or yields a similar outcome, the completion criteria are to be adjusted to account for shifts in greenness that arise from measurement biases or the influence of pasture.

9.1.8 Rehabilitation Milestone 8: Achievement of a Stable PMLU

The achievement of a stable landscape that can support low-intensity cattle grazing is to be monitored through five field survey programs, described below.

Landscape Function Analysis

Monitoring of the stability of rehabilitated land is to be based on the "stability", "infiltration/run-off" and "nutrient cycling" indices of Landscape Function Analysis (LFA) (Tongway and Hindley 2004). Methodology to be adopted is described in detail by Tongway and Hindley (2004). Permanent monitoring sites used for vegetation monitoring (see **Section 9.1.7**) are also to be monitored for soil stability.

Reference sites are to be installed in nearby undisturbed land used for grazing. Reference sites are to be of a similar soil type and slope to rehabilitated sites, and must have a vegetation density appropriate for Squatter Pigeons. Five reference sites are to be installed on flat land (gradients <6%) and five are to be installed on sloping land (gradient of 10-20%). Locations of proposed reference sites are listed in **Table 9-1** and shown in **Figure 9-2**. These reference sites were selected as (a) they meet the requirements for soil, slope and vegetation density and (b) they are evenly spaced, with at least 500 m between them. To avoid biases in the placement of these reference sites, their coordinates have been selected based on GIS information rather than through site visits. The baseline condition of reference sites therefore represents a random sample of analogous, nearby, unmined vegetation communities.

Reference sites are to be surveyed concurrently with every second rehabilitation area monitoring round. Reference sites must be monitored in the year rehabilitation success is expected. Vegetation development is to be assessed every two years until milestone criteria have been achieved.

Table 9-1 Proposed reference sites for LFA monitoring

Site	Slope	Latitude	Longitude
R1	Flat	-22.28313	148.16910
R2	Flat	-22.28582	148.17477
R3	Flat	-22.29014	148.18028
R4	Flat	-22.30203	148.19103
R5	Flat	-22.27888	148.17310
R6	Sloping	-22.27799	148.16634
R7	Sloping	-22.28109	148.16087
R8	Sloping	-22.28729	148.17035
R9	Sloping	-22.29139	148.17512
R10	Sloping	-22.29853	148.19032

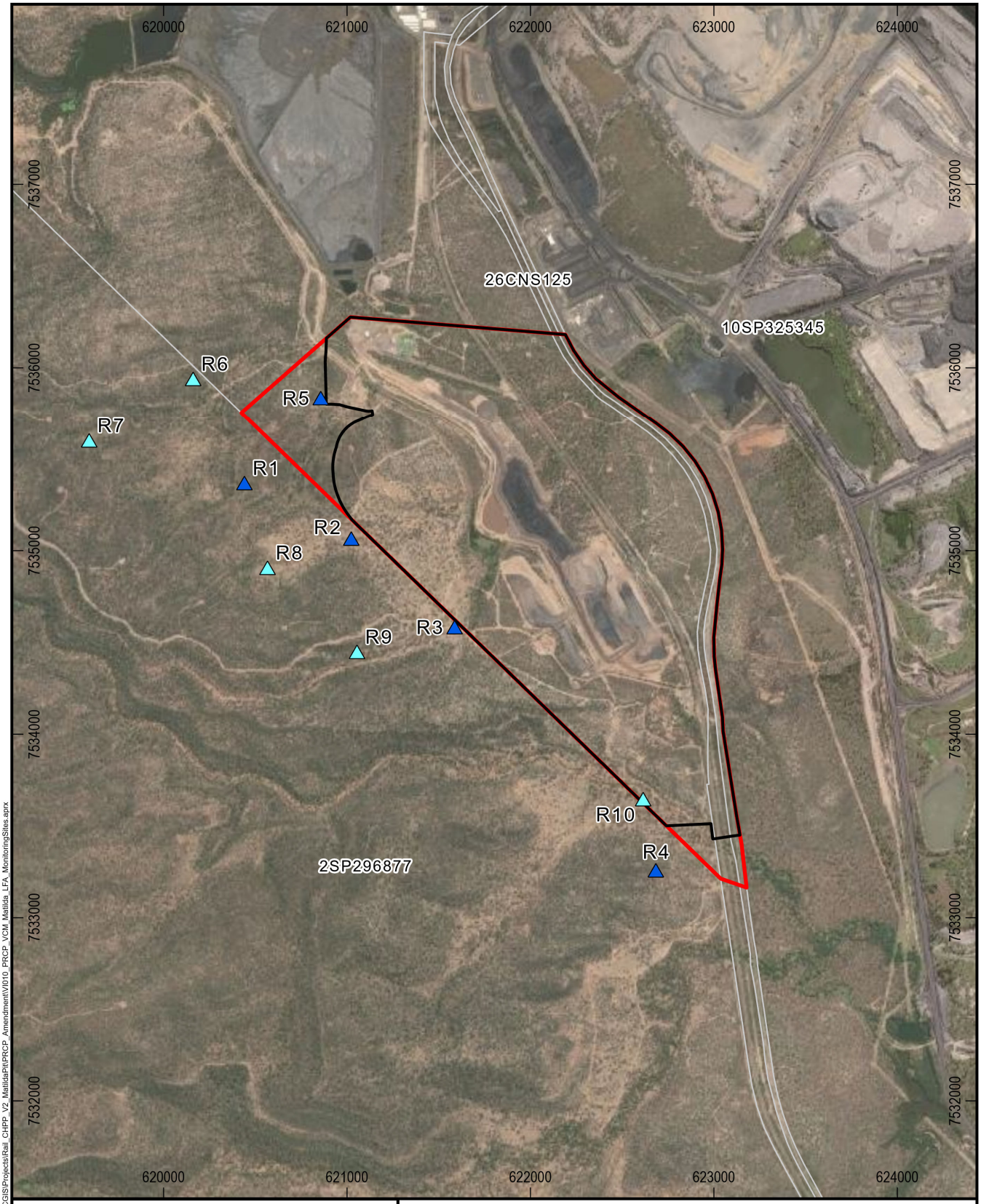
Monitoring is to take place in the late wet season (February-May), to coincide with maximum plant growth. Sites are to be monitored at the time of planting and then every two years for ten years after planting. This time series of six intervals will generate a sigmoidal curve for the three indices. A stable PMLU will be achieved when the landscape function analysis scores for soil stability, infiltration/runoff and nutrient cycling have started to plateau, and the plateau values predicted from sigmoidal curves fitted to the data are equivalent to or exceed values at analogue sites (Tongway and Hindley 2004). If the curves do not plateau or exceed the target value within ten years, additional rounds of monitoring will take place every five years until the target is achieved.

Erosion

In addition to the LFA monitoring to be undertaken for land stability (see above), additional erosion monitoring across the landform will also be undertaken for the early detection of erosion, to allow for early intervention. In-field erosion monitoring will be undertaken at permanent monitoring transects, (50 m in length) established across the landform in conjunction with the LFA monitoring sites, to provide a basis for temporal assessments.

Visual observations will be taken whilst traversing transects on foot and recording the number and average depth of any erosion features, rill lines or gullies. Visual assessments should identify any evidence of excessive sediment movement, including the formation of rills, removal of soil around the base of plants and accumulation of loose sediment at the base of slopes. In-field erosion monitoring will be accompanied by assessment of the water quality of run-off water released from the catchment of given rehabilitation areas (**Section 6.1.7**).

Rills are gullies are defined as “active” when (1) they have an average depth >25 cm, and (2) there is evidence of erosion during the most recent rain event (e.g., loose sediment is present, vegetation has not established within the rill/gully, and/or there has been an increase in depth or width of the rill/gully since the previous monitoring event).



Legend

- ML 700060
- VCM Revised Maximum Disturbance
- Cadastral Boundary

Reference Sites

- Flat
- Slope

Source: State of Queensland (Department of Resources) 2022, Vitrinite 2022, METServe 2022, Maxar.

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\PRCP_Amendment\VI010_PRCP_VCM_Matilda_LFA_MonitoringSites.aprx

Vulcan Coal Mine

Proposed Reference Sites for Vegetation Monitoring

0 250 500 1,000

Meters

Scale: 1:30,000 (A4)

28/10/2022

Datum: GDA2020
Projection: MGA55

FIGURE 9-2

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Ground Cover

Landscape Function Analysis, discussed above, involves an assessment of percentage ground cover as classes. A more accurate measurement is required to specifically assess the rehabilitation completion criteria that "grazed land maintains a percentage ground cover of between 50% and 96% on slopes up to 10% and between 70% and 96% on slopes between10-15%". While this criteria relates specifically to rehabilitation areas to which cattle have been introduced (at advanced stages of rehabilitation development), it is prudent to commence this monitoring prior to the introduction of cattle. This data can then be used to calculate the effect of grazing on percentage cover, and thereby predict the groundcover expected at ungrazed sites following cattle introduction. This in turn will be useful for adjusting stocking rates, if required.

Ground cover is to be calculated by running a 50 m measuring tape along the length of each vegetation monitoring transect. Observations of the type of cover (limited to the cover present below 1 m above ground level) are made at point intercepts along the centre line of the 50 m transect at 0.5 m intervals. Cover types include (a) vegetation (including all live vegetation and standing senescent vegetation that is still attached to the main plant and is not in intimate contact with the soil); (b) leaf litter and woody debris; (c) rock or (d) bare ground. The cover type that is intercepted directly below each point is recorded. The intercept point is to be assessed by viewing the ground through a small observation hole (in a piece of stiff card or plastic) or tube. Preferably, this should contain a cross hair, although this is not obligatory. A total of 100 observations are made per transect, and the sum of each cover type equates to its percentage cover.

Percentage cover is to be assessed at rehabilitation sites only (reference site data is not required). Monitoring is to be undertaken concurrently with assessments of landscape function and vegetation surveys in the late wet season.

Recruitment

The extent of natural recruitment of established woody species is to be assessed within each of the 10 m × 50 m belt transects used to assess weed cover (see **Section 9.1.7**). Percentage recruitment is simply the number of woody species present as seedlings or suckers <2 m tall divided by the the number of woody species >2 m tall that is found within the belt transect.

Pasture Productivity

Pasture productivity within rehabilitated sites is to be equivalent to nearby unmined sites on the same soil types. Pasture productivity is to be assessed via one of two methods:

1) Manual measurements of pasture mass at specific moments in time. An electronic dry matter capacitance meter (e.g., Grassmaster Pro) can be used to estimate pasture dry mass (kg/ha) at points within rehabilitation areas. This technique is superior to traditional plate meters on stony ground, such as will be found on sloping rehabilitation areas. The exact number of replicate points required per rehabilitation area is dictated by the variation observed between points and the need to meet the conditions of the completion criteria, namely that pasture mass is not significantly different from unmined areas, with adequate sampling to detect ≥10% difference between groups. An appropriate sample size (n) is based on the following formula:

$$n = 15.68*\sigma^2 / d^2,$$

where σ^2 is the population variance, and d is the minimum difference required to be detected. This formula is based on a standard 95% confidence interval and 80% power. It is anticipated that several hundred point-readings are likely to be required per rehabilitation area and reference paddock. Data from the first 100 readings can be used to calculate n for a d value that represents 10% of the mean dry mass at the reference site. Reference and rehabilitation areas are to be assessed concurrently, at the end of the growing season (April-May).

2) Satellite estimation of pasture growth rate. The CSIRO is in the process of developing their "Pastures from Space" website, which uses satellite imagery to provide real-time data on pasture growth rates at fine spatial scales. This technique has been optimised for temperate Australian pastures, but its applicability to the tropics and subtropics remains unclear. With further development and optimisation, this tool could provide a highly efficient method for comparing pasture productivity between rehabilitation and reference areas, without the need to undertake labour-intensive field studies. It is expected that this tool may be available by the time pasture productivity monitoring is to commence at the Mine (i.e. 2031, six years after the first planting).

Water Quality

The Mine will have a groundwater and surface water monitoring program operating throughout all phases of the Mine, including through rehabilitation and closure.

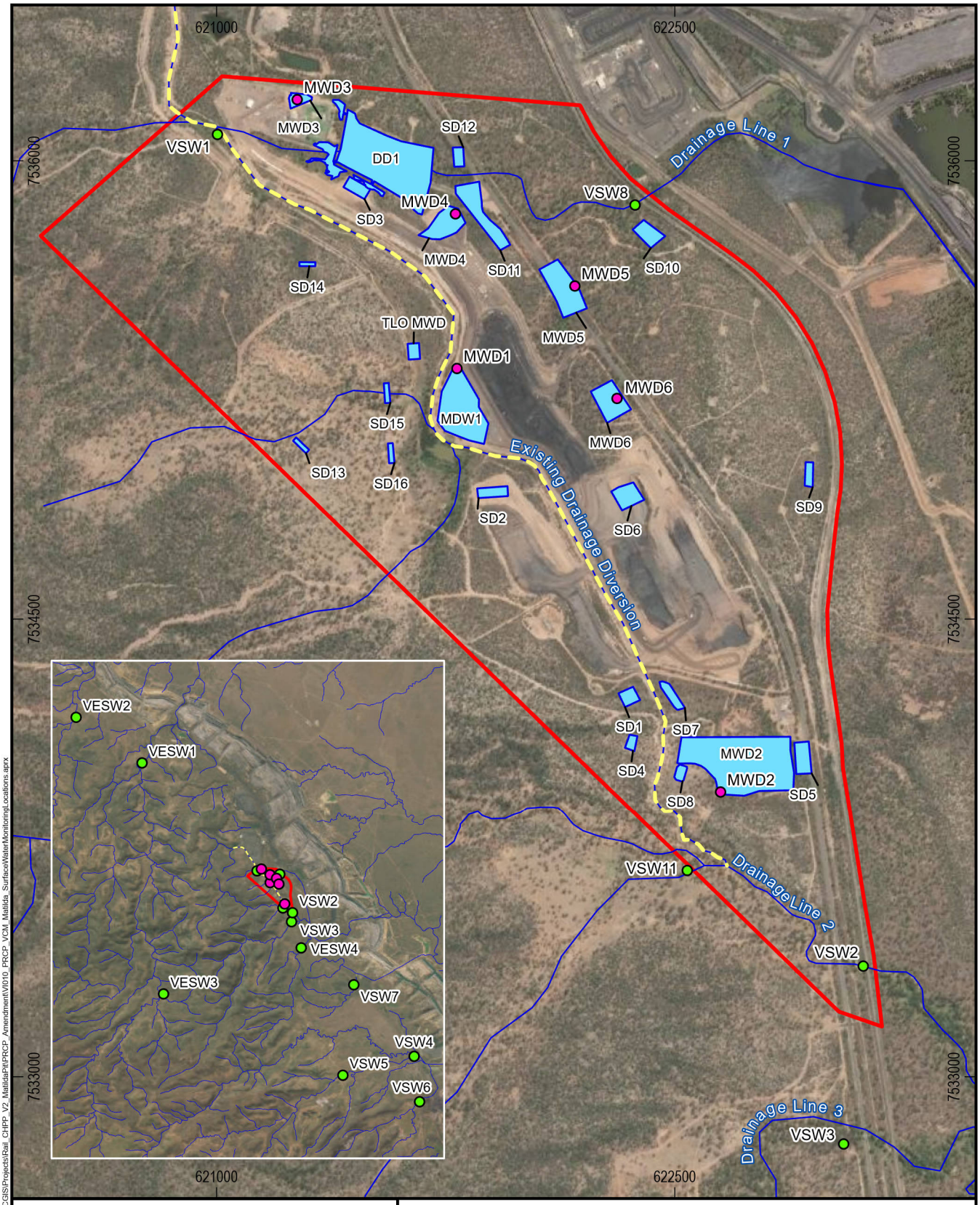
Surface water will be monitored at eight upstream, five downstream and six mine water dam locations listed in **Table 9-2** and shown on **Figure 9-3**. All four monitoring locations are highly ephemeral, and water sampling is to coincide with each flow event that occurs at each location.

Interim locally derived receiving waters trigger values have been proposed for the Mine using the 80th percentile of recorded reference site data in accordance with ANZG (2018). The 80th percentile values were compared against the Mine Water Quality Objective (WQO) default trigger values given in WRM (2022a) and the Model Mine Conditions guideline (DES 2017). ANZG (2018) states that reference data can be used to derive site-specific guideline values for water quality when natural background concentrations of a toxicant exceed the Mine WQO default trigger value.

ANZG (2018) recommends that baseline data is collected over two years of monthly sampling (18 to 24 samples), to indicate ecosystem variability. The recommended number of samples at each location has not yet been collected and therefore the proposed interim receiving water site-specific guidelines values (see **Section 5.1, Table 5-2)** should be reviewed once sufficient monitoring data has been collected.

Table 9-2 Surface water monitoring locations

Station ID	Catchment	Latitude	Longitude	Description
Upstream Sites				
VSW1	Boomerang Ck	-22.27661	148.17451	Diversion bund approximately 3.1 km upstream of Drainage Line 2. Used as an upstream monitoring location for all site dams
VSW3	Boomerang Ck	-22.30632	148.19465	Drainage line 3 upstream of Saraji Road
VSW5	Hughes Ck	-22.39594	148.22465	Hughes Creek approximately 5.0 km upstream of Saraji Road
VSW6	Hughes Ck	-22.41140	148.26944	Barrett Creek upstream of Saraji Road
VSW11	Boomerang Ck	-22.29796	148.18932	Minor drainage line, upstream of confluence of the existing drainage diversion and Drainage Line 2
VESW2	Harrow Ck	-22.18655	148.06881	Harrow Creek approximately 8.3 km upstream of Peak Downs Highway
VESW3	Harrow Ck	-22.34845	148.11988	Harrow Creek upstream of the Project
VESW4	Boomerang Ck	22.32156	148.20030	Drainage line 4 upstream of Saraji Road
Downstream sites (receiving waters)				
VSW2	Boomerang Ck	-23.30106	148.19523	Drainage Line 2 upstream of the railway. Used as a downstream monitoring location for MWD2, SD1, SD2, SD4, SD5, SD7, SD8, SD13, SD14, SD15 and SD16
VSW4	Hughes Ck	-22.38489	148.26627	Hughes Creek upstream of Saraji Road
VSW7	Hughes Ck	-22.34311	148.23103	Drainage line 7 upstream of Saraji Road.
VSW8	Boomerang Ck	-22.27861	148.18782	Drainage Line 1 upstream of the railway. Used as a downstream site for MWD1, MWD3, MWD4 MWD5, and MWD6 as well as SD3, SD6, SD9, SD10, SD11 and SD12
VESW1	Harrow Ck	-22.27860	148.18779	Harrow Creek approximately 8.7 km upstream of Peak Downs Highway
Mine water dam monitoring locations/release points				
MWD1	13.0 ha	-22.28347	148.18217	MWD1spillway
MWD2	6.2 ha	-22.29593	148.19065	MWD2 spillway
MWD3	4.5 ha	-22.27556	148.17703	MWD3 spillway
MWD4	6.6 ha	-22.27890	148.18209	MWD4 spillway
MWD5	15.6 ha	-22.28100	148.18590	MWD5 spillway
MWD6	10.4 ha	-22.28432	148.18727	MWD6 spillway



Legend

- Dam Monitoring Location
- Receiving Water Monitoring Location
- Local Drainage Feature
- Drainage Diversion
- Dams
- ML 700060

Source: State of Queensland (Department of Resources) 2022, WRM 2021-2022, Vitrinite 2022, METServe 2022, Maxar.

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\PRCP_Amendment\VI010_PRCP_VCM_Matilda_SurfaceWaterMonitoringLocations.aprx

Vulcan Coal Mine

Surface Water Monitoring Locations

0 200 400 600

Meters

Scale: 1:18,000 (A4)

5/01/2023

Datum: GDA2020
Projection: MGA55

FIGURE 9-3

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

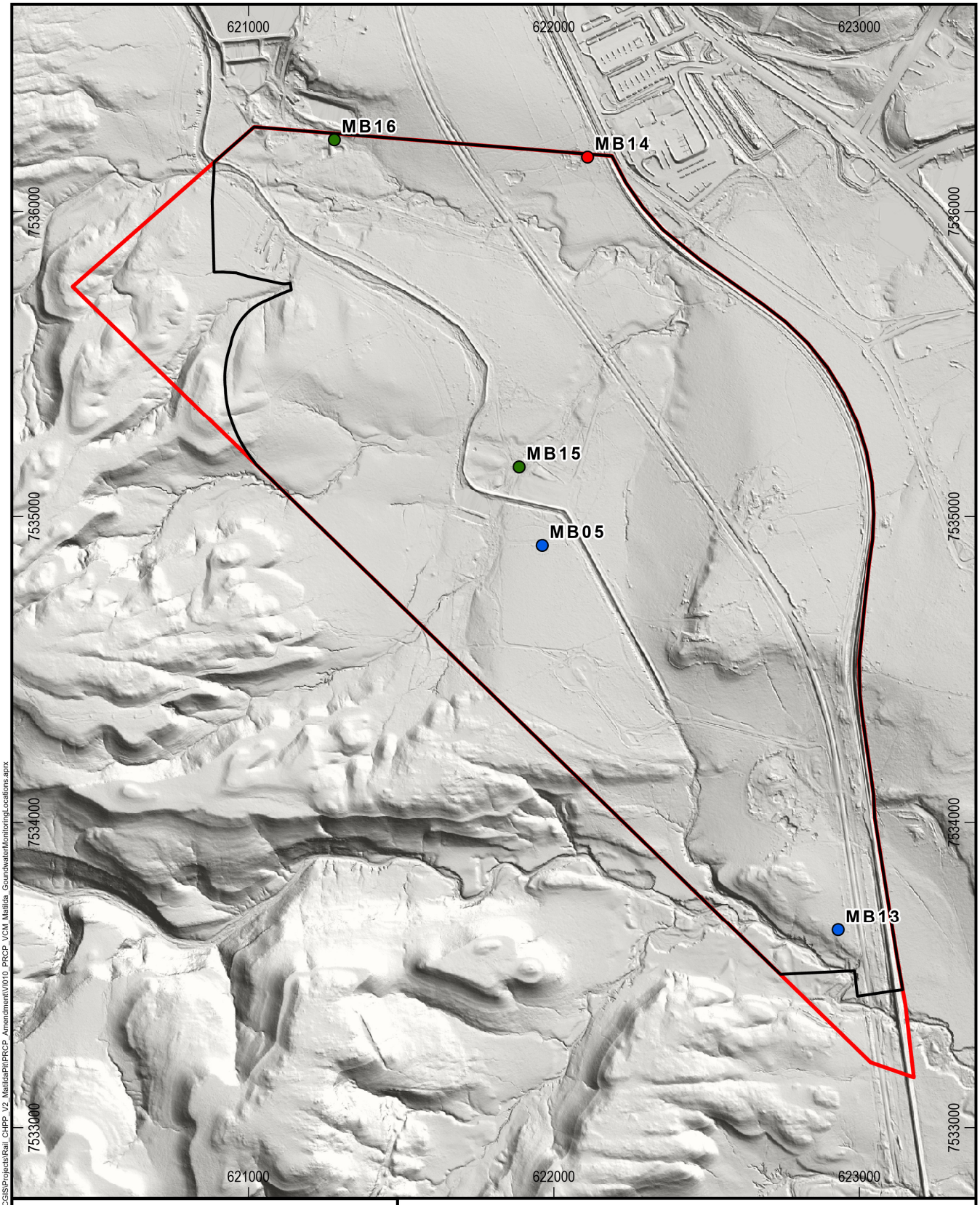
Groundwater will be monitored at five locations listed in **Table 9-3** and shown in **Figure 9-4**. Daily water level measurements are to be collected by installed data loggers, while water quality is assessed by collecting water samples each month. Electrical conductivity and pH is measured in the field, and all other attributes are assessed at an approved laboratory.

Table 9-3 Groundwater monitoring bore locations

Monitoring Location	Latitude (GDA94)	Longitude (GDA94)	Surface RL (mAHD)	Depth (mbGL)	Aquifer	Monit. Unit*
MB05	-22.28721	148.18392	252.70	40.9	Back Creek Group	MAT coal seam
MB13	-22.29849	148.19340	223.13	35	Back Creek Group	MAT coal seam
MB14	-22.27567	148.18525	242.38	29.50	Moranbah CM	DLL Coal Seam
MB15	-22.28468	148.18304	251.55	10	Moranbah CM	Permian interburden
MB16	-22.27524	148.17720	248.36	10	Moranbah CM	Permian interburden

*DLL = Dysart Lower Lower; MAT = Matilda.

Note that two other bores (MB02 and MB03) were initially included in the monitoring program, but have been removed due to an absence of water during pre-mining baseline monitoring.



Legend

- ML 700060
- VCM Revised Maximum Disturbance

Groundwater Monitoring Bores

- DLL coal seam
- MAT coal seam
- Permian interburden

Source: Aerometrex 2019, WRM 2019, Vitrinite 2022, METServe 2022.

Vulcan Coal Mine

Groundwater Monitoring Locations

0 150 300 600

Meters

Scale: 1:18,000 (A4)

28/10/2022

Datum: GDA2020
Projection: MGA55

FIGURE 9-4

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\PRCP_Amendment\VI010_PRCP_VCM_Matilda_GroundwaterMonitoringLocations.aprx

9.1.9 Rehabilitation Milestone 9: Acceptance of Saraji Road by Isaac Regional Council

Vitrnite is signatory to a formal compensation agreement with IRC for the realignment of Saraji Road. This agreement prescribes the terms and conditions for IRC's acceptance of responsibility for the management and maintenance of the realigned road.

Upon completion of the construction of the road realignment, Vitrinite is to provide IRC with a Certificate of Practical Completion. The receipt of this certificate denotes the start of a "Defects Period", during which Vitrinite will continue to be responsible for all maintenance costs associated with rectifying any identified defects in the realignment, and must do so at the direction of IRC if required.

The Defects Period will end on the later of a 12-month period after Vitrinite provides IRC with a Certificate of Practical Completion or the date that IRC notifies Vitrinite that the new road alignment is accepted "off maintenance". Rehabilitation milestone 9 is considered complete following this acceptance by IRC.

Inspections of road condition will be the responsibility of IRC, but Vitrinite will be responsible for undertaking traffic monitoring in accordance with the compensation agreement.

9.1.10 Rehabilitation Milestone 10: Transferral of Infrastructure to BMA

Any monitoring of infrastructure condition prior to transferral of ownership to BMA is to be in accordance with the conditions of the signed agreement with BMA.

9.1.11 Monitoring Report

Rehabilitation milestones RM6, RM7 and RM8 are generally to be assessed concurrently and, as these constitute the primary rehabilitation completion criteria for the Mine, they will be monitored over an extended period of at least ten years. The results of each round of monitoring (every two years for most attributes) are to be presented in a report that assesses progress of these three milestones. Each report is to contain details about how the methodology used is consistent with this PRC Plan. Each report is also to discuss how the results obtained indicate progression towards the fulfilment of milestone criteria. This monitoring report is to be completed by 1 October in the calendar year in which surveys are undertaken, to allow adequate time for Vitrinite to report on the findings by the state-wide reporting deadline of 10 December.

9.2 Audits

In accordance with section 285 of the *Environmental Protection Act 1994*, holders of a PRC Plan schedule must commission a rehabilitation auditor to undertake an audit of the PRC Plan schedule every three years. The first audit must be for the three-year period that commences from the day the schedule takes effect. Each subsequent audit period is for the three years commencing on the day after the previous audit period ended. Each audit report must be delivered to the administering authority within four months after the end of each audit period.

In accordance with section 286 of the *Environment Protection Act 1994*, each audit must include the following:

- a statement about whether the holder has complied with the schedule during the audit period;
- a description of actions the holder has taken with respect to rehabilitation milestones and management milestones;
- whether the holder has complied with conditions imposed on the schedule;
- a declaration stating the holder has not knowingly given false or misleading information;
- an assessment of whether the post-mining land use is likely to be achieved; and
- recommendations about actions the holder should take to ensure rehabilitation milestones and management milestones are achieved.

In addition to the mandatory three-yearly audits, the administering authority has the power (under section 322 of the *Environmental Protection Act 1994*) to issue an audit notice, which requires the holder of a PRC Plan schedule to commission an audit.

9.3 Annual Return

In addition to the annual return requirements that relate to EAs, in accordance with section 316IA of the *Environmental Protection Act 1994*, the annual return must also include an evaluation of the effectiveness of the PRC Plan schedule, including the environmental management carried out under the schedule, for the year to which the annual return relates. This evaluation must include:

- any milestones to be completed under the PRC Plan schedule during the year have been met; and
- the conditions imposed on the PRC Plan schedule have been complied with.

9.4 Progressive Rehabilitation Report

In the event that a particular rehabilitation area within the tenure of the Mine has been rehabilitated in accordance with all relevant requirements of the *Environmental Protection Act 1994*, the relevant environmental authority, the PRC Plan schedule and any relevant guidelines made under the *Environmental Protection Act 1994*, the holder of the EA can apply for progressive certification. In accordance with section 318ZD of the *Environmental Protection Act 1994*, the application for progressive certification must be accompanied by a progressive rehabilitation report. The requirements for a progressive rehabilitation report are listed in section 318ZF of the *Environmental Protection Act 1994*.

9.5 Final Rehabilitation Report

A final rehabilitation report is to be prepared when applying to surrender the EA. The purpose of this final rehabilitation report is to demonstrate that the conditions of the EA have been complied with, and that rehabilitation of disturbed land has been carried out satisfactorily. The requirements of this final rehabilitation report are listed in section 262 of the *Environmental Protection Act 1994*.

9.6 Post-mining Management Report

A post-mining management report is to be submitted as part of the surrender application for the EA. This report states the requirements for ongoing management of the land, and includes an environmental risk assessment. The requirements of this post-mining management report are listed in section 264A of the *Environmental Protection Act 1994*.

10 PRC PLAN SCHEDULE

This section has been prepared in accordance with section 126D(1) of the *Environmental Protection Act 1994*. It contains a description of each rehabilitation area, a schedule of land availability for rehabilitation and a detailed description of the rehabilitation milestones that apply to each rehabilitation area. This information has been used to develop a PRC Plan schedule that describes when each rehabilitation milestone is to be progressively achieved in each rehabilitation area.

10.1 Final Site Design

The final site design—showing the maximum disturbance footprint, the mining lease boundaries, the PMLUs for land within the mining lease, and flood plain extent—is shown in

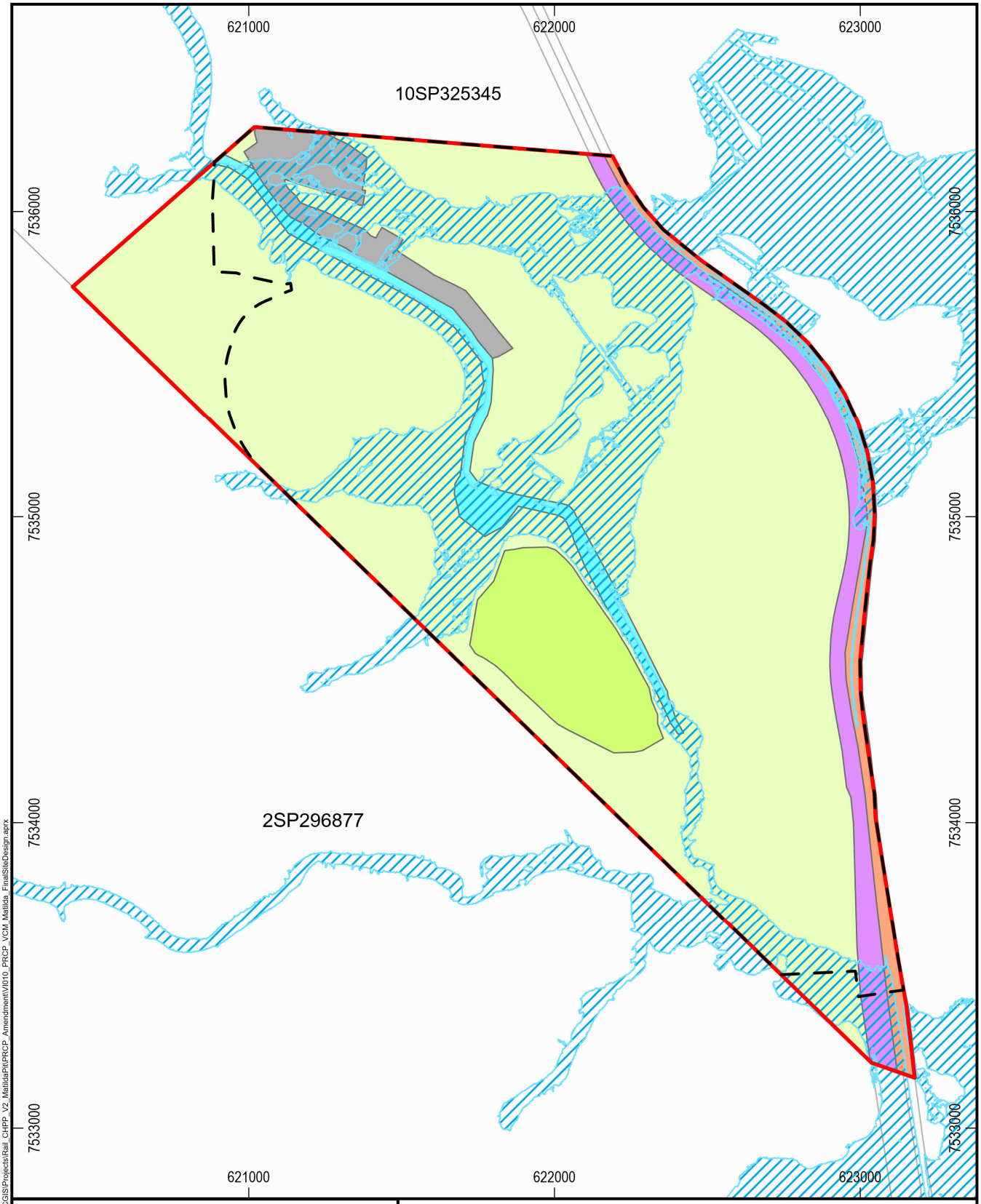
Figure 10-1.

10.1.1 Rehabilitation Areas

The disturbance footprint of the Mine has been divided into the following six rehabilitation areas with a common PMLU and rehabilitation methodology:

- RA1: Ex-Pit Waste Rock Dump;
- RA2: Open Cut Mining Pits; In-pit Waste Rock Dumps (Jupiter and Matilda);
- RA3: Infrastructure- CHPP, Rail loop, TLO, internal tracks, haul roads, stockpiles and run-of-mine pad;
- RA4: Water Management Infrastructure- dams, sediment control drains, ponds and flood protection levees;
- RA5: Saraji Road; and
- RA6: Retained Infrastructure.

The division of the disturbance footprint into rehabilitation areas is shown in **Figure 10-2**.



Legend

PMLU
- Cattle Grazing
- Cattle Grazing and Habitat for Threatened Fauna
- Flood Levee
- Mine-support Infrastructure
- Rail Corridor
- Saraji Road

- ML 700060
- VCM Revised Maximum Disturbance
- Cadastral Boundary
- 0.1% Annual Exeedance Probability (AEP) peak flood

Source: State of Queensland (Department of Resources) 2022, WRM 2022, Vitrinite 2022, METServe 2022, Maxar.

Vulcan Coal Mine

Final Site Design

0 150 300 600

Meters

Scale: 1:18,000 (A4)

16/11/2022

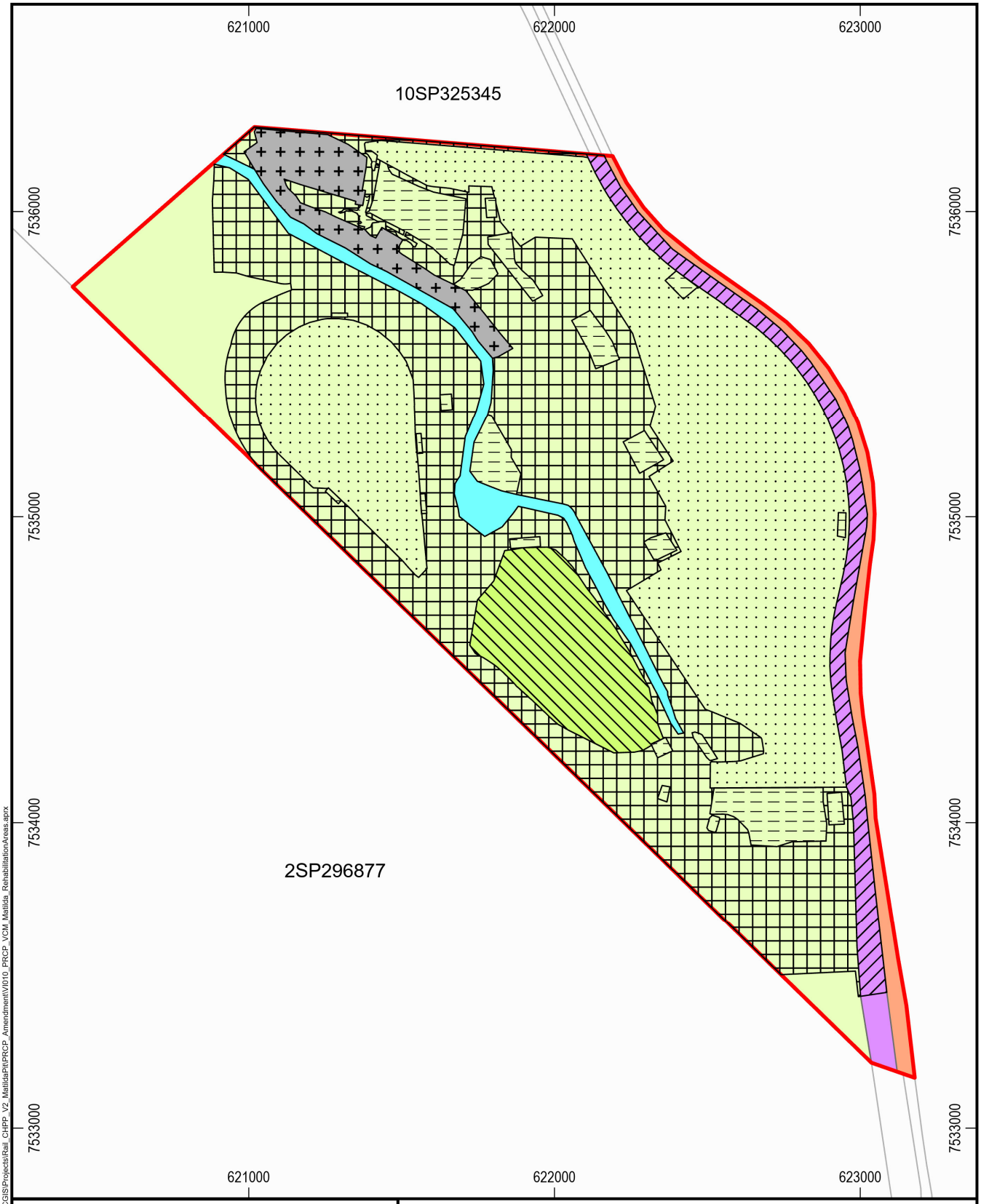
Datum: GDA2020
Projection: MGA55

FIGURE 10-1

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\PRCP_Amendment\VI010_PRCP_VCM_Matilda_FinalSiteDesign.aprx



Legend

- ML 700060
- Cadastral Boundary

Rehabilitation Areas

- RA1
- RA2
- RA3
- RA4
- RA5
- RA6

PMLU

- Cattle Grazing
- Cattle Grazing and Habitat for Threatened Fauna
- Flood Levee
- Mine-support Infrastructure
- Rail Corridor
- Saraji Road

Source: State of Queensland (Department of Resources) 2022, Vitrinite 2022, METServe 2022.

Vulcan Coal Mine

Rehabilitation Areas

0 150 300 600

Meters

Scale: 1:18,000 (A4)

22/11/2022

Datum: GDA2020
Projection: MGA55

FIGURE 10-2

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\PRCP_Amendment\VI010_PRCP_VCM_Matilda_RehabilitationAreas.aprx

10.2 Schedule of Land Availability

Due to the gradual back-filling of the mined pit, land will become progressively available for rehabilitation throughout the four years of the Mine. Disturbed land is available for rehabilitation when the land:

1) is no longer being mined;
2) is no longer being used to dump further waste rock;
3) is no longer being used for operating infrastructure or machinery for mining; and
4) does not support permanent infrastructure (e.g. Saraji Road, northern Mine Infrastructure Area).

10.2.1 Timing Considerations

Mine plans, which include the schedule of land available for rehabilitation, have been developed for each 12 months starting at the commencement of the Mine. However, in accordance with the *Progressive Rehabilitation and Closure Plans Guideline*, annual reporting of rehabilitation works is to be based on the completion date of 10 December each calendar year. Consequently, the progression of the mine (and its rehabilitation) within any one calendar year is strongly dependent on the date the Mine commences.

One rehabilitation milestone (revegetation) is strongly season-dependent, and is only to take place following the start of wet season rain. It is assumed that any land available for rehabilitation later than July in any one calendar year is unlikely to have sufficient time to undergo infrastructure removal, decontamination and final landform shaping in preparation for revegetation at the start of the wet season (November-January, depending on the year). Consequently, deferring the commencement of rehabilitation of such land until the following year will not delay the revegetation stage.

Land that is available for rehabilitation before July will commence rehabilitation in the same calendar year. It is expected that milestones RM1, RM2 and RM3 (see **Section 10.3**) will be completed in the year that land becomes available for rehabilitation. Milestones RM4 and RM5 may also be completed the same year (relative to the reporting date of 10 December), but only if the wet season commences early (e.g., November). As the start of the wet season is unpredictable, for the purposes of the schedule, it is assumed that milestones RM4 and RM5 will be completed early in the following year, and hence are attributed to the following years' progress in the schedule.

Based on tree growth rates and pasture development at other mines in central Queensland (Mulligan *et al.* 2006), it is expected that the target vegetation community will be established ten years after planting, and the land will be suitable for the commencement of grazing at this time. This is a conservative estimate to allow for opportunities for remedial planting in the event of initial failures; grazing has been successfully introduced to central Queensland pastures with trees that are as young as four years old (Donaghy *et al.* 2010).

10.2.2 Schedule of Availability

The schedule of land availability for rehabilitation in each rehabilitation area is shown in **Table 10-1**.

Table 10-1 Schedule of land availability for rehabilitation

Rehabilitation Area		Land available for rehabilitation in each year (ha)*						
		2022	2023	2024	2025	2026	2027	2028
RA1	Ex-Pit Waste Rock Dump	15	0	9	0	0	0	0
RA2	Open Cut Mining Pits; In-pit Waste Rock Dumps (Jupiter and Matilda)	0	10	51	70	0	0	0
RA3	Infrastructure- CHPP, Rail Loop, TLO, haul roads, internal tracks, stockpiles, run-of-mine pad	0	0	0	0	64	80	0
RA4	Water Management Infrastructure- dams, sediment control drains, ponds and flood protection levees†	0	0	0	0	0	0	22
RA5	Saraji Road‡	0	0	0	0	17	0	0
RA6	Retained infrastructure^	0	0	0	0	0	0	13
Total		**15**	**10**	**51**	**70**	**81**	**80**	**35**

*Land areas represent hectares of land that becomes available for the first time in that year (i.e., is not cumulative across years).

†Erosion control infrastructure is to remain in place until sufficient vegetative cover has developed on rehabilitated land. This is conservatively estimated to be three years post-mining but may be sooner.

‡The realigned Saraji Road corridor will be constructed and operational within year 1; however, further rehabilitation works within the corridor fringes may be required following construction of the final in-pit WRD landforms. Hence rehabilitation works are scheduled to occur after the landforms are established.

^BMA will ultimately accept ownership and liability of this retained infrastructure, so this is to be in accordance with the signed agreement. No rehabilitation works will be required for this area and handover will be completed in 2028.

10.3 Rehabilitation Milestones

Rehabilitation milestones relevant to the Mine area are listed in **Table 10-2**.

Table 10-2 Rehabilitation milestones

Code	Milestone	Description	Applicable Rehabilitation Areas
RM1	Infrastructure decommissioning and removal.	▪ Services such as water and electricity have been disconnected and terminated; ▪ Buildings (modular CHPP, TLO, administration, ablution block, workshops, warehouses, etc.) have been demolished and removed; ▪ Bitumen, blue metal, aggregate, etc., have been removed; ▪ Fencing has been removed; ▪ Rail tracks and balast have been removed; and ▪ Boreholes have been decommissioned.	RA3
RM2	Remediation of contaminated land.	▪ Contaminated land investigations have been carried out; ▪ Contaminated water (e.g. affected by hydrocarbons) has been treated on site or removed; ▪ Contaminated materials have been appropriately removed and disposed of; ▪ On-site remediation of hydrocarbon-contaminated soils has been completed; and ▪ Completion of validation testing to confirm that contaminated soils have been removed/remediated.	RA3, RA4
RM3	Landform development and reshaping/reprofiling.	▪ Bulk earthworks to achieve required landform and slopes have been completed; ▪ Placement of subsoils over waste rock has been completed; ▪ General reshaping to achieve final landform is complete; and ▪ Installation of erosion and sediment control systems is complete.	RA1, RA2, RA3, RA4
RM4	Surface preparation.	▪ Remediation any erosion or subsidence is complete; ▪ Growth media (topsoil) has been sourced, carted and spread; ▪ Ameliorants to improve or stabilise soils have been added; and ▪ Deep ripping has been undertaken.	RA1, RA2, RA3, RA4
RM5	Revegetation.	▪ Direct seeding has been completed; ▪ Fertiliser has been applied; ▪ Tube stock (except RA1) has been planted; and ▪ Stock fencing to protect planting has been installed.	RA1, RA2, RA3, RA4
RM6	Land is suitable for the commencement of grazing.	▪ Pasture is sufficiently productive to support grazing and (where relevant) trees are sufficiently tall to avoid damage by cattle; ▪ Internal stock fencing, to separate land ready for grazing from that not yet developed sufficiently, has been installed; and ▪ Water sources for cattle have been installed.	RA1, RA2, RA3, RA4
RM7	Establishment of target vegetation type.	▪ Monitoring has determined that vegetation meets the completion criteria.	RA1, RA2, RA3, RA4
RM8	Achievement of post-mining land use to stable condition.	▪ Monitoring has determined that that the land is safe, structurally stable, does not cause environmental harm and is able to sustain the PMLU.	RA1, RA2, RA3, RA4
RM9	Fulfilment of all conditions of the agreement with Isaac Regional Council for the construction and commissioning of Saraji Road.	▪ The Saraji road has been constructed in accordance with all conditions agreed between Isaac Regional Council and Vitrinite Pty Ltd in the signed compensation agreement. ▪ A “Defects Period” of at least 12 months has passed following the completion of construction. ▪ Isaac Regional Council has notified Vitrinite that the new Saraji road alignment is accepted “off maintenance”.	RA5

Code	Milestone	Description	Applicable Rehabilitation Areas
RM10	The infrastructure to be retained meets the conditions of the signed agreement with BMA.	▪ Monitoring has been undertaken in accordance with the signed agreement and all retained infrastructure is in accordance with the signed agreement. ▪ BMA accepts responsibility for the infrastructure.	RA6

10.3.1 Milestone Criteria

Milestone criteria pertaining to each of the rehabilitation milestones are listed in **Table 10-3**.

Table 10-3 Milestone criteria

Code	Milestone	Milestone criteria
RM1	Infrastructure decommissioning and removal.	▪ All services disconnected; ▪ All road materials (bitumen, gravel) removed; ▪ All pipelines drained and removed; ▪ All fencing that is not part of the PMLU removed; ▪ All buildings are demolished and removed; ▪ All machinery and equipment removed; ▪ All rail lines removed; ▪ All surface water drainage infrastructure not required in the PMLU has been removed; and ▪ All rubbish removed.
RM2	Remediation of contaminated land.	▪ All contamination is remediated or removed from site; ▪ Any contamination removed from site has been removed in accordance with relevant regulations; and ▪ A contaminated land investigation document has been prepared by an approved auditor, containing a site suitability statement that states that land is not contaminated and is suitable for the PMLU.
RM3	Landform development and reshaping/reprofiling.	▪ All earthworks except topsoil handling and placement are complete; ▪ Subsoil has been applied and spread to RA2 (the in-pit WRD's); ▪ All erosion and sediment control systems have been installed; ▪ The final landform surveyed and certified by a suitably qualified person as per the construction designs; ▪ Batters have a maximum slope of 15%; ▪ Rehabilitation areas RA1, RA2, RA3 and RA4 have 'as-constructed' plans prepared; and ▪ The back-filled pit has been certified as geotechnically stable by a suitably qualified person.
RM4	Surface preparation.	▪ Any erosion or subsidence that occurs after the achievement of RM3 has been remediated prior to topsoil application; ▪ 250 mm of topsoil has been be placed over all surfaces following amelioration of subsoils in accordance with the recommendations of an appropriately qualified person; ▪ Slopes greater than 10% have an average rock mulch cover of 30%; ▪ No slopes greater than 10% have a rock mulch cover exceeding 50%, to facilitate the safe movement of cattle and production of pasture; ▪ Slopes less than 10% do not have a rock mulch cover added; ▪ An assessment of soil health and suitability has been completed by an appropriately qualified person to confirm soil is suitable for target vegetation establishment; ▪ Any fertilisers/ameliorants recommended as a result of the soil assessment have been applied at the rate recommended by the appropriately qualified person; and ▪ Contour ripping and/or ploughing (depth of 0.4-0.5 m) has been undertaken after topsoil placement.
RM5	Revegetation.	▪ Seeding has been completed at a rate of 40.7 kg/ha using seed mixes; ▪ Any species not establishing after seeding (as identified 12 months after seeding) have been planted as tubestock in RA2, RA3 and RA4 at a density of 20-100 seedlings/ha; and

Code	Milestone	Milestone criteria
		▪ Supplementary seeding and tubestock planting completed within one year of sites failing to achieve vegetation establishment on initial attempts.
RM6	Land is suitable for the commencement of grazing.	▪ Rehabilitated areas have a pasture biomass that is not >10% less than pasture biomass on unmined areas within the same soil management unit measured at the same time, as measured under both wet and dry conditions; ▪ All corrective actions recommended by suitably qualified persons in response to erosion or deficient vegetation cover have been implemented; ▪ Rehabilitated areas are to have a land suitability class for cattle grazing of 4 or lower; ▪ No active rill or gully erosion deeper than 25 cm present; ▪ Trees are, on average, at least 4 m tall; ▪ Water sources have been installed; and ▪ Stock fencing installation is complete.
RM7	Establishment of target vegetation type*.	▪ *Eucalyptus crebra* and/or *Eucalyptus populnea* constitute ≥21% of the total basal area of woody vegetation on sand plains AND *Eucalyptus camaldulensis* is to constitute ≥33% of the total basal area of woody vegetation along Ripstone Creek and Drainage Line 2 (not applicable to RA1); ▪ Rehabilitated areas have a mean NDVI between 0.1240 and 0.1778.
RM8	Achievement of post-mining land use to stable condition*.	▪ All corrective actions recommended by suitably qualified persons in response to erosion or deficient vegetation cover have been implemented; ▪ A suitably qualified person has certified that the final landform is geotechnically stable; ▪ The land suitability class of rehabilitated land is to be 4 or lower for cattle grazing; ▪ Rehabilitated areas have a pasture biomass that is not >10% less than pasture biomass on unmined areas with the same soil management unit measured at the same time, as measured under both wet and dry conditions; ▪ Landscape function analysis scores for soil stability, infiltration/runoff and nutrient cycling have started to plateau, and the plateau values predicted from sigmoidal curves fitted to the data are equivalent to or exceed values at analogue sites; ▪ Erosion monitoring has been completed; ▪ No active rill or gully erosion deeper than 25 cm present; ▪ Grazed land maintains a percentage ground cover of between 50% and 96% on slopes up to 10% and between 70% and 96% on slopes between 10-15%; ▪ Rehabilitated areas have ≤0.2% cover of *Parthenium hysterophorus* AND ≤0.1% cover of *Harrisia martini*; ▪ Any other weeds listed under the *Biosecurity Act* are present in densities of <1 individual per hectare; ▪ Surface water in downstream monitoring locations remains within site-specific water quality monitoring limits detailed in environmental authority EA0002912 in Table F2: Interim contaminant trigger investigation levels; ▪ Groundwater in downstream monitoring locations remains within site-specific water quality monitoring limits detailed in environmental authority EA0002912 in Table E2: Groundwater quality limits; ▪ At least 50% of established species show natural recruitment; and ▪ Sites fulfil all other milestone criteria after having experienced at least one “drought” year (defined as having a total rainfall over a 12-month period that falls within the lowest decile recorded at the nearest weather station, Moranbah Airport).
RM9	Fulfilment of all requirements of the agreement with Isaac Regional Council for the construction and commissioning of Saraji Road.	▪ Isaac Regional Council (IRC) has notified Vitrinite that the new Saraji road alignment is accepted “off maintenance”, in accordance with processes prescribed by the signed compensation agreement between Vitrinite and IRC.
RM10	The infrastructure to be retained meets the conditions of the signed agreement with BMA.	▪ Monitoring has been undertaken in accordance with the signed agreement and all retained infrastructure is in accordance with the signed agreement; and ▪ BMA accepts responsibility for the infrastructure in accordance with a formal written agreement.

*For a more detailed description and justification of milestone criteria used for the final two rehabilitation milestones, refer to **Section 5.1**.
^For Erosion Monitoring Classifications, see Section 9.6.1 of the VCM Soils and Land Suitability Assessment (Appendix I of the EA Application Supporting Information document).

10.4 PRC Plan Schedule

The PRC Plan Schedule is provided in **Table 10-4**.

Table 10-4 PRC Plan Schedule

Rehabilitation area				RA1						
Relevant activities				Ex-pit waste rock dump						
Total size of rehabilitation area (ha)				24 ha						
Commencement of first milestone (RM3)				01 Aug 2022						
PMLU				Low-intensity cattle grazing						
Date area is available	31 Jul 2022		31 Jul 2024							
Cumulative area available (ha)	15		24							
	Milestone completed by									
	10 Dec 2022	10 Dec 2023	10 Dec 2024	10 Dec 2025	10 Dec 2033	10 Dec 2035				
Milestone code	**Cumulative area achieved (ha)**									
RM3	15		24							
RM4		15		24						
RM5		15		24						
RM6					15	24				
RM7					15	24				
RM8					15	24				

Rehabilitation area				RA2						
Relevant activities				Open Cut Mining Pits; In-pit Waste Rock Dumps (Jupiter and Matilda)						
Total size of rehabilitation area (ha)				131 ha						
Commencement of first milestone (RM3)				01 Aug 2023						
PMLU				Low-intensity cattle grazing with habitat for threatened fauna						
Date area is available	31 Jul 2023	31 Jul 2024	31 Jul 2025							
Cumulative area available (ha)	10	61	131							
	Milestone completed by									
	10 Dec 2023	10 Dec 2024	10 Dec 2025	10 Dec 2026	10 Dec 2034	10 Dec 2035	10 Dec 2036			
Milestone code	**Cumulative area achieved (ha)**									
RM3	10	61	131							
RM4		10	61	131						
RM5		10	61	131						
RM6					10	61	131			
RM7					10	61	131			
RM8					10	61	131			

Rehabilitation area				RA3						
Relevant activities				Infrastructure- CHPP, Rail Loop, TLO, haul roads, internal tracks, stockpiles, run-of-mine pad						
Total size of rehabilitation area (ha)				144 ha						
Commencement of first milestone (RM1)				01 Aug 2026						
PMLU				Low-intensity cattle grazing with habitat for threatened fauna						
Date area is available	31 Jul 2026	31 Jul 2027								
Cumulative area available (ha)	64	144								
	Milestone completed by									
	10 Dec 2028	10 Dec 2029	10 Dec 2030	10 Dec 2039	10 Dec 2040					
Milestone code	**Cumulative area achieved (ha)**									
RM1	64	144								
RM2	64	144								
RM3	64	144								
RM4		64	144							
RM5		64	144							
RM6				64	144					
RM7				64	144					
RM8				64	144					

Rehabilitation area				RA4						
Relevant activities				Water Management Infrastructure- dams, sediment control drains, ponds and flood protection levees						
Total size of rehabilitation area (ha)				22 ha						
Commencement of first milestone (RM1)				01 Aug 2028						
PMLU				Low-intensity cattle grazing with habitat for threatened fauna						
Date area is available	31 Jul 2028									
Cumulative area available (ha)	22									
	Milestone completed by									
	10 Dec 2028	10 Dec 2029	10 Dec 2039							
Milestone code	**Cumulative area achieved (ha)**									
RM2	22									
RM3	22									
RM4		22								
RM5		22								
RM6			22							
RM7			22							
RM8			22							

Rehabilitation area				RA5						
Relevant activities				Saraji Road						
Total size of rehabilitation area (ha)				17 ha						
Commencement of first milestone (RM9)				1 May 2026						
PMLU				Road Reserve						
Date area is available	30 Apr 2026									
Cumulative area available (ha)	17									
	Milestone completed by									
	10 Dec 2027									
Milestone code	**Cumulative area achieved (ha)**									
RM9	17									

Rehabilitation area	RA6									
Relevant activities	Offices, workshops, warehouses, roads and associated water management infrastructure and topsoil stockpiles									
Total size of rehabilitation area (ha)	13 ha									
Commencement of first milestone (RM9)	1 May 2028									
PMLU	Retained infrastructure									
Date area is available	30 Apr 2028									
Cumulative area available (ha)	13									
	Milestone completed by									
	10 Dec 2028									
Milestone code	**Cumulative area achieved (ha)**									
RM10	13									

11 REVISION OF THE PRC PLAN

The holder of a PRC plan may, at any time, apply to the administering authority to amend their PRC Plan schedule (an amendment application). An application may be made to amend only the PRC Plan schedule, or as part of an amendment application for an EA. An amendment application must be submitted in the approved form and be accompanied by the relevant fee and an amended rehabilitation planning part for the holder's PRC plan that complies with section 126C of the EP Act. Due to the dependencies between an EA and the PRC Plan schedule, an applicant should always consider whether a proposed amendment to the PRC Plan schedule requires a concurrent amendment to the EA in order to ensure consistency between both instruments.

Once a PRC Plan schedule has been amended, the rehabilitation planning part of the PRC plan must be reviewed and revised to make any necessary or appropriate changes. The administering authority is to be provided with a copy of the amended PRC plan within 10 business days of receiving a copy of the amended PRC Plan schedule (or receiving written notice under section 211 of the EP Act), unless the administering authority agrees to a longer period.

12 SPATIAL INFORMATION

Shapefiles detailing the following spatial information were submitted to the administering authority accompanying the submission of this PRC plan.

- the location and maximum extent of the disturbance footprint for the mine life;
- the PMLU and NUMAs for the area within the resource tenures; and
- the rehabilitation areas within the resource tenures;
- the locations of sensitive receptors.

13 REFERENCES

AARC (2021). Vulcan Complex Project Soil and Land Suitability Assessment. Report prepared for METServe Pty Ltd by AARC Environmental Solutions Pty Ltd, Brisbane.

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, Australia. Available at: www.waterquality.gov.au/anz-guidelines

Australian Koala Foundation (2015). *National Koala Tree Planting List*. Available online at: https://www.savethekoala.com/about-koalas/trees-koalas

Ball J., M. Babister, R. Nathan, W. Weeks, E. Weinmann, M. Retallick and I. Testoni (Editors) (2019). Australian Rainfall and Runoff: A Guide to Flood Estimation. Geoscience Australia, Commonwealth of Australia, Canberra.

Bisrat, S.A., B.F. Mullen, A.H. Grigg and H.M. Shelton (2004). Net primary productivity and rainfall use efficiency of pastures on reconstructed land following open-cut coal mining in central Queensland, Australia. *Tropical Grasslands* **38,** 47-55.

Blackburn W.H. (1983). Livestock grazing impacts on watersheds. *Rangelands* **5,** 123-125.

Blackrock Mining Solutions Pty Ltd (2020). Vulcan Complex – Jupiter Final Landform Slope Stability Assessment. Memorandum to Vitrinite Pty Ltd on 3 March 2020.

Carroll C. and Tucker A. (2000). Effects of pasture cover on soil erosion and water quality on central Queensland coal mine rehabilitation. *Tropical Grasslands* **34,** 254-262.

Carroll C., Dougall C., Silburn M., Waters D., Packett B. and Joo M., (2010). Sediment erosion research in the Fitzroy basin central Queensland: an overview. *19th World Congress of Soil Science, Soil Solutions for a Changing World.*

Cayley, J.W.D. and P.R. Bird (1996) *Techniques for measuring pastures*. Pastoral and Veterinary Institute, Hamilton. ISBN 0 7306 64295.

CRDC (2020). Best Management Practices for Nitrogen (N) Fertilizer Use on Dairy Pastures – More Profit from Nitrogen Program. Retrieved from: https://www.crdc.com.au/more-profit-nitrogen (Viewed on 17th August 2020).

CSIRO (2015). Climate Change in Australia Information for Australia's Natural Resource Management Regions: Technical Report. CSIRO and Bureau of Meteorology, Australia.

Daws, M.I., J. Standish, J.M. Koch and T.K. Morald (2013). Nitrogen and phosphorus fertilizer regime affect jarrah forest restoration after bauxite mining in Western Australia. *Applied Vegetation Science* **16,** 610-618.

Department of Environment and Heritage Protection (2013). Isaac River Sub-basin Environmental Values and Water Quality Objectives Basin No. 130 (part), including all waters of the Isaac River Sub-basin (including Connors River). Document made pursuant to the Environmental Protection (Water) Policy 2009. Queensland Government, Brisbane.

Department of Environment and Science (2017). Guideline. Environmental Protection (Water) Policy 2009. Model mining conditions, March 2017, version 6.02.

Department of Environment and Science (2018). Environmental Protection (Water) Policy 2009. Monitoring and Sampling Manual, June 2018, version 2.

Department of Environment and Science (2019a). Guideline: Progressive rehabilitation and closure plans, version 2,0. Queensland Government, Brisbane.

Department of Environment and Science (2019b). SILO – Australian climate data from 1889 to yesterday. Accessed at: https://www.longpaddock.qld.gov.au/silo/

Department of Environment and Science (2020). Queensland Environmental Offsets Policy (Version 1.9). Queensland Government, Brisbane.

Department of Environment and Science (2021). Using monitoring data to assess groundwater quality and potential environmental impacts (version 2). Queensland Government, Brisbane.

Department of Primary Industries Victoria (n.d.). Fertilizing Pastures. Retrieved from: http://www.ccmaknowledgebase.vic.gov.au/shkb/brown_book/documents/15_Sulphur/Greener_pastures_Chapter5.pdf (viewed 17th August 2020).

DME (1995). Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland – Land Suitability Assessment Techniques. Department of Minerals and Energy, Queensland Government, Brisbane.

DNRME (2019). Groundwater Database – Queensland. Department of Natural Resources, Mines and Energy, Queensland Government, Brisbane. Accessed online from: https://www.data.qld.gov.au/dataset/groundwater-database-queensland

Donaghy, P., S. Bray, R. Gowen, J. Rolfe, M. Stephens, M. Hoffmann and A. Stunzer (2010). The bioeconomic potential for agroforestry in Australia's northern grazing systems. *Small-scale Forestry* **9,** 463-484.

DPIRD (2020). Department of Primary Industries and Regional Development. Agriculture and Food. Managing dispersive (sodic) soils. Retrieved from: https://www.agric.wa.gov.au/dispersive-and-sodicsoils/managing-dispersive-sodic-soils. (Viewed 17th August 2020).

DSITI (2015). *Soil Conservation Guidelines for Queensland.* Department of Science, Information Technology and Innovation, Queensland Government, Brisbane.

DSITI and DNRM (2015). *Guidelines for Agricultural Land Evaluation in Queensland* 2nd ed. Department of Science, Information Technology and Innovation and the Department of Natural Resources and Mines, Queensland Government, Brisbane.

Department of Science, Information Technology and Innovation (DSITI) (2017). Using monitoring data to assess groundwater quality and potential environmental impacts. Version 1. Queensland Government, Brisbane. March 2017.

Eamus, D., X. Chen, G. Kelley and L.B. Hutley (2002). Root biomass and root fractal analyses of an open *Eucalyptus* forest in a savanna of north Australia. *Australian Journal of Botany* **50,** 31-41.

Erskine, P.D. and A.T. Fletcher (2013). Novel ecosystems created by coal mines in central Queensland's Bowen Basin. *Ecological Processes* **2,** 33.

Fensham, R.J., J.E. Holman and M.J. Cox (1999). Plant species responses along a grazing disturbance gradient in Australian grassland. *Journal of Vegetation Science* **10,** 77-86.

Ganskopp D. and Vavra M. (1987). Slope use by Cattle, Feral Horses, Deer and Bighorn Sheep. *Northwest Science*. **61**. 74-81.

Geoscience Australia (2019). Bowen Basin https://www.ga.gov.au/scientific-topics/energy/province-sedimentary-basin-geology/petroleum/onshore-australia/bowen-basin visited on 1 August 2019.

Grant, J.C., J. D. Nichola, R.L. Yoa, R.G.B. Smith, P.D. Brennan and J.K. Vanclay (2012). Depth distribution of roots of *Eucalyptus dunnii* and *Corymbia citriodora* subsp. *variegata* in different soil conditions. *Forest Ecology and Management* **269,** 249-258.

Grice, A.C., M.H. Fiedel, N.A. Marshall and R.D. Van Klinken (2012). Tackling contentious invasive plant species: a case study of Buffel Grass in Australia. *Environmental Management* **49,** 285-294.

hydrogeologist.com.au (2020). Vulcan Complex Project Groundwater Impact Assessment. Report prepared for Vitrinite Pty Ltd by hydrogeologist.com.au, Brisbane

hydrogeologist.com.au (2021).Vulcan Complex Project Groundwater Quality Trigger Assessment. Report prepared for Vitrinite Pty Ltd by hydrogeologist.com.au, Brisbane

hydrogeologist.com.au (2022).Vulcan Coal Mine EA Amendment Groundwater Impact Assessment. Report prepared for Vitrinite Pty Ltd by hydrogeologist.com.au, Brisbane

IECA (2008). *Best Practice Erosion and Sediment Control.* International Erosion Control Association (Australasia).

Keipert, N.L., J. Duggin, P. Lockwood and C. Grant (2005). Effect of different stockpiling procedures on topsoil characteristics in open cut coal mine rehabilitation in the hunter Valley, New South Wales. Doctoral thesis, University of New England.

Kelly (2006). Recycled organics in mine site rehabilitation. Report prepared for the Department of Environment and Conservation NSW.

Kopittke, G., D. Mulligan, A. Grigg and B. Kirsch (2004). Development of reconstructed soils and vegetation communities at a central Queensland coal mine: a preliminary investigation of twelve years of monitoring. *SuperSoil 2004: 3rd Australian New Zealand Soils Conference* pp 1-9.

Lu, H., J. Gallant, I.P. Prosser, C. Moran and G. Priestly (2001). Prediction of sheet and rill erosion over the Australian continent, incorporating monthly soil loss distribution. CSIRO Land and Water Technical Report 13/01. https://doi.org/10.4225/08/5867f3fdeb410.

Loch, R.J. (2000). Effects of vegetation cover on runoff and erosion under simulated rain and overland flow on a rehabilitated site on the Meandu mine, Tarong, Queensland. *Australian Journal of Soil Research* **38,** 299-312.

Ludwig J.A. and Tongway D.J. (2002). Clearing savannas for use as rangelands in Queensland: altered landscapes and water-erosion processes. *Rangelands Journal* **24,** 83-95.

METServe (2020). Terrestrial Ecological Assessment for the Vulcan Complex Project. Reported prepared for Vitrinite Pty Ltd by Mining and Energy Technical Services Pty Ltd, Brisbane.

METServe (2022). Terrestrial Ecological Assessment for Vulcan Coal Mine Amendment. Reported prepared for Vitrinite Pty Ltd by Mining and Energy Technical Services Pty Ltd, Brisbane.

MLA (n.d.) Meat and Livestock Australia. Beef Cattle feedlots: waste management and utilization. Retrieved from: https://www.mla.com.au/globalassets/mla-corporate/research-anddevelopment/program-areas/feeding-finishing-and-nutrition/manure-handbook/section-5-utilisation-ofmanure-and-effluent-2016_07_28.pdf (viewed 17 August 2020).

Mueggler W.F. (1965). Cattle distribution on steep slopes. *Journal of Range Management*, 255-257.

Mulligan, D.R., M.J. Gillespie, A.J. Gravina and N.A. Currey (2006). An assessment of the direct revegetation strategy on the tailings storage facility at Kidston Gold Mine, North Queensland, Australia. In AB Fourie & M Tibbett (eds), *Proceedings of the First International Seminar on Mine Closure*, Australian Centre for Geomechanics, Perth, pp. 371-381.

NSW Government (2015), Transport Roads & Maritime Services. Guidelines for batter surface stabilisation.

RGS (2020). Geochemical assessment of waste rock and coal reject, Vulcan Complex Project. Report prepared for Vitrinite Pty Ltd by RGS Environmental Pty Ltd, Brisbane.

RGS (2022). VCM Matilda Pit Geochemistry Assessment, Vulcan Coal Mine. Report prepared for Vitrinite Pty Ltd by RGS Environmental Pty Ltd, Brisbane.

Scanlan J.C., Pressland A.J. and Myles D.J. (1996). Grazing modifies woody and herbaceous components of north Queensland woodlands. *Rangelands Journal* **18,** 47-57.

Smith, K.A., T. Ball, F.Conen, K.E. Dobbie, A. Massheder and A. Rey (2018). Exchange of greenhouse gases between soil and atmosphere: interactions of soil physical factors and biological processes. *European Journal of Soil Science* **69,** 10-20.

Stantec (2021). Vulcan Coal Mine- Transport Impact Assessment. Report prepared for Vitrinite Pty Ltd.

Story, R., R.W. Galloway, R.H. Gunn and E.A. Fitzpatrick (1967). *Lands of the Isaac-Comet Area, Queensland.* Land Research Series No. 19. CSIRO, Melbourne.

Tongway, D.J. and N.L. Hindley (2004). Landscape Function Analysis: Procedures for monitoring and assessing landscapes – with special reference to minesites and rangelands. CSIRO Sustainable Ecosystems, Canberra.

Victoria Government (2013). Corangamite Region 'Brown Book' – How to optimise your soils to enhance productivity, retrieved from: https://www.ccmaknowledgebase.vic.gov.au/brown_book/12_Superphosphate.htm (viewed 18 August 2020).

Walker, B.H., J.L. Langridge and F. McFarlane (2006). Resilience of an Australian savanna grassland to selective and non-selective perturbations. *Australian Journal of Ecology* **22,** 125-135.

Waters, D.K. (2004). Grazing management implications on runoff and erosion processes in semi-arid Central Queensland. In '*Conserving Soil and Water for Society: Sharing Solutions. Proceedings 13th International Soil Conservation Organisation Conference'*. Brisbane, 2004. Paper 427. (Eds S.R. Raine, A.J.W. Biggs, N.W. Menzies, D.M. Freebairn, P.E. Tolmie) (ASSSI/IECA: Brisbane, Qld).

Williams, D.J. (2001). Prediction of erosion from steep mine waste slopes. *Environmental Management and Health* **12,** 35-50.

WRM (2022a). Vulcan Coal Mine EA Amendment Surface Water Assessment. Report prepared for Mining and Energy Technical Services Pty Ltd by WRM Water & Environment Pty Ltd, Brisbane.

WRM (2022b). Vulcan Coal Mine Final Landform Drainage Summary. Memo prepared for Mining and Energy Technical Services Pty Ltd by WRM Water & Environment Pty Ltd, Brisbane.

Zerihun, A., K.D. Montagu, M.B. Hoffmann and S.G. Bray (2006). Patterns of below- and aboveground biomass in *Eucalyptus populnea* woodland communities on northeast Australia along a rainfall gradient. *Ecosystems* **9,** 501-515.

Appendix A- Surface Water Assessment Report

Vulcan Coal Mine

EA Amendment
Surface water assessment

Vitrinite Pty Ltd

1571-22-B3, 19 September 2022

Report Title	Vulcan Coal Mine Surface water assessment
Client	Vitrinite Pty Ltd
Report Number	1571-22-B3

Revision Number	Report Date	Report Author	Reviewer
0 [DRAFT]	11 March 2020	LZ/RN	JO
1	31 March 2020	LZ/RN	JO/DN
2	17 September 2020	LZ	JO
3 [DRAFT]	2 December 2021	RN	JO
4	6 December 2021	RN	JO
5 [DRAFT]	25 July 2022	RN	JO
6	9 September 2022	RN	JO
7	14 September 2022	RN	JO
8	19 September 2022	RN	JO

For and on behalf of WRM Water & Environment Pty Ltd
Level 9, 135 Wickham Tce, Spring Hill
PO Box 10703 Brisbane Adelaide St Qld 4000
Tel 07 3225 0200



Julian Orth
Principal Engineer

NOTE: This report has been prepared on the assumption that all information, data and reports provided to us by our client, on behalf of our client, or by third parties (e.g. government agencies) is complete and accurate and on the basis that such other assumptions we have identified (whether or not those assumptions have been identified in this advice) are correct. You must inform us if any of the assumptions are not complete or accurate. We retain ownership of all copyright in this report. Except where you obtain our prior written consent, this report may only be used by our client for the purpose for which it has been provided by us.

Contents

1 Introduction 12

1.1 Background 12

1.2 Current Project description 12

1.3 Proposed amendment 13

1.3.1 Overview 13

1.3.2 CHPP 13

1.3.3 Rail loop and train load-out facility 14

1.3.4 Matilda Pit 14

2 Regulatory framework 19

2.1 Commonwealth 19

2.2 State 24

2.2.1 EP Act 1994 24

2.2.2 Water Act 2000 27

2.2.3 Water Supply (Safety & Reliability) Act 2008 28

3 Environmental Values 29

4 Existing surface water environment 33

4.1 Regional drainage characteristics 33

4.2 Local drainage network 33

4.2.1 Drainage Line 1 37

4.2.2 Existing drainage diversion 38

4.2.3 Drainage Line 2 39

4.3 Rainfall and evaporation 42

4.4 Streamflow 43

4.5 Water quality 45

4.5.1 Regional Isaac River water quality 45

4.5.2 Baseline surface water quality data 48

4.5.3 Baseline surface water quality assessment methodology 48

4.5.4 Comparison of baseline surface water quality data with the Project WQO and MMC default trigger values 48

4.6 Recommended receiving waters trigger values 50

4.7 Soil characteristics 54

4.7.1 Soil management units 54

4.7.2 Sodic and dispersive soils 54

5 Proposed surface water management strategy and infrastructure 55

5.1 Types of water generated onsite 55

5.2 Proposed water management infrastructure 55

5.3 Water management strategy overview 55

5.4 Diverted runoff water management 57

5.4.1 Flood protection levee 57
5.4.2 Diverted water drains and dams 57
5.5 Surface water management 58
5.5.1 Sediment dam locations and sizing 59
5.5.2 Haul road and access road sediment management 60
5.6 Mine affected water management 61
5.6.1 Mine affected water dams 61
5.6.2 Preliminary consequence assessment 62
5.6.3 Pit dewatering rates 63
5.7 Release of waters to the receiving environment 63
5.8 Sewage and effluent disposal 63
5.9 Post-closure conditions water management 63
6 Water balance model configuration 65
6.1 Overview 65
6.2 Simulation methodology 65
6.3 Catchment yield parameters 66
6.4 Conceptual water management system configuration and schematic 67
6.5 Site water demands 71
6.5.1 Haul road dust suppression 71
6.5.2 CHPP demand 72
6.5.3 TLO demand 73
6.5.4 Potable water demand 73
6.6 Water sources 73
6.6.1 Groundwater 73
6.6.2 External water 74
6.7 Watercourse flow modelling 74
6.8 Water quality modelling 75
6.8.1 Adopted salinity parameters 75
7 Water management system assessment 77
7.1 Overview 77
7.2 Interpretation of model results 77
7.3 Water balance model results 78
7.3.1 Overall water balance 78
7.3.2 Mine affected water inventory 79
7.3.3 Jupiter pit water inventory 82
7.3.4 Matilda Pit 83
7.3.5 External water requirements 84
7.3.6 Spillway water discharges 84
7.3.7 Overall salt balance 86
7.3.8 Receiving waters water quality 87

7.3.9 Release scenarios 88
7.4 Sensitivity analysis 91
7.4.1 Haul road dust suppression 91
7.4.2 Climate change 93
7.5 Adaptive management of the water management system 96
8 Flood modelling and impact assessment 97
8.1 Overview 97
8.2 Adopted methodology 97
8.2.1 Hydrological model 97
8.2.2 Hydraulic model 97
8.3 Conditions assessed 97
8.3.1 General 97
8.4 Existing Conditions hydrologic model configuration 98
8.4.1 General 98
8.4.2 Design rainfall depths, intensities and temporal patterns 98
8.4.3 Design rainfall losses 98
8.4.4 Peak flow validation 100
8.4.5 Adopted design discharges 100
8.5 Hydraulic model development 101
8.5.1 Topographic data 101
8.5.2 Inflow and outflow boundaries 101
8.5.3 Manning's 'n' values 101
8.5.4 Hydraulic structures 102
8.6 Changes to Pre-mining conditions 104
8.6.1 Operational Conditions model changes 104
8.6.2 Post-closure Conditions model changes 104
8.6.3 Proposed haul road crossings and upgraded haul road 108
8.6.4 Proposed modifications to the BMA levee and existing drainage diversion 108
8.6.5 Proposed rail loop and culverts 109
8.6.6 Proposed CHPP infrastructure area 109
8.6.7 Proposed DD1 dam, northern diversion drain and bunds 110
8.6.8 Proposed Matilda Pit diversion drain 111
8.6.9 Saraji Road and culverts 112
8.6.10 Proposed flood protection levee 113
8.6.11 Proposed drainage corridor 116
8.7 Pre-mining Conditions design flood levels and extents 117
8.7.1 Pre-mining Conditions modelling results 117
8.7.2 Scenario 1 – Pre-mining Conditions (with levee) 117
8.7.3 Scenario 2 – Pre-mining Conditions (no levee) 118

8.8 Operational Conditions design flood levels and extents 118
8.8.1 General 118
8.8.2 Operational Conditions impacts 119
8.9 Post-closure conditions potential flood impacts 120
8.9.1 General 120
8.9.2 Scenario 1 – Post-closure Conditions impacts (with levee) 121
8.9.3 Scenario 2 – Post-closure Conditions impacts (no levee) 122
9 Surface water monitoring 124
9.1 Overview 124
9.2 Receiving water quality monitoring 127
9.3 Mine affected water quality monitoring 128
9.4 Sediment dam monitoring 128
9.5 Trigger investigation 128
9.6 Receiving Environment Monitoring Program (REMP) 129
10 Cumulative impacts 130
10.1 Overview 130
10.2 Existing projects 130
10.3 New or developing projects 130
10.4 Cumulative impacts – surface water resources 131
10.4.1 Water quality 131
10.4.2 Loss of catchment and stream flows in the Isaac River 135
11 Summary of findings 137
11.1 Overview 137
11.2 Water management system performance 137
11.3 Flooding 137
11.4 Water quality objectives 138
11.5 Impacts on downstream water quality 138
11.6 Cumulative impacts 138
11.7 Operational Conditions 139
11.8 Final landform 139
12 References 140
Appendix A - **Pre-mining Conditions flood maps and results 142**
Appendix B - **Operational Conditions flood maps and results 155**
Appendix C - **Post-closure Conditions flood impact maps 168**

List of Figures

Figure 1.1 – Locality plan ____ 15
Figure 1.2 – Stage 1 (Year 2022) water management system plan ____ 16
Figure 1.3 - Stage 2 (Year 2024) water management system plan ____ 17
Figure 1.4 – Final landform (post-mining conditions) for the Project ____ 18
Figure 3.1 - Isaac River Sub-Basin EVs (source: DES, 2013) ____ 30
Figure 4.1 – Upper Isaac River drainage characteristics ____ 34
Figure 4.2 – Regional catchments in the vicinity of the Project ____ 35
Figure 4.3 – Local drainage features in the vicinity of the Project ____ 36
Figure 4.4 – Photograph of Drainage Line 1 within the Project area ____ 37
Figure 4.5 – Photograph of the existing railway culvert crossing of Drainage Line 1 at the eastern (downstream) Project boundary ____ 38
Figure 4.6 – Photograph of the existing drainage diversion and levee within the Project area ____ 39
Figure 4.7 – Photograph of Drainage Line 2 within the Project area ____ 40
Figure 4.8 – Drainage line cross sections with 1% AEP flood levels ____ 41
Figure 4.9 – Long term mean monthly rainfall and evaporation from SILO at the Project ____ 42
Figure 4.10 – Flow volume and river height in the Isaac River at Deverill ____ 43
Figure 4.11 – Sample flow sequence – Phillips Creek at Tayglen 1977 - 1979 ____ 44
Figure 4.12 – Measured mean monthly streamflow – Phillips Creek at Tayglen 1968-1988 ____ 44
Figure 4.13 – Recorded frequency curves at nearby RDMW gauges (no flow days included) ____ 45
Figure 4.14 - Electrical Conductivity and Flow (Isaac River at Deverill Gauge) ____ 47
Figure 4.15 - Flow vs Electrical Conductivity (Isaac River at Deverill Gauge) ____ 47
Figure 4.16 - Water monitoring locations ____ 53
Figure 6.1 – Water management system schematic for the Project ____ 69
Figure 7.1 – Forecast MWD1 inventory ____ 81
Figure 7.2 – Forecast annual maximum MWD1 inventory ____ 81
Figure 7.3 – Forecast annual combined maximum water inventory in MWD2, MWD3, MWD4, MWD5 and MWD6 ____ 82
Figure 7.4 – Jupiter forecast mine pit inventory ____ 83
Figure 7.5 – Jupiter forecast annual maximum pit inventory ____ 83
Figure 7.6 – Forecast external water requirement for dust suppression, CHPP and TLO use ____ 84
Figure 7.7 – Forecast annual sediment dam releases to the receiving waters ____ 85
Figure 7.8 – Forecast total annual pumped transfers from DD1 to the existing drainage diversion ____ 86
Figure 7.9 – Predicted Boomerang Creek annual maximum EC variation downstream of the Project ____ 88

Figure 7.10 – Project release rate compared to flow rate in the receiving waters – Scenario 1 ____ 89
Figure 7.11 – Project release EC levels compared to EC levels in the receiving waters and corresponding water quality criteria – Scenario 1 ____ 89
Figure 7.12 – Project release rates compared to flow rates in the receiving waters– Scenario 2 ____ 90
Figure 7.13 – Project release EC levels compared to EC levels in the receiving waters as well as the corresponding water quality criteria – Scenario 2 ____ 91
Figure 7.14 – Forecast annual maximum MWD1 inventory – dust suppression sensitivity analysis ____ 92
Figure 7.15 – Jupiter forecast annual maximum mine pit inventory – dust suppression sensitivity analysis ____ 92
Figure 7.16 – Forecast annual total external water requirement - dust suppression sensitivity analysis ____ 93
Figure 7.17 – Forecast annual total external water requirement – climate change 'best case' sensitivity analysis ____ 95
Figure 7.18 – Forecast annual total external water requirement – climate change 'worst case' sensitivity analysis ____ 95
Figure 8.1 – XP-RAFTS model configuration ____ 99
Figure 8.2 – Jupiter Pit Pre-mining Conditions hydraulic model configuration ____ 103
Figure 8.3 – Jupiter Pit Operational Conditions hydraulic model configuration ____ 105
Figure 8.4 – Location and extent of Operational Conditions infrastructure changes ____ 106
Figure 8.5 – Jupiter Pit Final Landform (Post-closure Conditions) hydraulic model configuration ____ 107
Figure 8.6 – Typical cross section (Access road XS in Figure 8.3) of the proposed levee and drainage diversion modifications at the existing access road haul road crossing upgrade ____ 109
Figure 8.7 – Typical cross section (XS1 in Figure 8.3) of proposed northern diverison drain around Jupiter Pit ____ 110
Figure 8.8 – Typical cross section (XS2 in Figure 8.3) of proposed northern/eastern diverison drain around Jupiter Pit ____ 111
Figure 8.9 – Typical cross section (XS3 in Figure 8.3) of proposed western diverison drain around Matilda Pit ____ 112
Figure 8.10 – Conceptual design of Saraji Road culverts along Drainage line 1 ____ 112
Figure 8.11 – Proposed flood protection levee alignment ____ 115
Figure 8.12 – Conceptual cross section of the proposed drainage corridor and the 10%, 1% and 0.1% AEP event water surface elevations for both levee scenarios ____ 116
Figure 9.1 – Proposed mine water dam quality monitoring locations ____ 126
Figure 10.1 – Cumulative impact assessment ____ 136
Figure A.1 – 10% AEP peak flood depths – Pre-mining Conditions (with levee) ____ 143
Figure A.2 – 1% AEP peak flood depths – Pre-mining Conditions (with levee) ____ 144
Figure A.3 – 0.1% AEP peak flood depths – Pre-mining Conditions (with levee) ____ 145
Figure A.4 – 10% AEP peak velocities – Pre-mining Conditions (with levee) ____ 146
Figure A.5 – 1% AEP peak velocities – Pre-mining Conditions (with levee) ____ 147

Figure A.6 – 0.1% AEP peak velocities – Pre-mining Conditions (with levee) 148
Figure A.7 – 10% AEP peak flood depths – Pre-mining Conditions (no levee) 149
Figure A.8 – 1% AEP peak flood depths – Pre-mining Conditions (no levee) 150
Figure A.9 – 0.1% AEP peak flood depths – Pre-mining Conditions (no levee) 151
Figure A.10 – 10% AEP peak velocities – Pre-mining Conditions (no levee) 152
Figure A.11 – 1% AEP peak velocities – Pre-mining Conditions (no levee) 153
Figure A.12 – 0.1% AEP peak velocities – Pre-mining Conditions (no levee) 154
Figure B.1 – 10% AEP change in peak water levels – Operational Conditions (proposed crossing at existing access road) impacts 156
Figure B.2 - 1% AEP change in peak water levels – Operational Conditions (proposed crossing at existing access road) impacts 157
Figure B.3 - 0.1% AEP change in peak water levels – Operational Conditions (proposed crossing at existing access road) impacts 158
Figure B.4 - 10% AEP change in peak velocities – Operational Conditions (proposed crossing at existing access road) impacts 159
Figure B.5 - 1% AEP change in peak velocities – Operational Conditions (proposed crossing at existing access road) impacts 160
Figure B.6 - 0.1% AEP change in peak velocities – Operational Conditions (proposed crossing at existing access road) impacts 161
Figure B.7 - 10% AEP change in peak water levels – Operational Conditions (proposed crossing at northern MIA) impacts 162
Figure B.8 - 1% AEP change in peak water levels – Operational Conditions (proposed crossing at northern MIA) impact 163
Figure B.9 - 0.1% AEP change in peak water levels – Operational Conditions (proposed crossing at northern MIA) impacts 164
Figure B.10 - 10% AEP change in peak velocities – Operational Conditions (proposed crossing at northern MIA) impacts 165
Figure B.11 - 1% AEP change in peak velocities – Operational Conditions (proposed crossing at northern MIA) impacts 166
Figure B.12 - 0.1% AEP change in peak velocities – Operational Conditions (proposed crossing at northern MIA) impacts 167
Figure C.1 – 10% AEP change in peak water levels – Post-closure Conditions (with levee) impacts 169
Figure C.2 - 1% AEP change in peak water levels - Post-closure Conditions (with levee) impacts 170
Figure C.3 - 0.1% AEP change in peak water levels – Post-closure Conditions (with levee) impacts 171
Figure C.4 - 10% AEP change in peak velocities – Post-closure Conditions (with levee) impacts 172
Figure C.5 - 1% AEP change in peak velocities – Post-closure Conditions (with levee) impacts 173
Figure C.6 - 0.1% AEP change in peak velocities – Post-closure Conditions (with levee) impacts 174
Figure C.7 - 10% AEP change in peak water levels – Post-closure Conditions (no levee) impacts 175

Figure C.8 - 1% AEP change in peak water levels – Post-closure Conditions (no levee) impacts _____176
Figure C.9 - 0.1% AEP change in peak water levels – Post-closure Conditions (no levee) impacts _____177
Figure C.10 - 10% AEP change in peak velocities - Post-closure Conditions (no levee) impacts _____178
Figure C.11 - 1% AEP change in peak velocities – Post-closure Conditions (no levee) impacts _____179
Figure C.12 - 0.1% AEP change in peak velocities – Post-closure Conditions (no levee) impacts _____180

List of Tables

Table 2.1 – IESC information requirements – surface water _____19
Table 2.2 – Application requirements for activities with impact to Water – Guideline ____26
Table 2.3 – Wastewater release to Queensland waters – technical guideline _____27
Table 3.1 – Water Quality Objectives default trigger values for the Project (from EPP WWB for Isaac Western Upland Tributaries) _____31
Table 4.1 – Evaporation (Morton's lake) statistics over the historical period (mm)_____42
Table 4.2 – Rainfall statistics over the historical period (mm) _____42
Table 4.3 – Water quality median data in the Isaac River at Deverill _____46
Table 4.4 – 80th percentile values for the combined upstream monitoring points data set compared with the receiving water WQO default trigger values and MMC Table F3 trigger values _____49
Table 4.5 – Proposed receiving waters trigger values for the VCM EA _____52
Table 4.6 – Soil Management Units surveyed on site (AARC, 2019)_____54
Table 5.1 – Types of water managed within the Project _____56
Table 5.2 - Proposed sediment dams _____60
Table 5.3 - Proposed mine affected water dams _____62
Table 5.4 - 1% AEP 24 hour pit dewatering rates _____63
Table 6.1 - Simulated inflows and outflows to the water management system _____65
Table 6.2 - Application of representative mine stages to full mine life _____65
Table 6.3 - Adopted AWBM parameters _____66
Table 6.4 - Water management system operating rules for the Project _____67
Table 6.5 - Water storage catchment areas (Stage 1) _____70
Table 6.6 - Water storage catchment areas (Stage 2) _____71
Table 6.7 - Forecast Haul Road Dust Suppression usage_____72
Table 6.8 – Forecast annual production data_____72
Table 6.9 – Key CHPP parameters _____73
Table 6.10 – Estimated CHPP makeup requirements _____73
Table 6.11 - Estimated groundwater inflows _____74
Table 6.12 - Phillips Creek AWBM parameters_____75

Table 6.13 - Adopted salinity concentrations 76
Table 7.1 - Average annual water balance – all realisations 79
Table 7.2 - Average annual salt balance (based on TDS) 87
Table 7.3 – Projections of changes to climate 94
Table 8.1 – Peak design discharge comparison between XP-RAFTS and Rational Method 100
Table 8.2 - FFA at Tayglen gauge compared to XP-RAFTS peak discharge 100
Table 8.3 - Adopted design discharges, critical storm durations and temporal pattern 101
Table 8.4 – Adopted culvert configuration for the proposed haul road crossings 108
Table 8.5 – Adopted culvert configuration for the proposed rail loop 109
Table 8.6 – 0.1% AEP flood levels adjacent to the proposed flood protection levees required for operations 114
Table 8.7 – Indicative drainage corridor depths and velocities during Post-closure Conditions 116
Table 8.8 – Changes in peak water levels and peak velocities under Operational Conditions (for crossing location at existing access road) compared to Pre-mining Conditions 120
Table 8.9 – Changes in peak water levels and peak velocities under Operational Conditions (for crossing location at northern MIA) compared to Pre-mining Conditions 120
Table 8.10 – Changes in peak water levels under Post-closure Conditions compared to Pre-mining Conditions 123
Table 8.11 – Changes in peak velocities under Post-closure Conditions compared to Pre-mining Conditions 123
Table 9.1 – Proposed surface water and mine water dam quality monitoring locations 124
Table 9.2 – Receiving water contaminant trigger investigation levels 127
Table 10.1 – Existing projects considered in the cumulative impact assessment 132
Table 10.2 – Proposed projects considered in the cumulative impact assessment 134
Table 10.3 – Catchment area of existing projects considered in the cumulative impact assessment 135

1 Introduction

1.1 BACKGROUND

The Vulcan Coal Mine (VCM) is a small-scale open-cut mine located to the southeast of Moranbah, in Central Queensland. Queensland Coking Coal Pty Ltd (QCC) and Queensland Coal Aust. No. 1 Pty. Ltd. (QCA1) hold the coal tenure associated with the VCM. Vitrinite Pty. Ltd. (Vitrinite) is the majority owner of both companies and, as such, Vitrinite is the proponent of the VCM. The Project is located on Mining Lease (ML) 700060. The location of the Exploration Permits (Coal) (EPCs) and the Project ML area are shown in Figure 1.1.

The proposed amendment primarily includes the establishment of a Coal Handling and Preparation Plant (CHPP), Train Load-out facility (TLO),a dedicated rail loop and a small additional open cut pit on ML700060 (the Project). The proposed mine stage layouts for the Project, including all major surface water infrastructure elements required during operations and post-mining, are shown in Figure 1.2, Figure 1.3 and Figure 1.4.

WRM Water & Environment Pty Ltd (WRM) was engaged by Mining and Energy Technical Services Pty Ltd (METServe), on behalf of Vitrinite, to complete a surface water impact assessment as part of the Environmental Authority (EA) amendment application for the Project. The EA amendment is in support of an application to amend the VCM EA and surface water assessment completed in September 2020 (WRM, 2020).

This report presents the following:

- An overview of the regulatory framework which applies to the Project (including aspects which do not directly relate to the surface water assessment) (Section 2);
- A description of the environmental values (EVs) of the receiving waters surrounding the Project (Section 3);
- A description of the existing surface water environment at the Project (Section 4);
- A description of the proposed water management strategy and details regarding water management infrastructure (Section 5);
- A detailed description of the configuration of the Project water balance model (Section 6);
- An assessment of the Project water management system performance (Section 7);
- An assessment of the potential flooding impacts of the Project (Section 8); and
- A description of the surface water monitoring strategy proposed for the Project (Section 9).

1.2 CURRENT PROJECT DESCRIPTION

Vitrinite holds approved Environmental Authority (EA0002912) and ML 700060 authorising the extraction of black coal. The Jupiter hard coking coal target has been defined and selected for open cut development via a single pit. The Project is approved to operate for approximately 4 years and will extract approximately 6 million tonnes of run of mine (ROM) hard coking coal at a rate of up to 1.95 million tonnes per annum. The Project will target the Alex and multiple Dysart Lower coal seams. Truck and shovel mining operations will be utilised in the pit. ROM coal is currently trucked off site to a coal handling and preparation plant (CHPP) at a nearby facility between Moranbah and Coppabella on the Peak Downs Highway.

An ex-pit waste rock dump will be established prior to commencing in-pit dumping activities that will continue for the life of the operation. Ancillary infrastructure, including a ROM pad, Mine Infrastructure Area (MIA), offices, roads and surface water management infrastructure will be established to the west and south of the open cut.

A realignment of the existing Saraji Road and services infrastructure to the eastern boundary of the Project ML, adjacent to the existing rail easement, is also proposed. The re-alignment will occur on lease however the connection back to the existing alignment of Saraji Road to the north will extend off lease and will be subject to a separate approvals process.

In-pit dumping will fill most of the pit during operations with the remaining final void to be backfilled upon cessation of mining, resulting in the establishment of a low waste rock dump landform over the former pit area. The initial ex-pit waste rock dump will be rehabilitated in-situ.

1.3 PROPOSED AMENDMENT

1.3.1 Overview

The proposed amendment primarily includes the establishment of a Coal Handling and Preparation Plant (CHPP), Train Load-out (TLO) Facility, a dedicated rail loop and a small additional open cut pit on ML700060. Establishment of this infrastructure at the VCM provides Vitrinite with a reliable and secure mechanism for transport of its coal to market. Ancillary infrastructure will include product stockpiles, updated water management infrastructure, access roads and a number of minor amendments to existing infrastructure layouts. The proposed open cut pit, referred to as the 'Matilda pit' is proposed to be located within the rail loop and will provide supplementary coal to the ROM stockpile. Development of the Matilda pit will not require an increase of the approved production rate, nor have a significant impact on the life of the project. Figure 1.2 and Figure 1.3 presents the proposed infrastructure for the new Project layout.

Construction of the CHPP, TLO and the rail loop, is expected to be completed within approximately 18 months. Once commissioned, operation of the CHPP, TLO and rail loop will replace the current approved road haulage of ROM coal to third party processing facilities, which will continue in the interim period. The Matilda pit is expected to be developed concurrently with the existing VCM pit.

The amendment will significantly reduce heavy vehicle traffic on the road network in the latter stages of the project. It is also important to note that only dry tailings, rather than wet tailings, will be produced and stored at the VCM.

The amendment will necessitate the inclusion of the following additional ERA in EA0002912:

- ERA 31 - Mineral Processing (2) processing, in a year, the following quantities of mineral products, other than coke - (b) more than 100,000t.

1.3.2 CHPP

The Project will include a modular CHPP to process ROM coal into a number of marketable products (coking coal and thermal coal). In summary, the CHPP will operate as follows:

- haul trucks will deliver ROM coal from the pit to the ROM hopper. The trucks will dump directly into the ROM hopper or onto the 100 kt ROM stockpile for reclaim by a front end loader;
- the raw coal will be sized before being conveyed to a 300 t raw coal surge bin before being fed to the CHPP at up to 550 t/h;
- the CHPP will be an open steel structure. Coal will be processed through three circuits to produce a primary and secondary product (metallurgical and thermal);
- tailings will be further processed through tailings dewatering plant to produce a dry tailings product. Recovered water will be recirculated to the process plant for reuse;
- coarse, fine and dry tailings will be conveyed to a reject bin, where it will be loaded into trucks for placement within active waste rock dumps (primarily within the in-pit dump); and

- products will be conveyed and stacked on the product coal stockpiles. Product coal will be reclaimed via dozer push into coal valves and conveyed to the TLO. The CHPP will operate 24 hours a day, seven days per week.

1.3.3 Rail loop and train load-out facility

The TLO will be positioned on the eastern side of the loop, on the western side of the existing levee. Product coal will be transported by aerial conveyor, across the levee from the product stockpile to the TLO. Appropriate design controls will be incorporated to manage potential impacts on surface water systems from fugitive coal from the overpassing conveyor.

The TLO will link the product stockpiles with the proposed rail loop to load at a rate of 3,500 tph. The train load out facility will be managed via a fully automated system, including overload protection and load veneering. The facility will be positioned over the rail line and will incorporate a suitable under rail spillage pit.

The rail loop will connect to the existing network in the south east of the Mining Lease and will traverse the south western boundary of the ML. The loop is positioned in the western portion of the ML, between the ML boundary and the existing BMA flood levee that runs north-south through the ML.

The loop will require approximately 4.5 km of rail to be located on the ML. A number of areas of cut and fill will be required along the alignment to facilitate required grades.

Controlled level crossings are proposed where the rail line will cross Saraji Road and connect to the existing Goonyella rail network.

Product coal will be railed from the Project rail loop onto the Goonyella Rail network. Export options include Dalrymple Bay to the north and the RG Tanna terminal, in Gladstone, to the south.

1.3.4 Matilda Pit

The Matilda Pit will be a small, shallow (maximum depth 40 m) open pit within the rail loop alignment. It will target the Matilda coal seam which underlies the Alex and multiple Dysart Lower coal seams mined in the pit to the east. For the purposes of approval and environmental assessment, it is assumed that the full extent of the rail loop interior is disturbed for mining purposes.

The Matilda Pit will be mined concurrently with the main pit to the east. There is no requirement to increase the production rate or significantly alter project timeframes. This is because further planning work has been completed on the main pit and the amount of coal to be extracted has reduced from what was originally proposed and approved. Further, this means that there is sufficient capacity within the waste rock dump final landforms previously proposed to store some of the waste from this pit, without design modification. There would be no change to the equipment fleet, workforce, accommodation etc. This is largely an exercise to supplement material that has been decided not to be mined from the main pit.

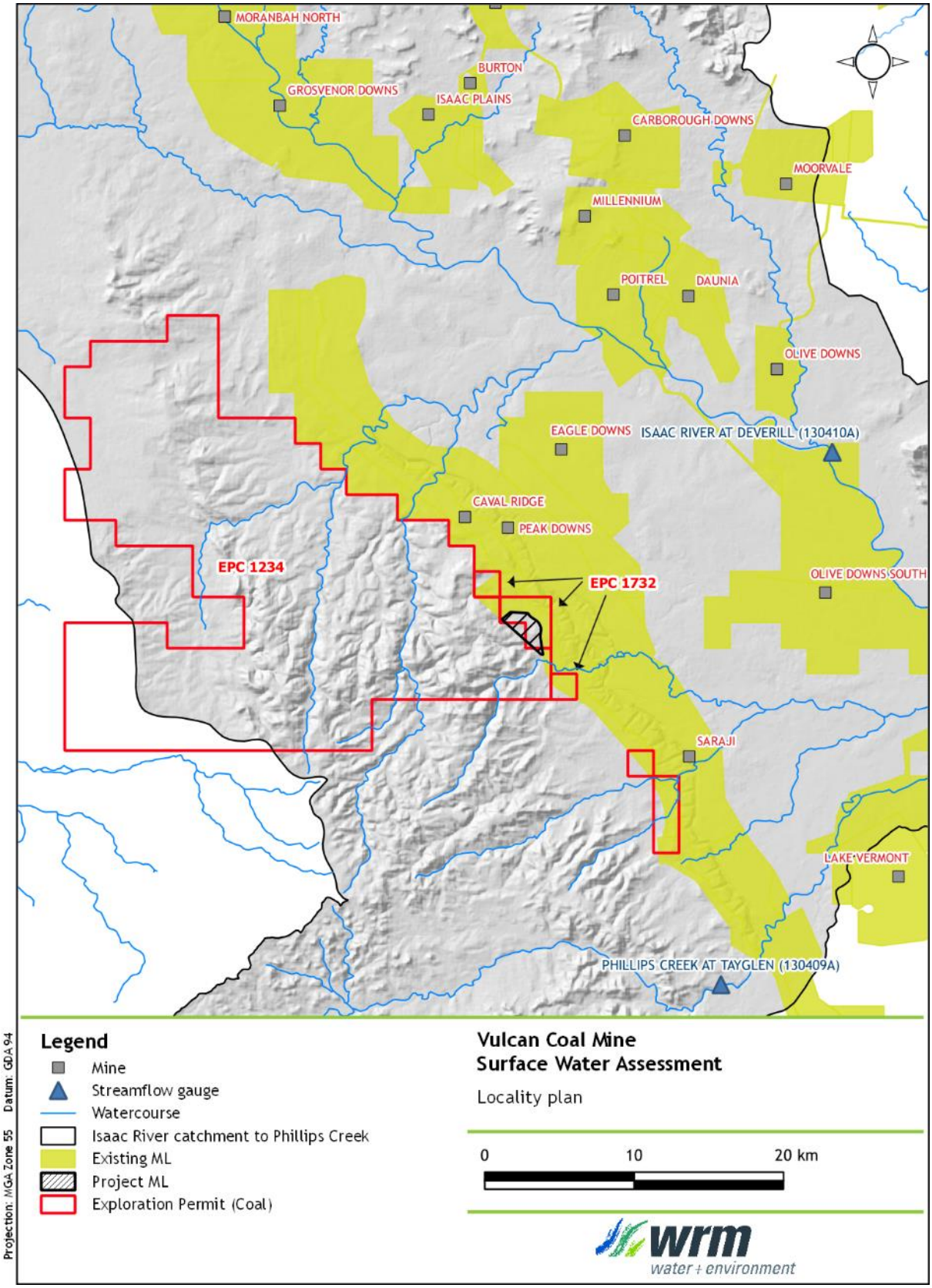


Figure 1.1 – Locality plan

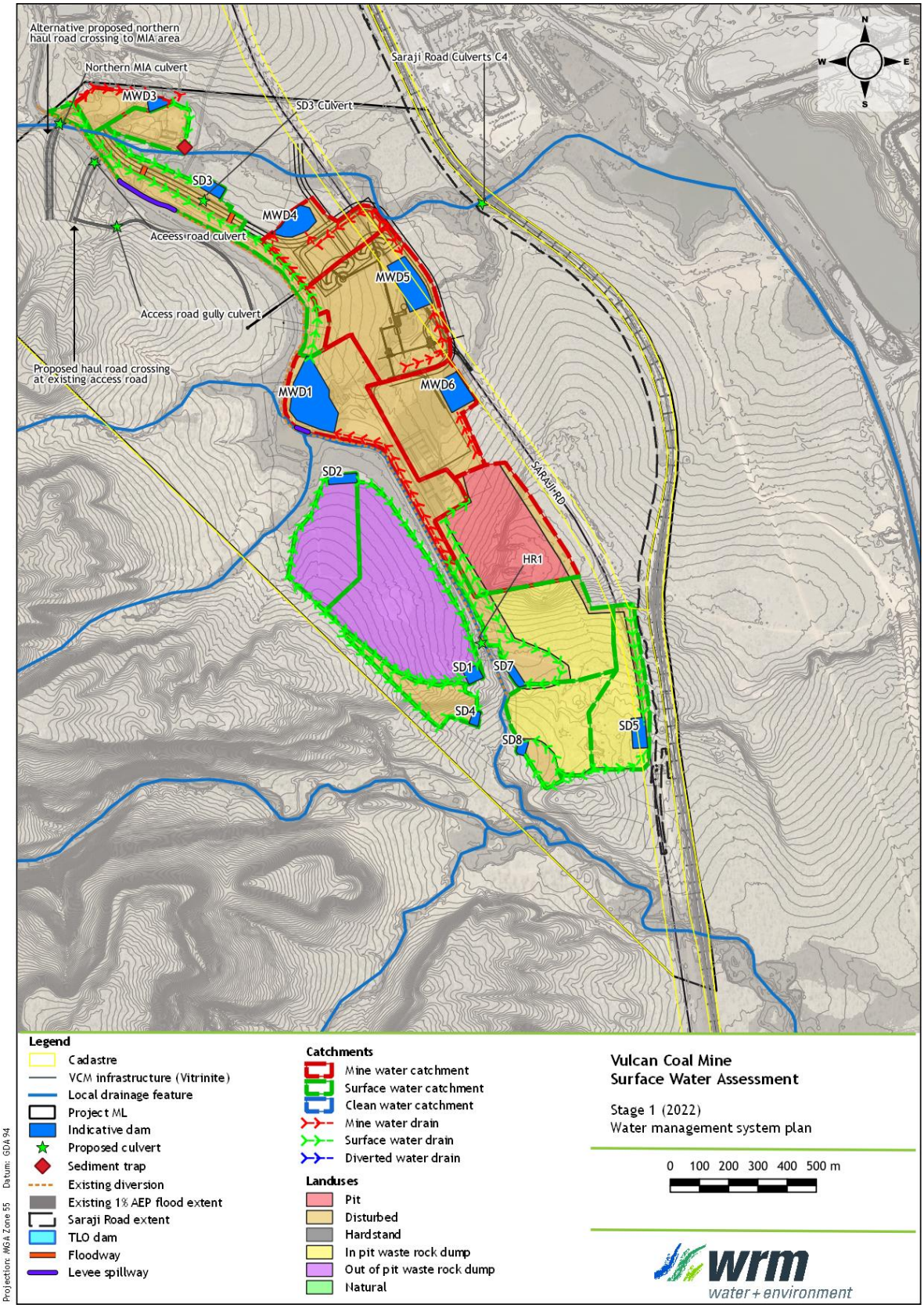


Figure 1.2 – Stage 1 (Year 2022) water management system plan

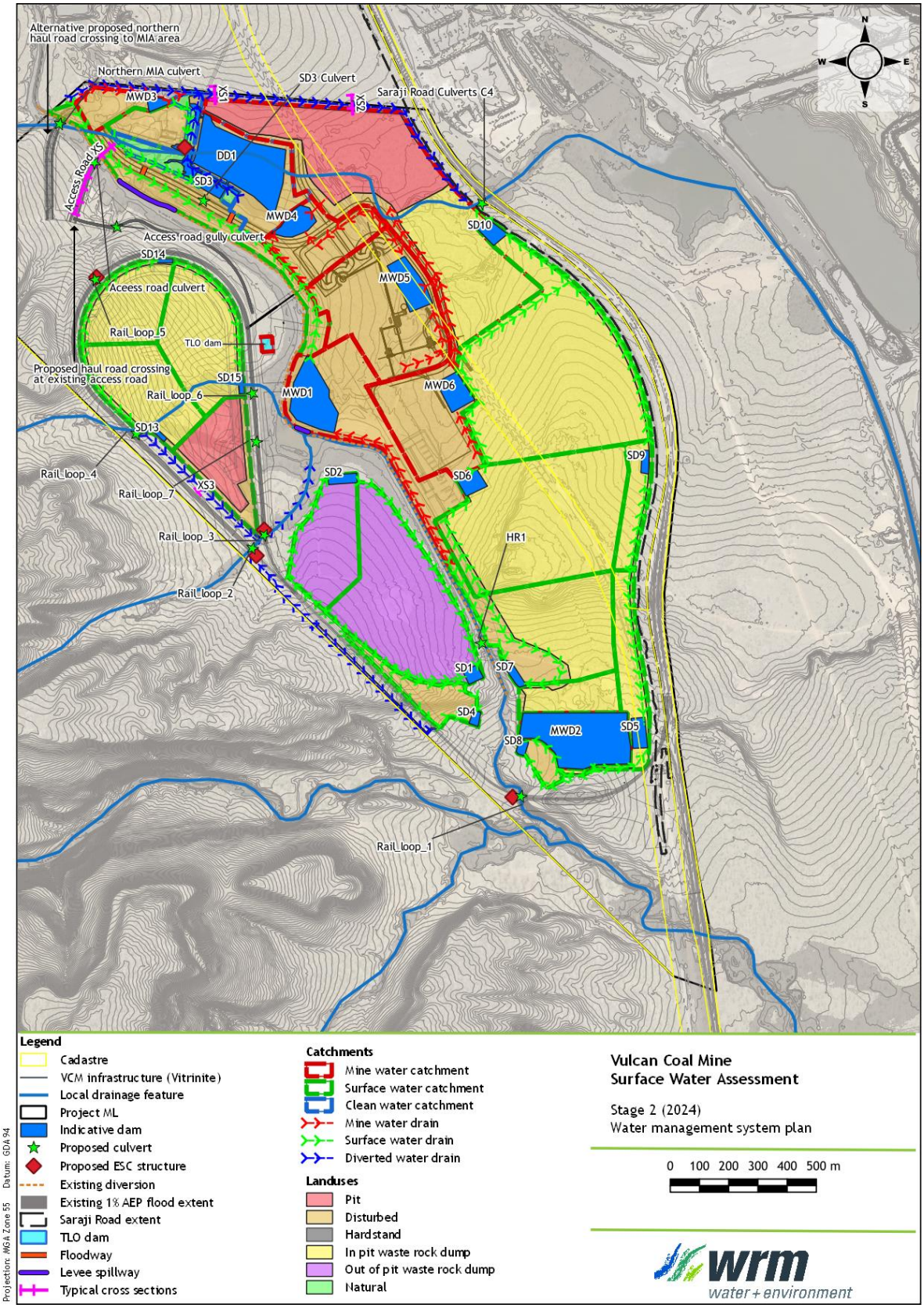


Figure 1.3 - Stage 2 (Year 2024) water management system plan

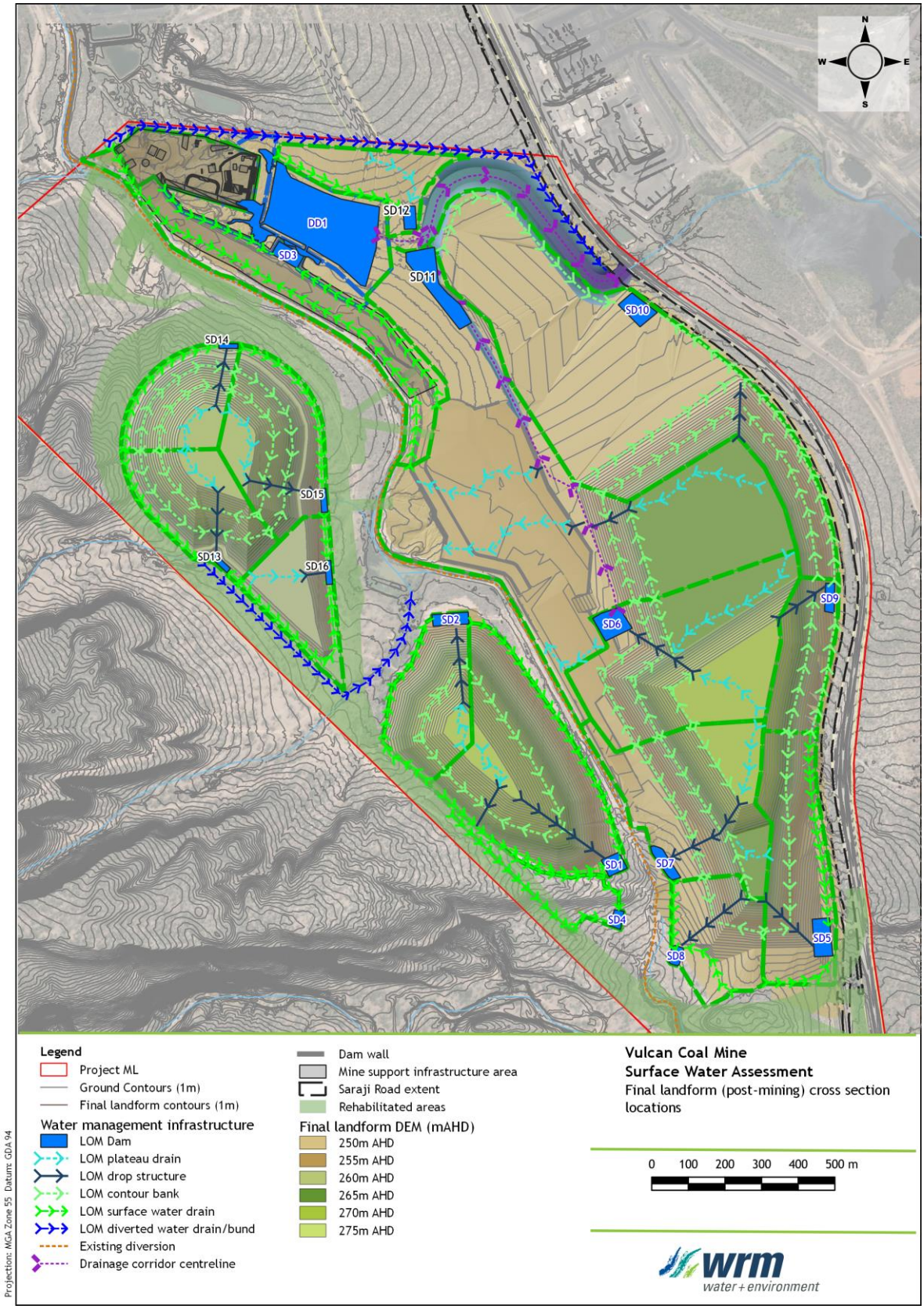


Figure 1.4 - Final landform (post-mining conditions) for the Project

2 Regulatory framework

This section describes the regulatory framework (legislation, policies and standards) at Commonwealth and State level that would apply to surface water management for the Project.

2.1 COMMONWEALTH

The Project will be referred to the Department of Climate Change, Energy, Environment and Water for consideration under the *Environment Protection and Biodiversity Conservation Act 1999*.

The Independent Expert Scientific Committee (IESC) on Coal Seam Gas and Large Coal Mining Development has published information guidelines (IESC, 2018) for advice on coal seam gas and large coal mining development proposals. The report sections where the IESC information requirements have been addressed are outlined in Table 2.1.

Table 2.1 – IESC information requirements – surface water

Project information	Report section
Description of the proposal	
Provide a regional overview of the proposed project area including a description of the geological basin; coal resource; surface water catchments; groundwater systems; water-dependent assets; and past, current and reasonably foreseeable coal mining and CSG developments.	Section 1 and Supporting Information Report for the EA Application
Describe the proposal's location, purpose, scale, duration, disturbance area, and the means by which it is likely to have a significant impact on water resources and water-dependent assets.	Section 1 and Supporting Information Report for the EA Application
Describe the statutory context, including information on the proposal's status within the regulatory assessment process and any applicable water management policies.	Section 2 and Supporting Information Report for the EA Application
Describe how impacted water resources are currently being regulated under state or Commonwealth law, including whether there are any applicable standard conditions.	Section 2
Surface water – context and conceptualisation	
Describe the hydrological regime of all watercourses, standing waters and springs across the site including:	
• geomorphology, including drainage patterns, sediment regime, and floodplain features;	Section 4
• spatial, temporal and seasonal trends in streamflow and/or standing water levels;	Section 4.4
• spatial, temporal and seasonal trends in water quality data (such as turbidity, acidity, salinity, relevant organic chemicals, metals, metalloids and radionuclides); and	Section 4.5
• current stressors on watercourses, including impacts from any currently approved projects.	Section 4 & 10
Describe the existing flood regime, including flood volume, depth, duration, extent and velocity for a range of annual exceedance probabilities. Provide flood hydrographs and maps identifying peak flood extent, depth and velocity. This assessment should be informed by topographic data that has been acquired using lidar or other reliable survey methods with accuracy stated.	Section 8

Project information	Report section
Provide an assessment of the frequency, volume, seasonal variability and direction of interactions between water resources, including surface water/groundwater connectivity and connectivity with sea water.	Refer to Groundwater report
Surface water – analytical and numerical modelling	
Provide conceptual models at an appropriate scale, including water quality, stores, flows and use of water by ecosystems.	Section 5 & 6
Use methods in accordance with the most recent publication of *Australian Rainfall and Runoff* (Ball et al. 2016).	Section 8
Develop and describe a program for review and update of the models as more data and information becomes available.	Section 6 & 8
Describe and justify model assumptions and limitations and calibrate with appropriate surface water monitoring data.	Section 6 & 8
Provide an assessment of the risks and uncertainty inherent in the data used in the modelling, particularly with respect to predicted scenarios.	Section 7.4
Provide a detailed description of any methods and evidence (e.g. expert opinion, analogue sites) employed in addition to modelling.	N/A
Surface water – impacts to water resources and water-dependent assets	
Describe all potential impacts of the proposed project on surface waters. Include a clear description of the impact to the resource, the resultant impact to any assets dependent on the resource (including water-dependent ecosystems such as riparian zones and floodplains), and the consequence or significance of the impact. Consider:	
• Impacts on streamflow under the full range of flow conditions;	Section 8.8 & 10
• Impacts associated with surface water diversions;	Section 8.8
• Impacts to water quality, including consideration of mixing zones;	Section 7.3.8
• The quality, quantity and ecotoxicological effects of operational discharges of water (including saline water), including potential emergency discharges, and the likely impacts on water resources and water-dependent assets; and	Section 7.3.8
• Landscape modifications such as subsidence, voids, post rehabilitation landform collapses, onsite earthworks (including disturbance of acid-forming or sodic soils, roadway and pipeline networks) and how these could affect surface water flow, surface water quality, erosion, sedimentation and habitat fragmentation of water-dependent species and communities.	Sections 5, 8.6.2 & 8.8
Discuss existing water quality guidelines, environmental flow objectives and requirements for the surface water catchment(s) within which the development proposal is based.	Section 2 & 3
Identify processes to determine surface water guidelines and quantity thresholds which incorporate seasonal variation but provide early indication of potential impacts to assets.	Section 9
Propose mitigation actions for each identified significant impact.	Section 6 & 8
Describe the adequacy of proposed measures to prevent or minimise impacts on water resources and water-dependent assets.	Section 6 & 8
Describe the cumulative impact of the proposal on surface water resources and water-dependent assets when all developments (past, present and/or reasonably foreseeable) are considered in combination.	Section 10
Provide an assessment of the risks of flooding (including channel form and stability, water level, depth, extent, velocity, shear stress and stream power), and impacts to ecosystems, project infrastructure and the final project landform.	Section 8
Surface water – data and monitoring	
Identify monitoring sites representative of the diversity of potentially affected water-dependent assets and the nature and scale of potential impacts, and match with suitable replicated control and reference sites (BACI design) to enable detection and monitoring of potential impacts.	Section 4.5

Project information	Report section
Ensure water quality monitoring complies with relevant National Water Quality Management Strategy (NWQMS) guidelines (ANZECC/ARMCANZ 2000) and relevant legislated state protocols (e.g. QLD Government 2013).	Section 4.5
Identify data sources, including streamflow data, proximity to rainfall stations, data record duration and a description of data methods, including whether missing data has been patched.	Sections 4.3 & 4.4
Develop and describe a surface water monitoring programme that will collect sufficient data to detect and identify the cause of any changes from established baseline conditions and assess the effectiveness of mitigation and management measures. The program will:	
• include baseline monitoring data for physico-chemical parameters, as well as contaminants (e.g. metals);	Section 4.5
• comparison of physico-chemical data to national/regional guidelines or to site- specific guidelines derived from reference condition monitoring if available; and	Section 4.5
• identify baseline contaminant concentrations and compare these to national guidelines, allowing for local background correction if required.	Section 4.5
Describe the rationale for selected monitoring parameters, duration, frequency and methods, including the use of satellite or aerial imagery to identify and monitor large-scale impacts.	Section 9
Identify dedicated sites to monitor hydrology, water quality, and channel and floodplain geomorphology throughout the life of the proposed project and beyond.	Section 9
Water-dependent assets – context and conceptualisation	
Identify water-dependent assets, including:	
• water-dependent fauna and flora and provide surveys of habitat, flora and fauna (including stygofauna) (see Doody et al. [in press]); and	Refer to Supporting Information Report for the EA Application
• public health, recreation, amenity, Indigenous, tourism or agricultural values for each water resource.	
Identify GDEs in accordance with the method outlined by Eamus et al. (2006). Information from the GDE Toolbox15 (Richardson et al. 2011) and GDE Atlas (CoA 2017a) may assist in the identification of GDEs (see Doody et al. [in press]).	Refer to Groundwater Report
Describe the conceptualisation and rationale for likely water-dependence, impact pathways, tolerance and resilience of water-dependent assets. Examples of ecological conceptual models can be found in Commonwealth of Australia (2015).	Refer to Groundwater Report
Estimate the ecological water requirements of identified GDEs and other water-dependent assets (see Doody et al. [in press]).	Refer to Groundwater Report
Identify the hydrogeological units on which any identified GDEs are dependent (see Doody et al. [in press]).	Refer to Groundwater Report
Provide an outline of the water-dependent assets and associated environmental objectives and the modelling approach to assess impacts to the assets.	Section 3 & 4
Describe the process employed to determine water quality and quantity triggers and impact thresholds for water-dependent assets (e.g. threshold at which a significant impact on an asset may occur).	Section 9
Water dependent assets – impacts, risk assessment and management of risk	
Provide an assessment of direct and indirect impacts on water-dependent assets, including ecological assets such as flora and fauna dependent on surface water and groundwater, springs and other GDEs (see Doody et al. [in press]).	Refer to Groundwater Report

Project information	Report section
Describe the potential range of drawdown at each affected bore, and clearly articulate the scale of impacts to other water users.	Refer to Groundwater Report
Indicate the vulnerability to contamination (e.g. from salt production and salinity) and the likely impacts of contamination on the identified water-dependent assets and ecological processes.	Section 7.3.8
Identify and consider landscape modifications (e.g. voids, on-site earthworks, and roadway and pipeline networks) and their potential effects on surface water flow, erosion and habitat fragmentation of water-dependent species and communities.	Section 5
Provide estimates of the volume, beneficial uses and impact of operational discharges of water (particularly saline water), including potential emergency discharges due to unusual events, on water-dependent assets and ecological processes.	Section 7.3.8 & 7.3.9
Assess the overall level of risk to water-dependent assets through combining probability of occurrence with severity of impact.	Section 7 & 8
Identify the proposed acceptable level of impact for each water-dependent asset based on leading-practice science and site-specific data, and ideally developed in conjunction with stakeholders.	Section 7 & 8
Propose mitigation actions for each identified impact, including a description of the adequacy of the proposed measures and how these will be assessed.	Section 5 & 9
Water-dependent assets – data and monitoring	
Identify an appropriate sampling frequency and spatial coverage of monitoring sites to establish pre-development (baseline) conditions, and test potential responses to impacts of the proposal (see Doody et al. [in press]).	
Consider concurrent baseline monitoring from unimpacted control and reference sites to distinguish impacts from background variation in the region (e.g. BACI design, see Doody et al. [in press]).	
Develop and describe a monitoring program that identifies impacts, evaluates the effectiveness of impact prevention or mitigation strategies, measures trends in ecological responses and detects whether ecological responses are within identified thresholds of acceptable change (see Doody et al. [in press]).	Section 9
Describe the process for regular reporting, review and revisions to the monitoring program.	
Ensure ecological monitoring complies with relevant state or national monitoring guidelines (e.g. the DSITI guideline for sampling stygofauna (QLD Government 2015)).	
Water and salt balance, and water management quality	
Provide a quantitative site water balance model describing the total water supply and demand under a range of rainfall conditions and allocation of water for mining activities (e.g. dust suppression, coal washing etc.), including all sources and uses.	Section 7
Describe the water requirements and on-site water management infrastructure, including modelling to demonstrate adequacy under a range of potential climatic conditions.	Section 7
Provide estimates of the quality and quantity of operational discharges under dry, median and wet conditions, potential emergency discharges due to unusual events and the likely impacts on water-dependent assets.	Section 7.3.6 & 7.3.9
Provide salt balance modelling that includes stores and the movement of salt between stores and takes into account seasonal and long-term variation.	Section 7.3.7
Cumulative impacts – context and conceptualisation	
Provide cumulative impact analysis with sufficient geographic and temporal boundaries to include all potentially significant water-related impacts.	Section 10
Consider all past, present, and reasonably foreseeable actions, including development proposals, programs and policies that are likely to impact on the water resources of concern in the cumulative impact analysis. Where a proposed project is located within the area of a bioregional assessment consider the results of the bioregional assessment.	Section 10

Project information	Report section
Cumulative impacts – impacts	
Provide an assessment of the condition of affected water resources which includes: • identification of all water resources likely to be cumulatively impacted by the proposed development; • a description of the current condition and quality of water resources and information on condition trends; • identification of ecological characteristics, processes, conditions, trends and values of water resources; • adequate water and salt balances; and • identification of potential thresholds for each water resource and its likely response to change and capacity to withstand adverse impacts (e.g. altered water quality, drawdown).	Section 4, 7, 9 & 10
Assess the cumulative impacts to water resources considering: • the full extent of potential impacts from the proposed project, (including whether there are alternative options for infrastructure and mine configurations which could reduce impacts), and encompassing all linkages, including both direct and indirect links, operating upstream, downstream, vertically and laterally; • all stages of the development, including exploration, operations and post closure/decommissioning; • appropriately robust, repeatable and transparent methods; • the likely spatial magnitude and timeframe over which impacts will occur, and significance of cumulative impacts; and • opportunities to work with other water users to avoid, minimise or mitigate potential cumulative impacts.	Section 10
Cumulative impacts – mitigation, monitoring and management	
Identify modifications or alternatives to avoid, minimise or mitigate potential cumulative impacts. Evidence of the likely success of these measures (e.g. case studies) should be provided.	Section 7.4, 7.5, 9 & 10
Identify measures to detect and monitor cumulative impacts, pre and post development, and assess the success of mitigation strategies.	
Identify cumulative impact environmental objectives.	
Describe appropriate reporting mechanisms.	
Propose adaptive management measures and management responses.	
Final landforms and voids – coal mines	
Identify and consider landscape modifications (e.g. voids, on-site earthworks, and roadway and pipeline networks) and their potential effects on surface water flow, erosion, sedimentation and habitat fragmentation of water-dependent species and communities.	Section 5 and Supporting Information Report for the EA Application
Assess the adequacy of modelling, including surface water and groundwater quantity and quality, lake behaviour, timeframes and calibration.	
Provide an assessment of the long-term impacts to water resources and water-dependent assets posed by various options for the final landform design, including complete or partial backfilling of mining voids. Assessment of the final landform for which approval is being sought should consider: • groundwater behaviour – sink or lateral flow from void; • water level recovery – rate, depth, and stabilisation point (e.g. timeframe and level in relation to existing groundwater level, surface elevation);	

Project information	Report section
• seepage – geochemistry and potential impacts; • long-term water quality, including salinity, pH, metals and toxicity; and • measures to prevent migration of void water off-site. For other final landform options considered sufficient detail of potential impacts should be provided to clearly justify the proposed option.	
Assess the probability of overtopping of final voids with variable climate extremes, and management mitigations.	N/A
Acid-forming materials and other contaminants of concern	
Identify the presence and potential exposure of acid-sulfate soils (including oxidation from groundwater drawdown).	Refer to Supporting Information Report for the EA Application, Geochemical Assessment Report and Section 6.8
Identify the presence and volume of potentially acid-forming waste rock, fine-grained amorphous sulphide minerals and coal reject/tailings material and exposure pathways.	
Identify other sources of contaminants, such as high metal concentrations in groundwater, leachate generation potential and seepage paths.	
Describe handling and storage plans for acid-forming material (co-disposal, tailings dam, encapsulation).	
Assess the potential impact to water-dependent assets, taking into account dilution factors, and including solute transport modelling where relevant, representative and statistically valid sampling, and appropriate analytical techniques.	
Describe proposed measures to prevent/minimise impacts on water resources, water users and water-dependent ecosystems and species.	

2.2 STATE

2.2.1 EP Act 1994

Resource activities are defined as environmentally relevant activities (ERAs) under the Queensland *Environmental Protection Act 1994* (EP Act) and as such, the development and operation of the Project are governed by the EP Act. The aim of the EP Act is to:

> *Protect Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends (ecologically sustainable development).*

2.2.1.1 Environmental Authority

An Environmental Authority (EA) is granted in accordance with the EP Act and details the prescribed conditions that govern the ERA. In the context of surface water management, the EA sets out conditions that will be relevant to the Project, including:

- Management of contained water including release;
- Water management plan requirements;
- Regulation of water structures including dams and levees;
- Saline drainage management;
- Acid rock drainage management; and
- Storm water and sediment laden runoff management.

2.2.1.2 Model Mining Conditions

New mining project applications should apply the model mining conditions as outlined in *Model mining conditions* (DES, 2017). The purpose of the model mining conditions is to provide a set of model conditions to form the general environmental protection

commitments given for EA's for mining activities administered under the EP Act. The model conditions may be used as a basis for proposing environmental protection commitments in application documents.

Model conditions can be modified to suit the specific circumstances of a mining project, subject to the assessment criteria outlined in the EP Act. It is unlikely that the administering authority will accept less rigorous environmental protection commitments or EA conditions without clear evidence that the risk of the environmental harm is addressed by environmental management practices, technologies or the nature of the EVs impacted by the Project.

Schedule F – Water (Fitzroy model conditions) form the basis of the requirements for the Project water management system design.

2.2.1.3 Environmental Protection (Water and Wetland Biodiversity) Policy 2019

The *Environmental Protection (Water and Wetland Biodiversity) Policy 2019* (EPP WWB) is the primary instrument for surface water management under the EP Act. The EPP WWB governs discharge to land, surface water and groundwater, aims to protect EVs and sets water quality guidelines and objectives.

The processes to identify EVs and to determine Water Quality Guidelines (WQGs) and Water Quality Objectives (WQOs) in Queensland waters is based on the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ guidelines).

The EVs for the Project location are outlined in Section 3.

2.2.1.4 Isaac River sub-basin Environmental Values and Water Quality Objectives 2011

The relevant document, pursuant to the EPP WWB, for the Project is the *Isaac River Sub-basin Environmental Values and Water Quality Objectives Basin No. 130 (part)*, including all waters of the Isaac River Sub-basin (including Connors River, September 2011 [DEHP, 2011]). The document is made pursuant to the provisions of the EPP WWB. It contains EVs and WQOs for waters in the Isaac River Sub-basin, and they are listed under Schedule 1 of EPP WWB. Refer to Section 3 for further details.

2.2.1.5 Manual for Assessing Consequence Categories and Hydraulic Performance of Structures

The *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures* (the Manual) defines the methodology and assessment criteria to determine if a structure associated with an ERA should be regulated under the EP Act. The manual details the hydraulic design requirements for regulated structures and this document has been used as a reference in the preliminary design of the water management system and preliminary sizing of dams associated with the Project.

2.2.1.6 Guideline – Application Requirements for Activities with Impacts to Water

This guideline focuses on the types of impacts that environmentally relevant activities (ERAs) can have on water and outlines the information to be provided to the department as part of the ERA application process.

Section 4 of the guideline requires the applicant to provide details on a number of surface water-related issues, including:

- Discharges and releases;
- Unplanned and uncontrolled releases;
- Water infrastructure;
- Wetlands;
- Hydrology of receiving waters; and

- Mixing zones.

Table 2.2 lists the elements of the guideline relevant to this assessment and the sections of this report where those elements are addressed.

The guideline also refers to the department's technical guideline "Wastewater releases to Queensland waters", which is discussed in Section 2.2.1.7.

Table 2.2 – Application requirements for activities with impact to Water – Guideline

Item	Report section
Discharges and releases	
Identify activities that could lead to indirect impacts and unplanned/uncontrolled release of contaminants to water, such as, spills and leaks or stream bed and/or bank disturbance and describe the magnitude of the disturbance	Section 7.3.6 & 7.3.9
Identify the location, depth and configuration (if relevant) of the areas where the unplanned/uncontrolled release could be discharged to waters	Section 5 & 7.3.6
Identify infrastructure (including containment devices) with the potential to release unplanned/uncontrolled contaminants to waters	Section 6.4
Identify the potential contaminant type and quantities that could be released from infrastructure	Section 6.8 & 7.3.6
Water infrastructure	
Provide detail on the location and storage capacity of water infrastructure on the site which may include regulated structures, tailings dams, waste rock dams, water storage dams, levees, heap leach pads and any other water management infrastructure	Section 6.4
Wetlands	
Applicants must describe how the existing environmental values of any wetlands on, or adjacent to, the site will be maintained, or enhanced	Section 3
Ecology and hydrology of receiving waters	
Describe, preferably through the use of water quality monitoring or modelling, how the proposed ERA will impact on hydrology of receiving waters, preferably through modelling	Section 7.3

2.2.1.7 Technical Guideline – Wastewater release to Queensland Waters

This guideline is provided to support a risk-based assessment approach to licensing releases of wastewater to surface water and applies the philosophy of the ANZECC & ARMCANZ (2000) Water Quality Guidelines and the intent of the EPP (WWB).

The information requirements identified in this guideline are as follows:

- Describe the proposed activity;
- Describe the receiving environment;
- Predict outcomes or impacts of the proposed wastewater release; and
- Set circumstances, limits and monitoring conditions.

Table 2.3 lists the elements of the guideline relevant to this assessment and the sections of this report where those elements are addressed.

Table 2.3 – Wastewater release to Queensland waters – technical guideline

Item	Report section
Step 1 – Describe the proposed activity	
Define industry type and size (estimated production, current and ultimate)	Section 1.2
Identify the potential contaminants of concern in the proposed release	Section 6.8
Location and configuration of the proposed release	Section 6.4
Step 2 – Describe the receiving environment	
Identify water bodies potentially affected by the proposed release	Section 4
Provide all relevant information on the receiving environment based on desktop and field studies (e.g. current, background water quality condition)	
Include special consideration for ephemeral streams	
Identify all relevant EV and WQOs	Section 3
Ensure all government planning requirements applying to the water bodies have been considered	Section 2
Step 3 - Predict outcomes or impacts of the proposed wastewater release	
Assess whether contaminants are potentially toxic	Section 6.8 and 7.3
Predict the assimilative capacity and sustainable load	Section 7.3
Consider other potential impacts	Section 7.3
Step 4 – Set circumstances, limits and monitoring conditions	
Specify any circumstances related to the approved wastewater release	Section 6.4
Include a receiving environment monitoring program (REMP) requirement	Section 0
Include reporting requirements for the approved activity	Section 9

2.2.2 Water Act 2000

In Queensland, the Water Act 2000 (Water Act) is the primary statutory document that establishes a framework for the planning, allocation and use of non-tidal water. The Water Act is primarily administered by the Department of Environment and Science (DES).

The main purpose of the Water Act is to provide a framework for the following:

- The sustainable management of Queensland's water resources by establishing a system for the planning, allocation and use of water and riverine protection;
- The sustainable and secure water supply for the south-east Queensland region and other designated regions;
- The management of impacts on underground water caused by the exercise of underground water rights by the resource sector; and
- The effective operation of water authorities.

A watercourse is defined by the Water Act as a river, creek or stream, including a stream in the form of an anabranch or a tributary, in which water flows permanently or intermittently. The DES have published a watercourse identification map of the state that shows: watercourses (other than their lateral limits); the downstream limit of watercourses; drainage features; lakes; and springs.

A watercourse determination for drainage features in the Project ML area has been undertaken by the DES. DES has determined that no watercourses intersect the Project ML area and all features are drainage features defined by the Water Act. These features are described in Section 4.

2.2.2.1 Water Plan (Fitzroy Basin) 2011

The Water Plan (Fitzroy Basin) 2011 is subordinate legislation to the Water Act. The plan is developed and administered by ES. The purpose of the plan is:

- To define the availability of water in the Fitzroy Basin;
- To provide a framework for sustainably managing water and the taking of water;
- To identify priorities and mechanisms for dealing with future water requirements;
- To provide a framework for establishing water allocations;
- To provide a framework for reversing, where practicable, degradation in natural ecosystems;
- To regulate the taking of overland flow water; and
- To regulate the taking of groundwater.

2.2.2.2 Water Regulation 2016

The Water Regulation 2016 is subordinate legislation to the Water Act and provides details, protocol and instruction for the following:

- Water rights and planning;
- Statutory authorisations to take or interfere with water;
- Matters relating to water licenses;
- Water allocations;
- Water supply and demand management; and
- Declarations about watercourses.

2.2.3 Water Supply (Safety & Reliability) Act 2008

The Water Supply (Safety and Reliability) Act 2008 provides for the safety and reliability of water supply in Queensland. The purpose is achieved primarily by:

- Providing a regulatory framework for providing water and sewerage services in the State;
- Providing a regulatory framework for providing recycled water and drinking water quality, primarily for protecting public health;
- The regulation of referable dams; and
- Stating flood mitigation responsibilities.

3 Environmental Values

The Queensland Water Quality Guidelines and EPP WWB guidelines establish environmental values (EVs) and WQOs for natural waters in Queensland. The Project is located within the 'Isaac western upland tributaries' area of the Isaac River sub-basin, shown in Figure 3.1. Under the EPP WWB, the following EVs have been nominated for this area:

- Aquatic ecosystems;
- Irrigation;
- Farm supply/use;
- Stock Water;
- Aquaculture;
- Human consumption;
- Primary recreation;
- Secondary recreation;
- Visual recreation;
- Drinking water;
- Industrial use; and
- Cultural and spiritual values.

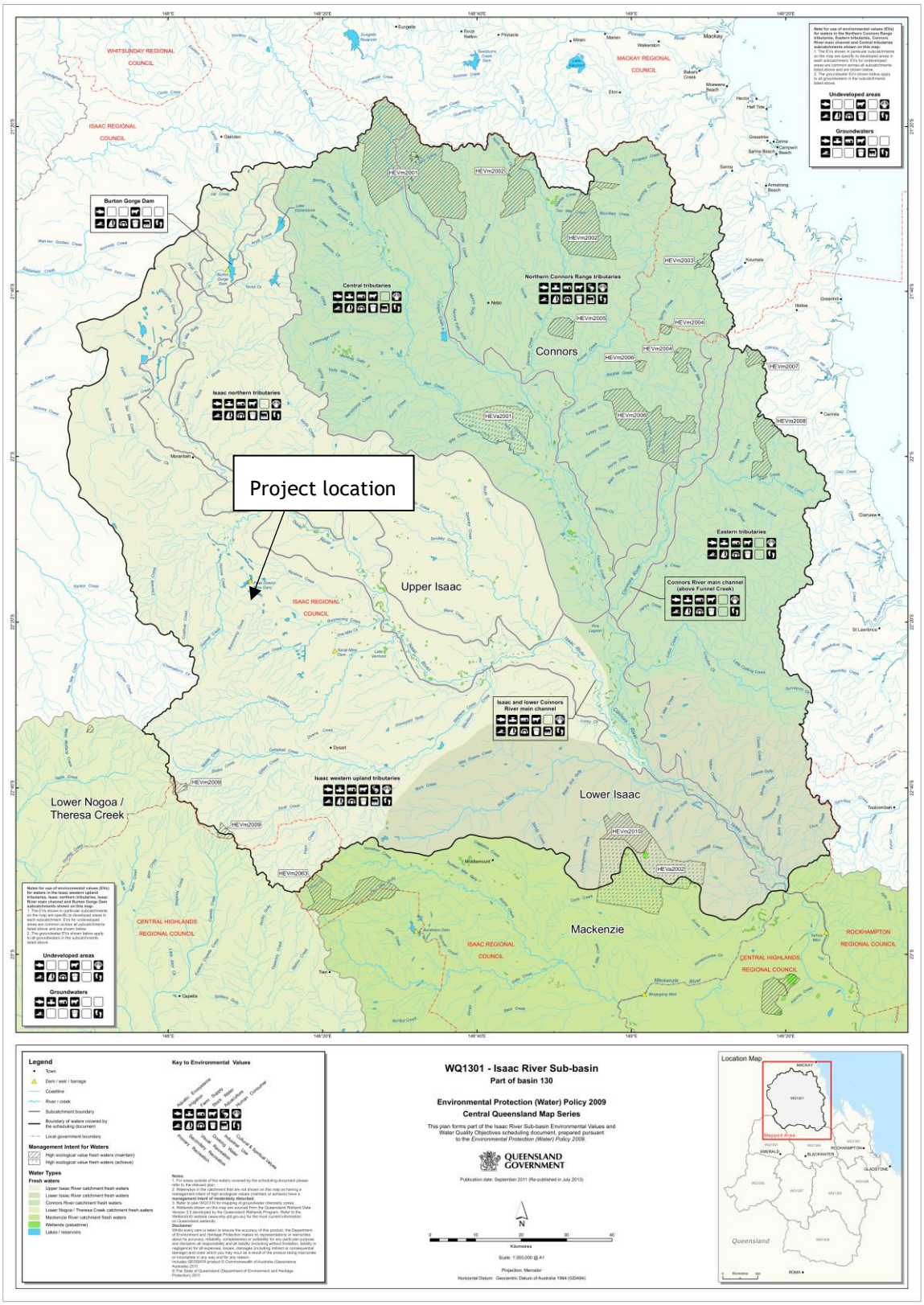


Figure 3.1 - Isaac River Sub-Basin EVs (source: DES, 2013)

The WQO default trigger values for the above EVs are provided in Table 3.1. The indicators and water quality guidelines relevant to the above surface water EVs are listed in Schedule 1 of EPP WWB and the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG, 2018).

Where different EVs have different WQOs, the Project has adopted the lowest concentration value for mine water and receiving waters trigger levels. WQO default trigger values are displayed for physio-chemical parameters only.

Table 3.1 – Water Quality Objectives default trigger values for the Project (from EPP WWB for Isaac Western Upland Tributaries)

Parameter	WQO	Relevant EV
Ammonia N	< 20 µg/L	Aquatic ecosystem[a]
Oxidised N	< 60 µg/L	Aquatic ecosystem[a]
Organic N	< 420 µg/L	Aquatic ecosystem[a]
Total nitrogen	< 500 µg/L	Aquatic ecosystem[a]
Filterable Reactive Phosphorus (FRP)	< 20 µg/L	Aquatic ecosystem[a]
Total Phosphorus	< 50 µg/L	Aquatic ecosystem[a]
Chlorophyll a	< 5 µg/L	Aquatic ecosystem[a]
Dissolved oxygen	85-110% saturation > 4 mg/L at surface	Aquatic ecosystem[a] Drinking water[b]
Turbidity	< 50 NTU	Aquatic ecosystem[a]
Suspended solids	< 55 mg/L	Aquatic ecosystem[a]
pH	pH 6.5-8.5	Aquatic ecosystem[a]
Conductivity (EC) baseflow	720 µS/cm	Aquatic ecosystem[a]
Conductivity (EC) high flow	250 µS/cm	Aquatic ecosystem[a]
Sulfate	25 mg/L	Aquatic ecosystem[a]
Total Dissolved Solids	< 2000 mg/L	Stock watering[c]
Colour	50 Hazen Units	Drinking water[b]
Total Hardness	150 mg/L as CaCO3	Drinking water[b]
Sodium	< 30 mg/L	Drinking water[b]
Aluminium	< 5 mg/L < 0.055 mg/L	Stock watering[c] Aquatic ecosystem[d]
Arsenic	2.0 mg/L 0.5 mg/L up to 5 mg/L < 0.024 mg/L	Irrigation[b, e] Stock watering[f] Aquatic ecosystem[d]
Beryllium	< 0.5 mg/L	Irrigation[g]
Boron	< 5 mg/L < 0.37 mg/L	Stock watering[f,e] Aquatic ecosystem[d]
Cadmium	< 0.01 mg/L < 0.0002 mg/L	Stock watering[f,e] Aquatic ecosystem[d]
Chromium	< 1 mg/L < 0.001 mg/L	Stock watering[f,e] Aquatic ecosystem[d]
Cobalt	< 0.1 mg/L	Irrigation[g]
Copper	< 1 mg/L < 0.0014 mg/L	Stock watering (cattle)[f,e] Aquatic ecosystem[d]
Fluoride	< 2 mg/L	Irrigation[g]
Iron	< 10 mg/L	Irrigation[g]
Lead	< 0.1 mg/L < 0.0034 mg/L	Stock watering[f,e] Aquatic ecosystem[d]
Lithium	< 2.5 mg/L	Irrigation[g]

Parameter	WQO	Relevant EV
Manganese	< 10 mg/L < 1.9 mg/L	Irrigation[g] Aquatic ecosystem[d]
Mercury	< 0.002 mg/L < 0.00006 mg/L	Irrigation[g] Aquatic ecosystem[d]
Molybdenum	< 0.05 mg/L	Irrigation[g]
Nickel	< 1 mg/L < 0.011 mg/L	Stock watering[f, e] Aquatic ecosystem[d]
Selenium	< 0.02 mg/L < 0.005 mg/L	Stock watering[f,e] Aquatic ecosystem[d]
Uranium	< 0.1 mg/L	Irrigation[g]
Vanadium	< 0.5 mg/L	Irrigation[g]
Zinc	< 5 mg/L < 0.008 mg/L	Irrigation[g] Aquatic ecosystem[d]

[a] Table 2 of Isaac River Sub-basin Environmental Values and Water Quality Objectives: Aquatic ecosystem - moderately disturbed
[b] Table 4 of Isaac River Sub-basin Environmental Values and Water Quality Objectives: Drinking water EV
[c] Table 10 of Isaac River Sub-basin Environmental Values and Water Quality Objectives: Stock watering EV: salinity
[d] Table 3.4.1 of Australian and New Zealand Guidelines for Fresh and Marine Water Quality: trigger values for slightly-moderately disturbed systems (95% level of protection)
[e] short-term trigger value
[f] Table 11 of Isaac River Sub-basin Environmental Values and Water Quality Objectives: Stock watering EV: heavy metals and metalloids
[g] Table 9 of Isaac River Sub-basin Environmental Values and Water Quality Objectives: Irrigation EV: heavy metals and metalloids

The Queensland Globe service (Queensland Government, 2019) was used to identify any wetlands in the vicinity of the Project. There were no matters of state environmental significance (MSES) wetlands, wetland values or wetland protection areas identified in the vicinity of the Project.

4 Existing surface water environment

4.1 REGIONAL DRAINAGE CHARACTERISTICS

The Project is located within the Isaac River sub-basin of the greater Fitzroy Basin. Figure 4.1 shows the Upper Isaac River catchment to its confluence with Phillips Creek.

The Isaac River commences approximately 100 km to the north of the Project site within the Denham Range. It drains in a south westerly direction through the Carborough and Kerlong Ranges before turning in a south easterly direction near the Goonyella Riverside Mine. It drains approximately 30 km to the east of the Project, and eventually flows to the Mackenzie River some 150 km to the southeast.

Three open water bodies are located in the Isaac upper catchment including Lake Elphinstone, Teviot Creek Dam and Burton Gorge Dam (Figure 4.1). Lake Elphinstone is a natural lake formed behind the Carborough Range whereas Teviot Creek Dam and Burton Gorge Dam are man-made structures that supply water to Burton and North Goonyella mines in the upper catchment.

Other than along the ranges, the majority of the Isaac River catchment has been cleared for agricultural use or for mining. There are several existing coal mines in the catchment, including Burton, North Goonyella, Goonyella Riverside, Broadmeadow, Broadlea North, Isaac Plains, Moranbah North, Millennium, Daunia, Poitrel, Grosvenor, Peak Downs, Saraji, Norwich Park and Lake Vermont.

Figure 4.2 shows the surrounding catchments of the Project area. The Project is located in the headwaters of the Boomerang Creek catchment. Boomerang Creek is a watercourse and tributary of the Isaac River. The catchment area of the Isaac River to Boomerang Creek is 5,226 square kilometres (km^2).

The Boomerang Creek catchment commences to the west of the Project area and drains in an easterly direction towards Saraji Road and the Norwich Park Branch Railway. The Ripstone Creek catchment lies to the north of the Project area and drains into Boomerang Creek approximately 30 km southeast of the Project. The headwater tributaries of Boomerang Creek are ephemeral streams which experience flow only after sustained or intense rainfall.

The predominant catchment land uses of Boomerang Creek include undeveloped areas with some stock grazing to the west of Saraji Road and stock grazing and coal mining to the east. Downstream of the Project, Boomerang Creek, as well as its tributaries to the south, flow into the existing BHP Billiton Mitsubishi Alliance (BMA) operations (Peak Downs and Saraji). The catchment area of Boomerang Creek is 788 km^2. The existing BMA operations have diverted and/or modified the original alignment of Boomerang Creek as shown in Figure 4.2 as well as Harrow Creek to the north. Additional diversions and/or modification of Boomerang Creek and its floodplain are also planned for approved operations further to the east.

4.2 LOCAL DRAINAGE NETWORK

Figure 4.3 shows the local drainage features within the vicinity of the Project. Drainage features that cross the Project area eventually drain to Boomerang Creek and subsequently to the Isaac River. The tributaries of Boomerang Creek which intersect the Project area include (Figure 4.3):

- Drainage Line 1;
- Drainage Line 2; and
- the existing drainage diversion.

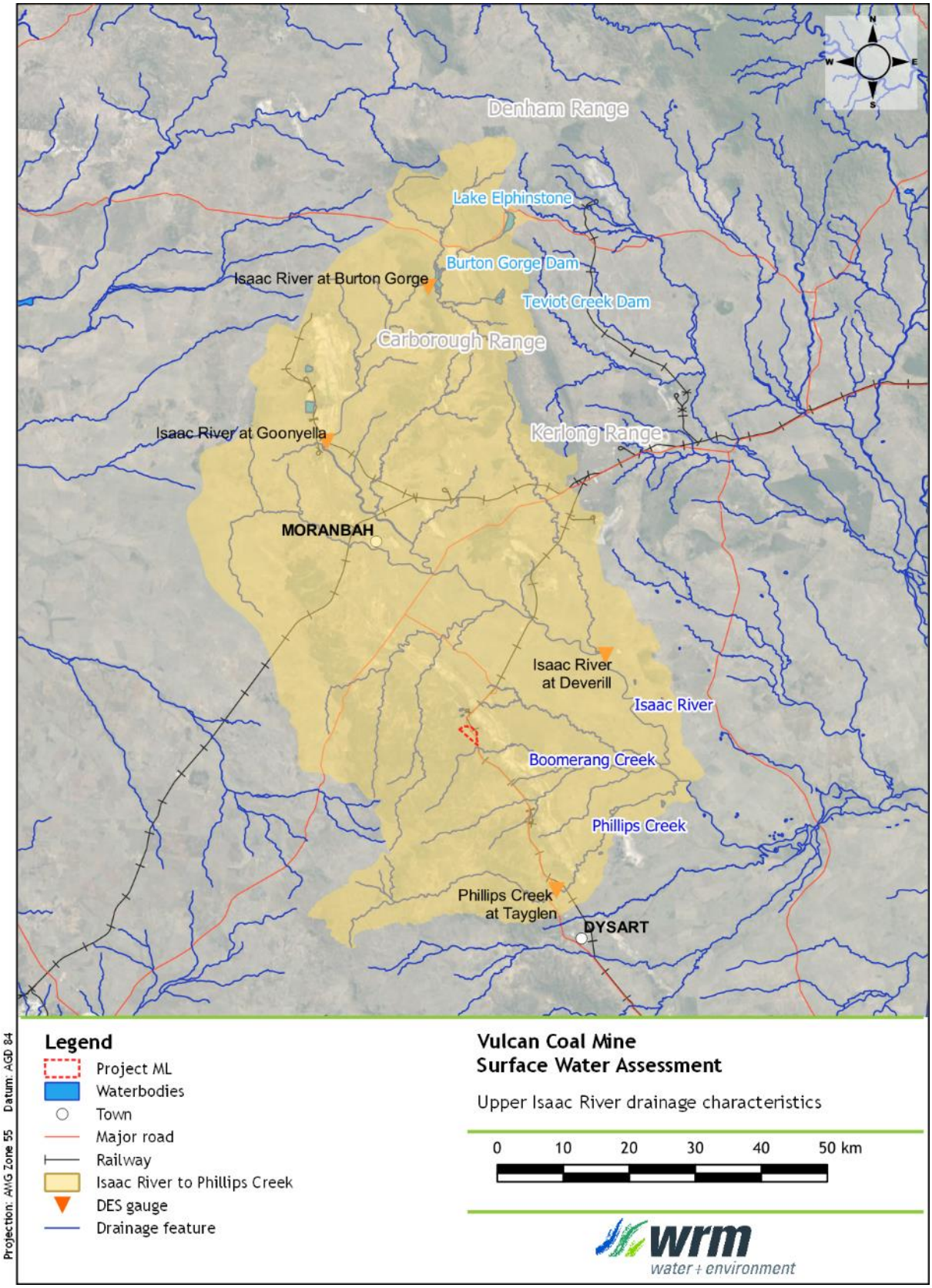


Figure 4.1 – Upper Isaac River drainage characteristics

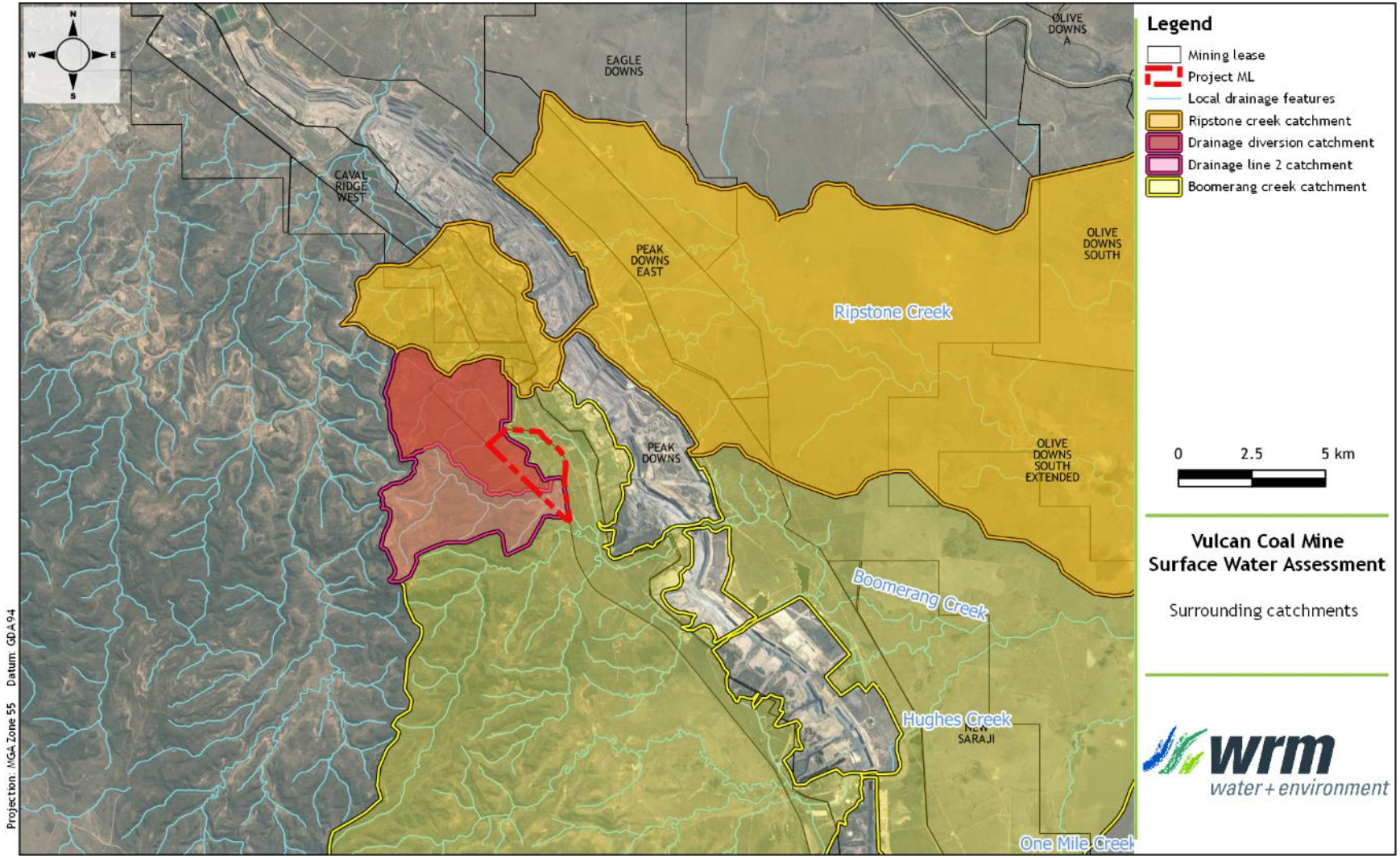


Figure 4.2 – Regional catchments in the vicinity of the Project

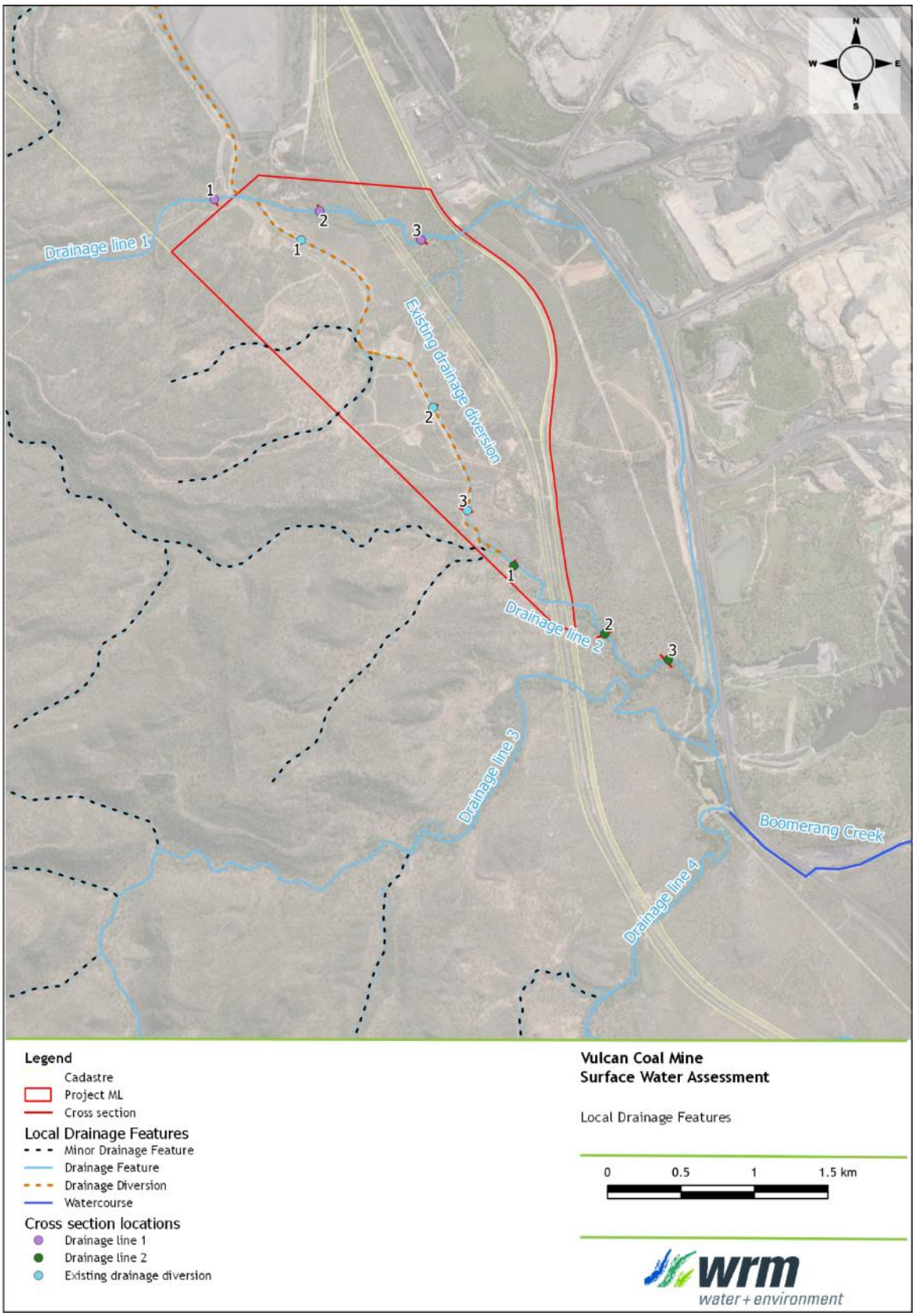


Figure 4.3 – Local drainage features in the vicinity of the Project

Figure 4.8 shows typical cross sections along the three local drainage features through the Project area at the locations shown in Figure 4.3.

4.2.1 Drainage Line 1

Drainage Line 1 drains the northern portion of the Project area to the east of the existing drainage diversion and includes the majority of the operational areas of the Project. Drainage Line 1 crosses the Saraji Road and the Norwich Park branch railway within the Project area before discharging into the Peak Downs Mine Lease (ML) downstream of the railway. Figure 4.4 and Figure 4.6 show photographs of Drainage Line 1 within the Project area and at the Railway culverts respectively.

Drainage Line 1 flows into an existing on-line water storage within the Peak Downs operations before eventually discharging into Drainage Line 2 approximately 1 km southeast of the Project boundary. Drainage Line 1 has been diverted and significantly modified within the Peak Downs ML.

The typical dimensions of the Drainage Line 1 channel through the Project area are (Figure 4.8):

- channel bed widths of 2 m to 5 m;
- channel top widths of 10 m to 25 m;
- channel depths 0.5 to 1 m; and
- overbank floodplain widths of 20 m to 50 m.

Drainage Line 1 will be diverted as part of the Project to allow access to the underlying coal. Drainage Line 1 will be reinstated by constructing a drainage corridor through the Jupiter Pit backfilled waste rock dump as shown in Figure 1.4. A new culvert crossing will be constructed under the realigned Saraji Road just upstream of the existing railway culverts.



Figure 4.4 – Photograph of Drainage Line 1 within the Project area



Figure 4.5 – Photograph of the existing railway culvert crossing of Drainage Line 1 at the eastern (downstream) Project boundary

4.2.2 Existing drainage diversion

An existing drainage diversion runs north-south along the length of the Project and flows into Drainage Line 2. Figure 4.6 shows a photograph of the existing drainage diversion and bund within the Project area. The existing drainage diversion appears to have been constructed in the 1970s to allow the construction of a Tailings Dam within the Peak Downs operations. The diversion flows in a south to southeast direction through the Project area and has a catchment area of approximately 16.0 km^2.

A levee is located along the majority of the existing drainage diversion and has an average height of 1 to 2 m and width of 5 to 10 m. The channel of the existing drainage diversion is located on the western side of the levee, with an average depth of 1 to 2 m and top width of 5 to 10 m (see cross section 1 and 2 in Figure 4.8). The channel width increases and deepens in the southern portion of the existing drainage diversion downstream of the levee (see cross section 3 in Figure 4.8).

The existing drainage diversion discharges into Drainage Line 2 within the Project area to the south of proposed operations. The Project will include upgrades to an existing crossing of the existing drainage diversion (which has been approved as part of the bulk sample). A second vehicle crossing will be included in this Project.



Figure 4.6 – Photograph of the existing drainage diversion and levee within the Project area

4.2.3 Drainage Line 2

Drainage Line 2 drains through the southeastern corner of the Project area and has a catchment area of approximately 30 km^2. Drainage Line 2 crosses the Saraji Road and the Norwich Park branch railway within the Project area before discharging into the Peak Downs ML downstream of the railway. Figure 4.7 shows a photograph of Drainage Line 1 within the Project area and at the Railway culverts respectively.

Drainage Line 1 flows into an existing on-line water storage within the Peak Downs operations before eventually discharging into Drainage Line 2 approximately 1 km southeast of the Project boundary. Drainage Line 2 has been diverted and significantly modified within the Peak Downs ML.

The typical dimensions of the Drainage Line 2 channel are:

- channel bed widths of 3 m to 5 m;
- channel top widths of 10 m to 30 m;
- channel depths 1 to 2 m; and
- overbank floodplain widths of 50 m to 150 m.

Drainage Line 2 will not be modified as part of the Project.



Figure 4.7 – Photograph of Drainage Line 2 within the Project area

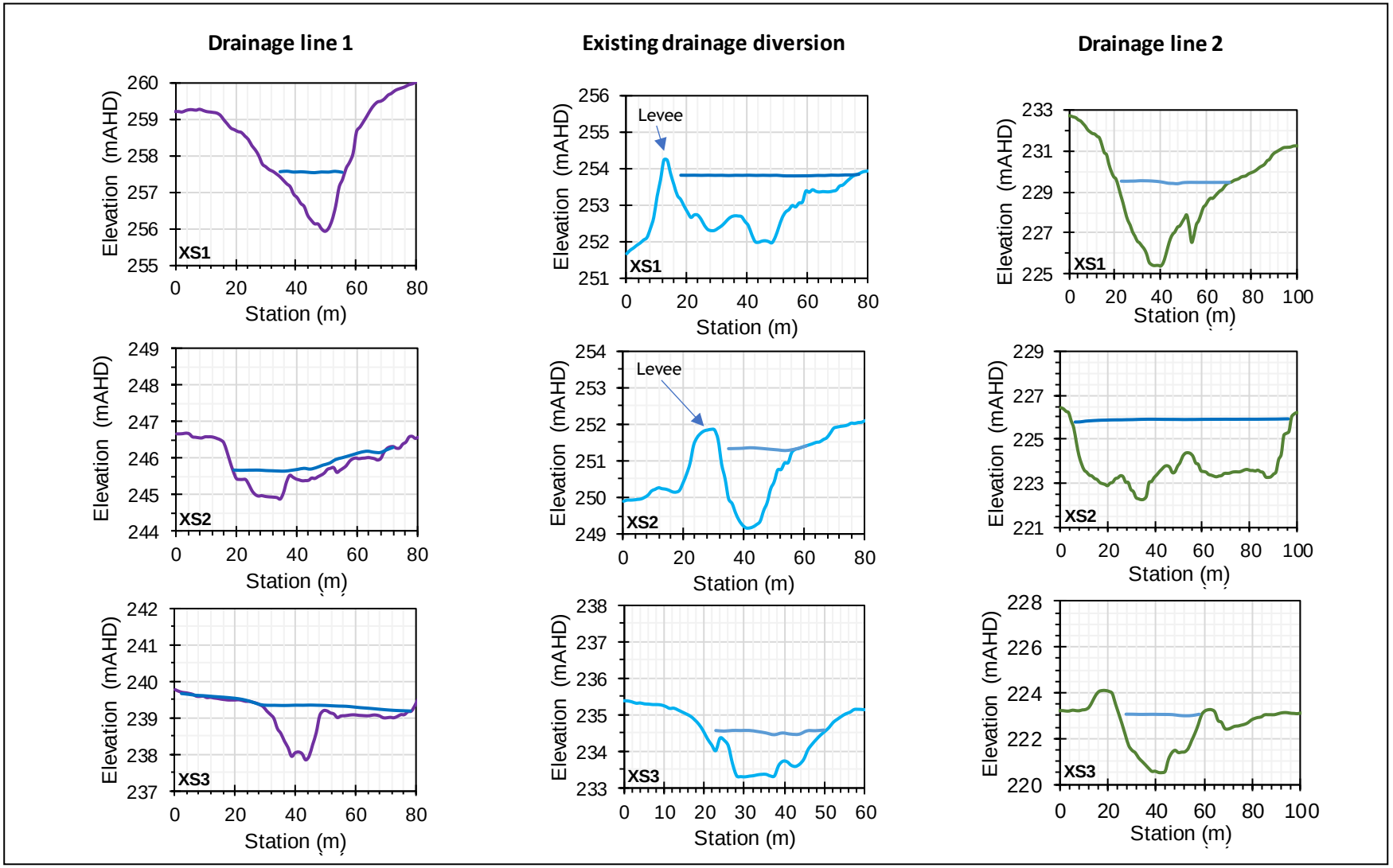


Figure 4.8 - Drainage line cross sections with 1% AEP flood levels

4.3 RAINFALL AND EVAPORATION

Long term rainfall and evaporation data at the Project is not available. Long term daily evaporation and rainfall data was sourced from the DES SILO climate data service at the approximate Project coordinates (Latitude: -22.35, Longitude: 148.2) from January 1889 to January 2019 (i.e. 130 years of data).

Table 4.1 shows statistics for Morton's lake evaporation and Table 4.2 shows statistics for rainfall (as mm/month and mm/year) over the historical dataset.

Figure 4.9 shows a comparison between the evaporation and rainfall. Evaporation rates are generally higher than rainfall throughout the year.

Table 4.1 - Evaporation (Morton's lake) statistics over the historical period (mm)

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Max	240	204	201	152	118	94	103	142	171	215	222	239	1,967
90th %ile	224	190	186	144	109	88	97	125	160	199	214	229	1,891
Median	202	168	167	132	102	80	91	118	152	189	200	212	1,805
10th %ile	171	143	150	121	94	75	83	110	141	174	182	188	1,725
Min	120	122	127	94	76	59	77	97	121	160	121	145	1,506

Table 4.2 - Rainfall statistics over the historical period (mm)

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Max	502	471	324	267	208	168	132	273	134	143	191	351	1254
90th %ile	209	221	160	70	66	74	61	61	48	88	100	150	882
Median	98	85	45	19	15	21	7	7	7	22	40	72	567
10th %ile	20	14	2	0	0	0	0	0	0	0	6	23	362
Min	0	0	0	0	0	0	0	0	0	0	0	2	221

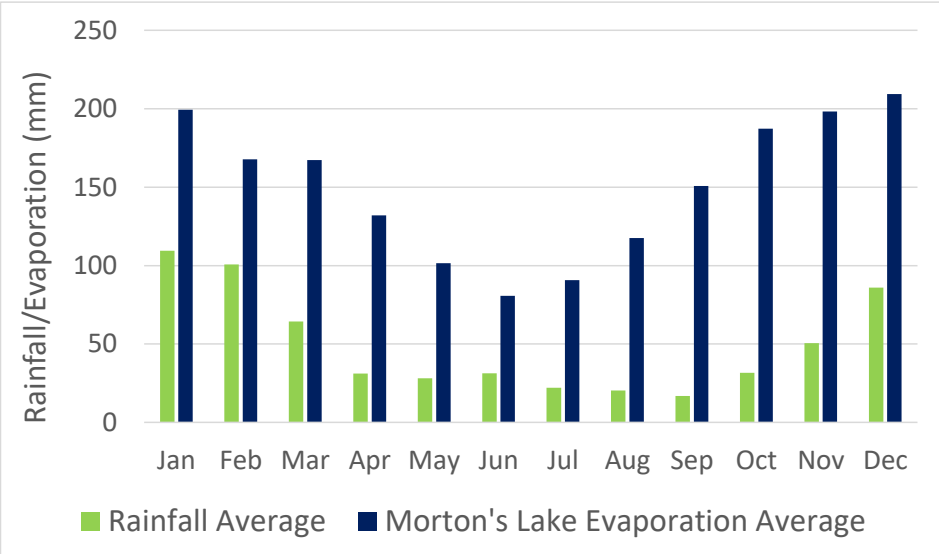


Figure 4.9 - Long term mean monthly rainfall and evaporation from SILO at the Project

4.4 STREAMFLOW

There is no stream flow data available for Boomerang Creek at the time of preparing this report. There are two streamflow gauges operated by the Department of Regional Development, Manufacturing and Water (RDMW) in the vicinity of the Project including (see Figure 1.1):

- Isaac River at Deverill (approximately 25 km northeast of the Project); and
- Phillips Creek at Tayglen (approximately 30 km southeast of the Project).

The closest stream gauge is located on the Isaac River at Deverill (Station ID: 130410A). This gauge is located approximately 20 km upstream of where Boomerang Creek meets the Isaac River.

Historical flow and river height monitoring data (1968 to 2018) for the Isaac River at Deverill provides an indication of the flow regime (refer Figure 4.10). Surveyed cross section data for this gauging station collected in September 2014 (DES, 2017) indicates that sediment covers the bottom one metre of the gauge range. The mean river height data shown in Figure 4.10 suggests that surface flow above the sand is more likely to occur only in the wetter months from November to April, reducing to shallow subsurface flows from about May to October in an average year.

The Phillips Creek at Tayglen Creek streamflow gauge (Station ID: 130409A) is located on Phillips Creek. Phillips Creek is an easterly draining tributary of the Isaac River. RDMW maintains data for the gauge between 1968 and 1988. The catchment area to the gauge location is 344 km^2.

A typical sequence of recorded flows from this station is shown in Figure 4.11. The creek is characterised by brief periods of flow interspersed by long periods of no flow. This ephemeral behaviour is typical for streams in this part of the Fitzroy Basin.

The median annual flow over the period of record was approximately 12,730 ML/a (52 mm of runoff), most of which occurred in the summer months (as shown in Figure 4.12). Figure 4.13 compares flow frequency curves for a number of gauged catchments in the Isaac River catchment which are located in the vicinity of the Project. Figure 4.13 shows that for Phillips Creek at Tayglen, flow only occurred approximately 22% of the time, which would be similar to other creeks in the vicinity of the Project.

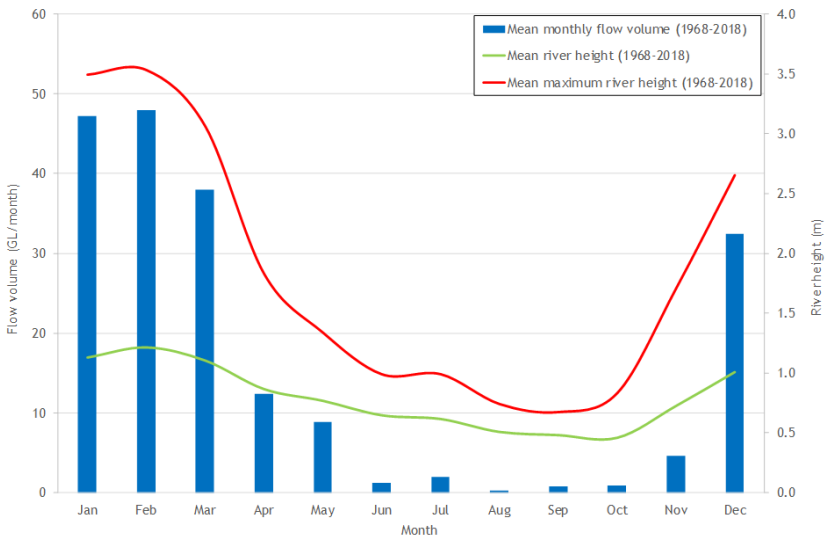


Figure 4.10 – Flow volume and river height in the Isaac River at Deverill

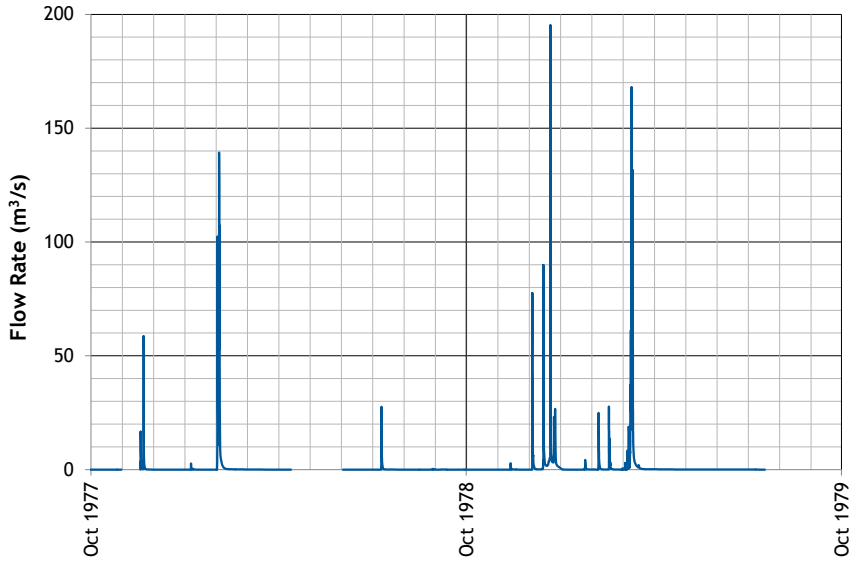


Figure 4.11 - Sample flow sequence - Phillips Creek at Tayglen 1977 - 1979

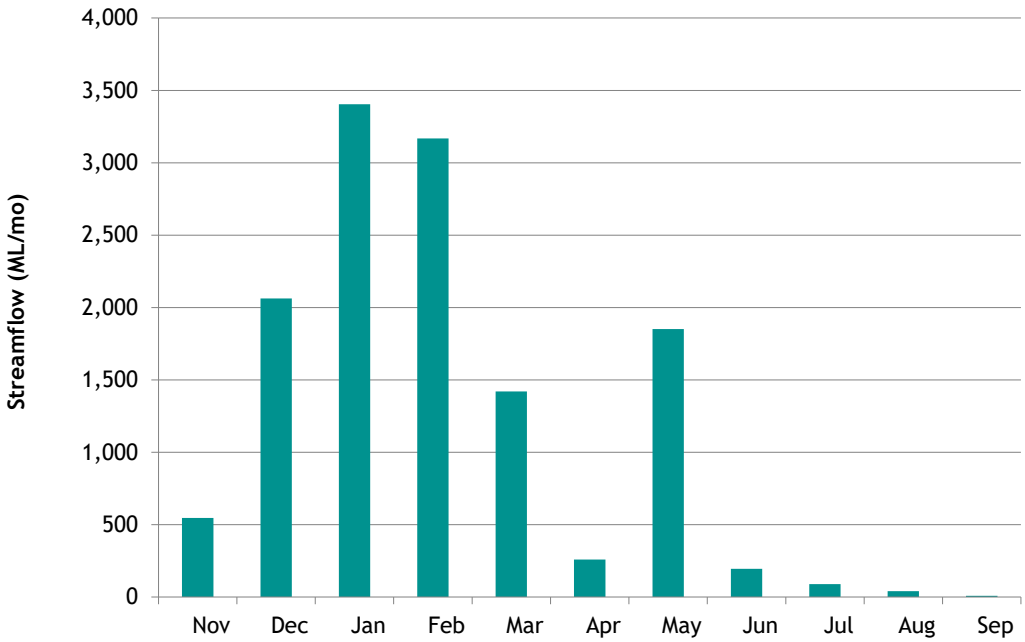


Figure 4.12 - Measured mean monthly streamflow - Phillips Creek at Tayglen 1968-1988

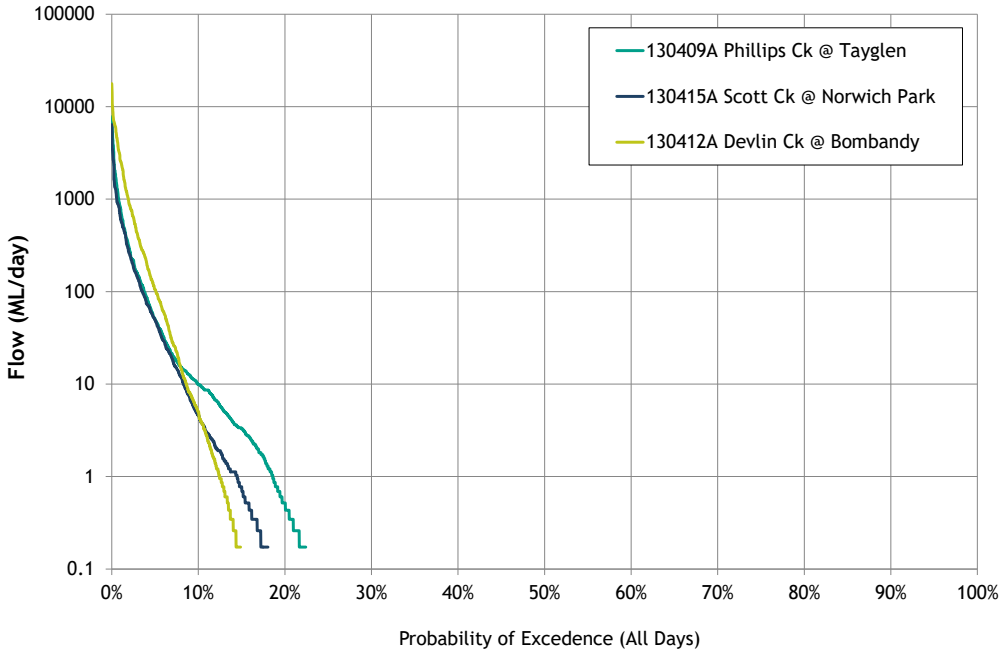


Figure 4.13 – Recorded frequency curves at nearby RDMW gauges (no flow days included)

4.5 WATER QUALITY

4.5.1 Regional Isaac River water quality

Publicly available regional water quality data for the Isaac River at the Deverill Gauging Station has been analysed for median results and are displayed in Table 4.3. This site was selected as complete datasets (i.e. individual sample analysis results) are publicly available, as opposed to summary data only.

RDMW has collected daily electrical conductivity (EC) data at the Isaac River at Deverill gauge. The Deverill gauge is located upstream of the point where Boomerang Creek drains into the Isaac River. The gauge would therefore be representative of water quality in the receiving waters of the Isaac River from the Project.

Figure 4.14 presents a time history of recorded instantaneous EC and stream flow for the Isaac River at Deverill gauging station. Figure 4.15 details the relationship between instantaneous flow and EC at the Isaac River at Deverill gauging station. The data collected by RDMW at the Deverill gauging station spans the period from 2011 to 2018 and indicates:

- The EC values for high flows greater than 200 m^3/s are generally below the high flow WQO EC of 250 µs/cm;
- The EC of instantaneous flows below 100 m^3/s vary significantly from 50 µS/cm to 1,870 µS/cm with many recorded values exceeding the low flow WQO EC of 720 µS/cm but are below the Peak Downs EA receiving waters trigger value of 2000 µS/cm;
- The mean daily EC has exceeded the low flow WQO on a total of 23 days over this period and all of these days experienced some flow (not stagnant flow); and
- The stream flows are highly ephemeral with baseflows ceasing within a few days or weeks of a runoff event, or at least flowing below the top of the sandy bed.

Table 4.3 – Water quality median data in the Isaac River at Deverill

Parameter	Unit	Isaac River at Deverill	WQO default guideline value (refer Table 3.1)
Aluminium - Total	mg/L	-	< 5 (stock)
Aluminium - Dissolved	mg/L	0.05	< 0.055 (aquatic)
Boron - Total	mg/L	0.06	< 5 (stock)
Calcium - Dissolved	mg/L	16	-
Chloride - Total	mg/L	32	-
Copper - Dissolved	mg/L	0.03	< 0.0014 (aquatic)
EC	µS/cm	261	< 720 (baseflow) < 250 (high flow)
Filterable Reactive Phosphorus	µg/L	0.35	< 20 (aquatic)
Fluoride - Total	mg/L	0.14	< 2 (irrigation)
Iron - Dissolved	mg/L	0.06	-
Manganese - Dissolved	mg/L	0.01	< 1.9 (aquatic)
Nitrate - Total	mg/L	1.4	-
Nitrogen – Total	µg/L	0.76	< 500 (aquatic)
pH	-	7.6	pH 6.5–8.5 (aquatic)
Phosphorus - Total	µg/L	0.35	< 50 (aquatic)
Potassium - Total	mg/L	4.55	-
Sodium - Total	mg/L	22	< 30 (drinking water)
Sulfate - Total	mg/L	10.9	< 25 (aquatic)
Total Alkalinity	mg/L	78	-
Total Dissolved Solids	mg/L	155	< 2,000 (stock)
Total Suspended Solids	mg/L	135	< 55 (aquatic)
Turbidity	NTU	247	< 50 (aquatic)
Zinc - Dissolved	mg/L	0.01	< 0.008 (aquatic)

Note: Recorded exceedances of the WQOs have been shaded in grey.

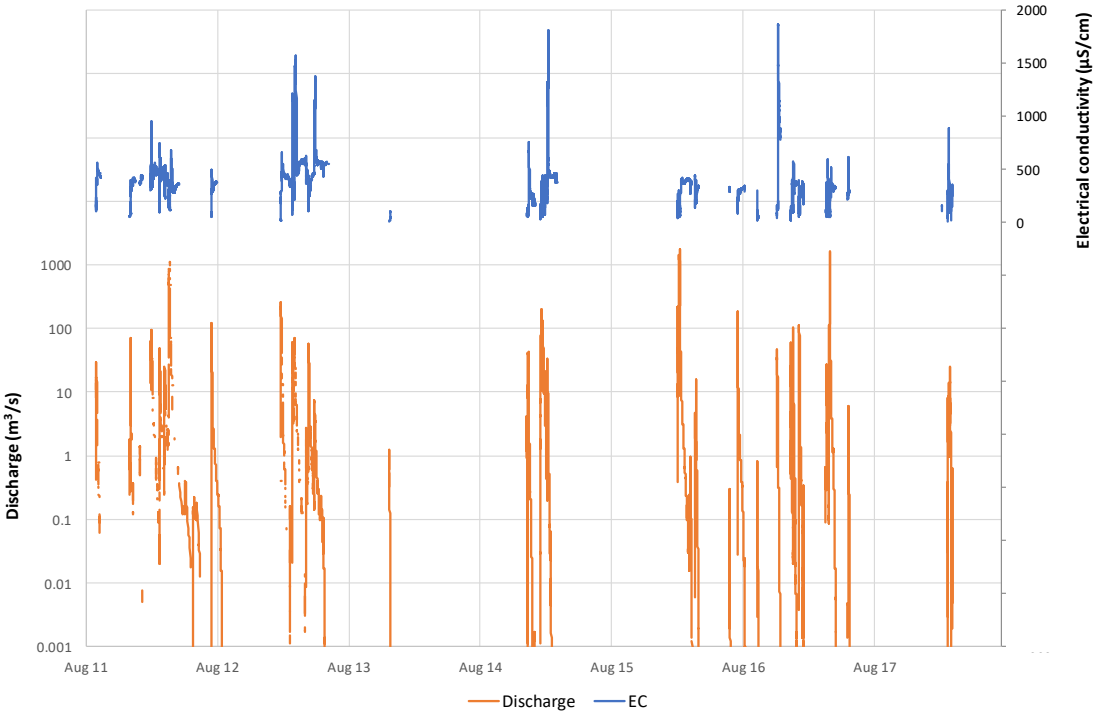


Figure 4.14 - Electrical Conductivity and Flow (Isaac River at Deverill Gauge)

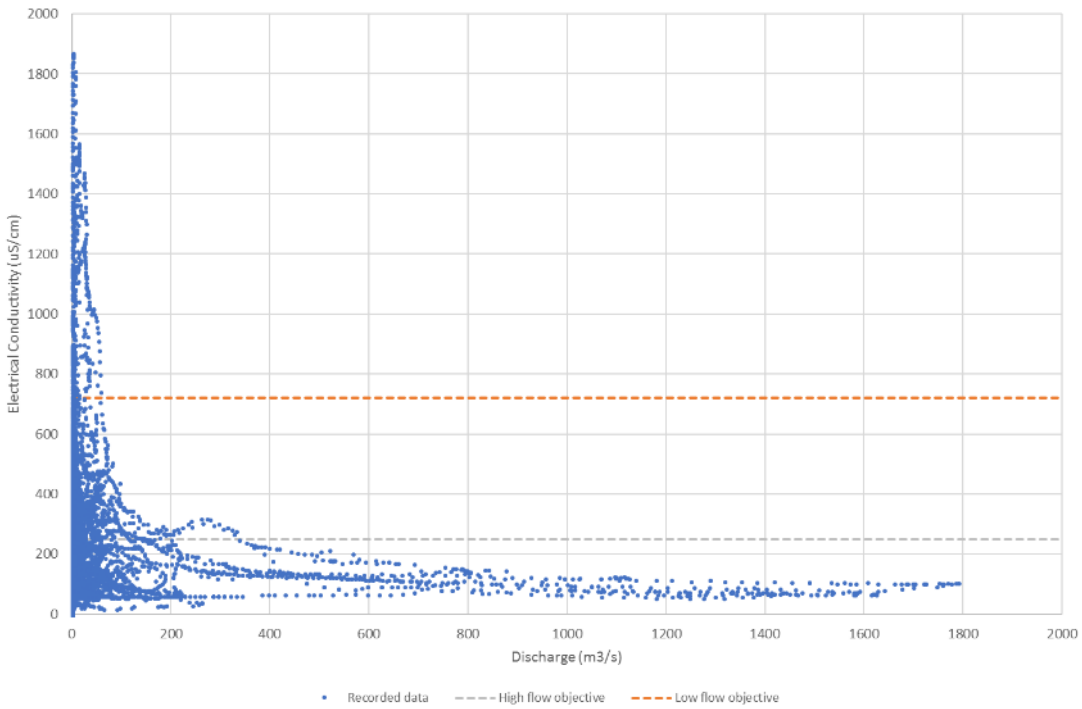


Figure 4.15 - Flow vs Electrical Conductivity (Isaac River at Deverill Gauge)

4.5.2 Baseline surface water quality data

Vitrinite has implemented a routine baseline water quality monitoring network since February 2020 within and in the vicinity of the Project to collect baseline (reference) surface water quality along natural drainage lines. A review of the available baseline (reference) surface water quality data has been undertaken to develop locally derived receiving waters trigger values for the VCM.

The review has been undertaken using natural surface water quality measurements at seven (7) relevant baseline (reference) monitoring sites on the following drainage lines (see Figure 4.16):

- VSW3, VSW5, VSW6, VSW11, VESW2, VESW3 and VESW4 are upstream monitoring points;
- VSW2, VSW4, VSW7, VSW8 and VESW1 are downstream monitoring points; and
- VSW1 was excluded from the assessment as sampling at this location shows anomalies and could have been potential influenced from external factors or catchments.

The monitoring points include receiving waters baseline monitoring locations to the south (along Hughes Creek) and north (along Harrow Creek) of the VCM. These monitoring points have been chosen because the catchment characteristics are similar to Boomerang Creek and sampling outcomes indicate that these locations would be relevant for setting baseline trigger values for the VCM EA.

The assessment was undertaken in accordance with the Australian and New Zealand Guidelines for Fresh and Marine Water Quality guidelines (ANZG, 2018) for deriving site specific guideline value (SSGVs) for aquatic ecosystems protection from local reference data.

4.5.3 Baseline surface water quality assessment methodology

Vitrinite provided site water quality data collected from February 2020 to July 2022 for this review. Based on available water quality data, samples were taken at the monitoring sites during seven natural flow events. One event occurred in February 2020, two events in March 2020, one event in January 2021, and three events in July 2022.

Locally derived receiving waters trigger values have been proposed for the Project using the 80th percentile of recorded reference site data in accordance with ANZG (2018). The 80th percentile values were compared against the Project Water Quality Objective (WQO) default trigger values given in Table 3.1 and the DES Model Mine Conditions (MMC) guidelines (DES, 2017). ANZG (2018) states that reference data can be used to derive SSGVs for water quality when natural background concentrations of a toxicant exceed the Project WQO default trigger value.

ANZG (2018) also states that data collected over 2 years of monthly sampling (18 to 24 samples) is regarded as sufficient to indicate ecosystem variability to derive guideline values based on reference site data. To establish local water quality objectives, the Queensland Water Quality Guidelines (QWQG) require that with 3 or more reference sites, 12 samples are collected over at least 12, but preferably 24 months. Vitrinite has established more than 3 reference sites, which will continue to be either upstream reference sites or reference sites until mining commences.

4.5.4 Comparison of baseline surface water quality data with the Project WQO and MMC default trigger values

The site monitoring data to date has been sampled for between two (2) and up to seven (7) events across the monitoring locations. As data collection is limited to periods of flow in an ephemeral system, the upstream monitoring points samples were combined so that the 80th percentile values could be analysed. In total, 24 samples were taken across the two year period. Table 4.4 shows the 80th percentile values for all parameters measured for the combined upstream monitoring points data set as well as the Project WQO default trigger values and MMC (DES, 2017) default trigger values.

Table 4.4 – 80th percentile values for the combined upstream monitoring points data set compared with the receiving water WQO default trigger values and MMC Table F3 trigger values

Parameter	Unit	Upstream monitoring points samples - 80th percentile values	WQO default trigger values (see Table 3.1)	MMC trigger
No. of Samples		24.000	-	
Physico-chemical parameters				
pH Value	-	7.382	< 6.5 or > 8.5	
Sodium Adsorption Ratio	-	1.860	-	
Electrical Conductivity	µS/cm	226.000	> 720 (baseflow) > 250 (high flow)	
Total Dissolved Solids (Calc.)	mg/L	147.200	> 2,000	
Suspended Solids (SS)	mg/L	195.200	> 55	
Turbidity	NTU	505.000	> 50	
Dissolved Oxygen	mg/L	8.600	< 4	
Dissolved Metals				
Aluminium	mg/L	0.720	> 0.055	>0.055
Arsenic	mg/L	0.003	> 0.024	> 0.013
Cadmium	mg/L	<0.0001	> 0.0002	> 0.0002
Chromium	mg/L	0.001	> 0.001	> 0.001
Cobalt	mg/L	0.005	-	> 0.090
Copper	mg/L	0.003	> 0.0014	> 0.002
Lead	mg/L	0.001	> 0.0034	> 0.004
Manganese	mg/L	0.217	> 1.9	> 1.9
Molybdenum	mg/L	0.001	-	> 0.034
Nickel	mg/L	0.003	> 0.011	>0.010
Selenium	mg/L	<0.01	> 0.005	>0.001
Silver	mg/L	<0.001	-	> 0.001
Uranium	mg/L	<0.001	> 0.1	>0.001
Vanadium	mg/L	<0.01	> 0.5	> 0.010
Zinc	mg/L	0.013	> 0.008	> 0.008
Boron	mg/L	0.098	> 0.37	> 0.37
Iron	mg/L	0.716	-	> 0.3
Mercury	mg/L	<0.0001	> 0.00006	> 0.0002
Total Metals				
Aluminium	mg/L	8.130	> 5	
Arsenic	mg/L	0.003	> 0.5	
Cadmium	mg/L	<0.0001	> 0.01	
Chromium	mg/L	0.007	> 1	
Cobalt	mg/L	0.006	> 0.1	
Copper	mg/L	0.011	> 1	
Lead	mg/L	0.011	> 0.1	
Manganese	mg/L	0.280	> 10	
Molybdenum	mg/L	0.006	> 0.05	
Nickel	mg/L	0.011	> 1	

Parameter	Unit	Upstream monitoring points samples - 80th percentile values	WQO default trigger values (see Table 3.1)	MMC trigger
Selenium	mg/L	<0.01	> 0.02	
Silver	mg/L	<0.001	-	
Uranium	mg/L	0.001	-	
Vanadium	mg/L	0.020	-	
Zinc	mg/L	0.032	> 5	
Boron	mg/L	0.156	> 5	
Iron	mg/L	10.440	> 10	
Mercury	mg/L	0.000	> 0.002	
Major cations and anions				
Total Hardness as CaCO3	mg/L	37.400	> 150	> 150
Hydroxide Alkalinity as CaCO3	mg/L	<1	-	
Carbonate Alkalinity as CaCO3	mg/L	8.000	-	
Bicarbonate Alkalinity as CaCO3	mg/L	38.400	-	
Total Alkalinity as CaCO3	mg/L	38.400	-	
Sulfate as SO4 - Turbidimetric	mg/L	15.600	> 770	
Chloride	mg/L	31.000	-	
Calcium	mg/L	5.800	-	
Magnesium	mg/L	5.400	-	
Sodium	mg/L	19.400	> 30	
Potassium	mg/L	7.000	-	
Fluoride	mg/L	0.200	> 2	> 2
Ammonia as N	mg/L	0.562	> 0.02	> 0.74
Nitrite as N	mg/L	0.738	-	
Nitrate as N	mg/L	0.564	-	> 0.248
Nitrite + Nitrate as N	mg/L	0.966	-	
Total Kjeldahl Nitrogen as N	mg/L	1.920	-	
Total Nitrogen as N	mg/L	2.860	> 0.5	
Total Phosphorus as P	mg/L	0.282	> 0.05	
Reactive Phosphorus as P	mg/L	0.658	> 0.02	
Total Anions	meq/L	1.984	-	
Total Cations	meq/L	2.178	-	
Ionic Balance	%	7.162	-	
Hydrocarbons				
C6 - C10 Fraction	µg/L	<20	-	
>C10 - C40 Fraction (sum)	µg/L	<100	-	
Biological				
Chlorophyll a	mg/m³	4.400	-	

Note: Recorded exceedances of the WQOs which are adopted as the locally derived WQO have been shaded in grey.

4.6 RECOMMENDED RECEIVING WATERS TRIGGER VALUES

Table 4.5 shows the recommended receiving waters trigger values for the water quality parameters. The parameters for which the combined upstream monitoring points dataset

80th percentile value exceeded the Project WQO and MMC default trigger values have been proposed as locally derived trigger values. The recommended receiving waters trigger values for all other parameters are based either on the Project WQO, MMC default guideline value or the Vulcan Bulk Sample Project EA value. The recommended locally derived receiving waters trigger values based on the 80th percentile monitoring points sample values exceeding the Project WQO and MMC default trigger values include:

- Filtered Iron - 0.72 mg/L;
- Filtered Aluminium – 0.72 mg/L;
- Filtered Selenium – 0.01 mg/L;
- Iron – 10.44 mg/L;
- Aluminium – 8.13 mg/L;
- Bicarbonate as CaCO3 - 97 mg/L;
- Carbonate as $CaCO_3$ – 8.00 mg/L;
- Calcium – 5.80 mg/L;
- Chloride – 31.00 mg/L;
- Potassium – 7.00 mg/L; and
- Magnesium – 5.40 mg/L.

The receiving water quality trigger levels proposed for the VCM EA will help reduce the risk of exceeding release trigger levels. The summary of the recommended receiving water trigger levels to be adopted for the VCM EA include:

- Initially adopt the 80th percentile values given in Table 4.5 as interim locally derived trigger values for Filtered Iron, Filtered Aluminium, Filtered Selenium, Iron, Aluminium, major cations and anions. Note that further monitoring of receiving waters should be continued to update these values;
- Adopt the WQO default trigger values in Table 3.1 for pH, Electrical Conductivity, Filtered Arsenic, Lead, Mercury, Arsenic, Molybdenum and Selenium;
- Adopt the MMC (DES, 2017) default trigger values for Filtered Lead, Filtered Mercury, Filtered Molybdenum, C6 – C10 Fraction and C10 – C40 Fraction; and
- Adopt the Sulfate trigger value of 770 mg/L from Table F4 of the Vulcan Bulk Sample Project EA.

Table 4.5 – Proposed receiving waters trigger values for the VCM EA

Parameter	Unit	Proposed receiving waters trigger values	Source
pH		<6.5 and >8.5	WQO (aquatic ecosystem)
Electrical Conductivity*	µS/cm	> 720 (baseflow) > 250 (high flow)	WQO (aquatic ecosystem)
Sulfate	mg/L	770	Vulcan Bulk Sample Project EA^
Filtered metals			
Iron*	mg/L	0.72	Locally derived
Lead	mg/L	0.004	MMC (aquatic ecosystem)
Mercury	mg/L	0.0002	MMC (aquatic ecosystem)
Arsenic	mg/L	0.024	WQO (aquatic ecosystem)
Aluminium*	mg/L	0.72	Locally derived
Molybdenum	mg/L	0.034	MMC (aquatic ecosystem)
Selenium*	mg/L	0.01	Locally derived
Total metals			
Iron*	mg/L	10.44	Locally derived
Lead	mg/L	0.10	WQO (stock)
Mercury	mg/L	0.002	WQO (aquatic ecosystem)
Arsenic	mg/L	0.50	WQO (stock)
Aluminium*	mg/L	8.13	Locally derived
Molybdenum	mg/L	0.05	WQO (irrigation)
Selenium	mg/L	0.02	WQO (stock)
Hydrocarbons			
C6 - C10 Fraction	mg/L	20.00	MMC (aquatic ecosystem)
C10 - C40 Fraction	mg/L	100.00	MMC (aquatic ecosystem)
Major Cations and Anions			
Bicarbonate as $CaCO_3$*	mg/L	38.40	Locally derived
Sodium*	mg/L	30.00	WQO (drinking water EV)
Carbonate as $CaC0_3$*	mg/L	8.00	Locally derived
Calcium*	mg/L	5.80	Locally derived
Chloride*	mg/L	31.00	Locally derived
Potassium*	mg/L	7.00	Locally derived
Magnesium*	mg/L	5.40	Locally derived

* Locally derived trigger value based on combined data set
^ Table F4 of the Vulcan Bulk Sample Project EA based on 95% species protection from Dunlop et al. (2016).
Notes:
Vulcan Bulk Sample EA: EA0002054 granted 30 October 2020
MMC: Model Mine Conditions ESR/2016/1936 (DES, 2017)
WQO: Relevant Water Quality Objective from Table 3.1
Locally Derived: Value based on the 80th percentile of combined upstream monitoring points data set

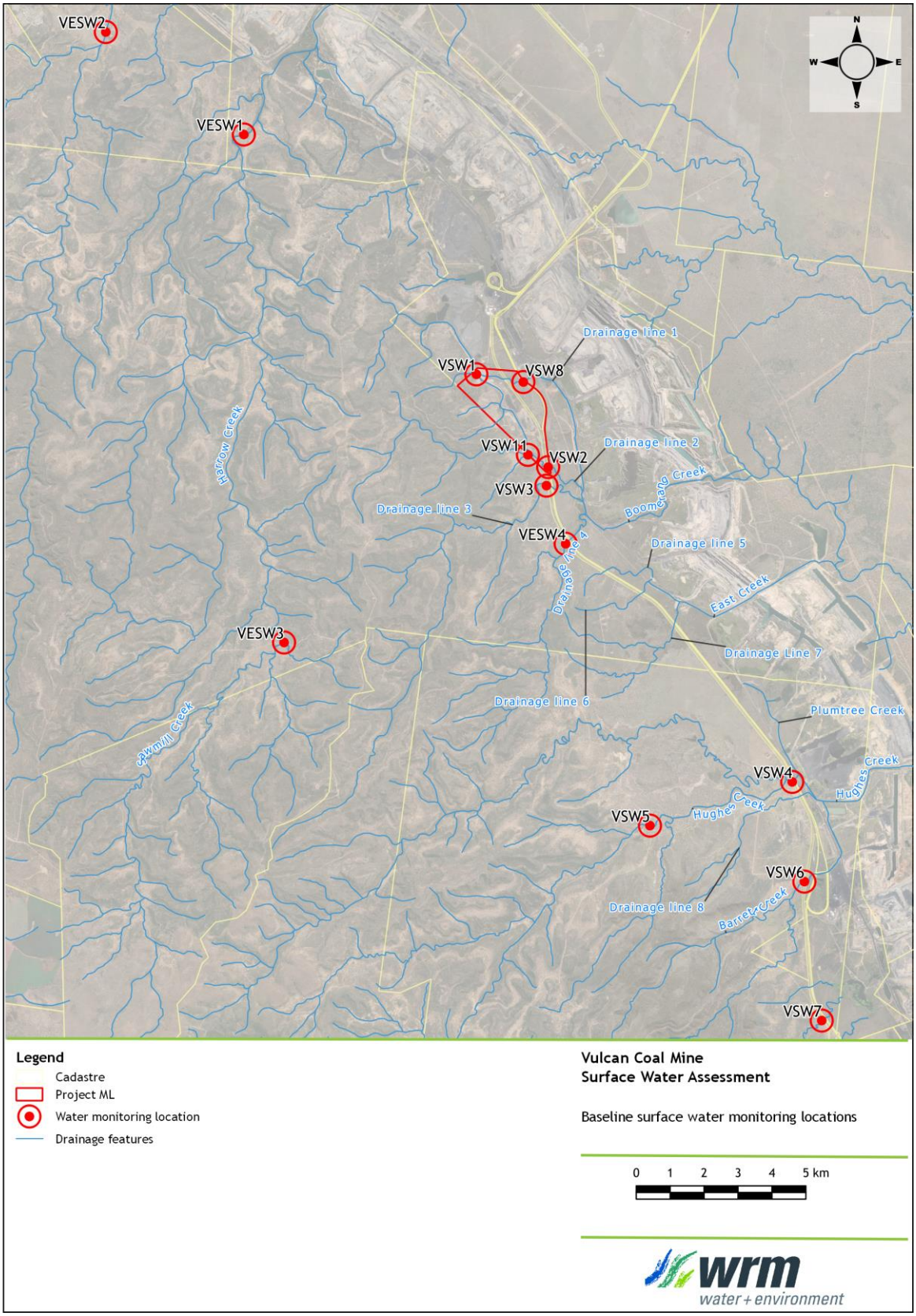


Figure 4.16 - Water monitoring locations

4.7 SOIL CHARACTERISTICS

AARC Environmental Solutions Pty Ltd (2019) completed a *Soil and Land Suitability Assessment* (SLSA) for the Project and surrounds. To characterise the soils at the site, AARC collected 42 detailed soil profiles and analysed 12 laboratory samples from the site and surrounds.

The area surrounding the Project is dominated by clastic sedimentary rocks of marine and lacustrine origin, including sandstones, mudstones, siltstones and coal. Surface geology at the site includes Quaternary clay, silt, sand, gravel and soil with colluvial and residual deposits, as well as late Tertiary to Quaternary poorly consolidated sand, silt, clay, minor gravel and high-level alluvial deposits (AARC, 2019).

4.7.1 Soil management units

AARC mapped the Soil Management Units (SMUs) across the site using the methodologies specified in the *Guidelines for Surveying Soil and Land Resources* (McKenzie et al, 2008) based on soil morphology, parent material and land attributes.

A description of each SMU found within the Project area is outlined in Table 4.6. The majority of the site consists of the Limpopo SMU, with a small southern portion of the Project site consisting of Crocodile and Zambezi SMUs.

Table 4.6 - Soil Management Units surveyed on site (AARC, 2019)

Soil Management Unit	Description
Crocodile	A shallow rocky soil unit associated with hill slopes and plateaus. Soil textures grade from loam at the surface, to loamy sands with depth; often containing rock material with little to no pedologic development throughout the solum.
Limpopo	The Limpopo unit is a brown texture-contrast soil. Soil textures predominantly grade from sands to clay sands in the surface soils to light clays in deeper horizons.
Zambezi	A predominantly grey coloured texture contrast soil with surface soils consisting of sands, increasing in clay content in deeper horizons. Lower horizons display diffuse orange to yellow mottles.

4.7.2 Sodic and dispersive soils

Sodic soils contain large concentrations of Sodium relative to other cations. These soils have a degree of dispersivity and can accelerate erosion.

AARC identified areas of high sodicity on site through the measurement of the Exchangeable sodium percentage and Emerson Class of surveyed soils. The Crocodile SMU was identified as having a low risk of dispersion and was not identified as being sodic.

For the remaining SMUs, AARC (2019) identified the depth horizons with sodic properties as follows:

- Limpopo SMU: Sodic below a depth of 0.5 m; and
- Zambezi SMU: Sodic below a depth of 0.5 m.

To control erosion from sodic dispersive soils, soils will be selectively handled and managed accordingly.

5 Proposed surface water management strategy and infrastructure

5.1 TYPES OF WATER GENERATED ONSITE

Land disturbance associated with mining has the potential to adversely affect the quality of surface runoff in downstream receiving waters through increased sediment loads. In addition, runoff from active mining areas (including coal stockpiles, etc.) may have increased concentrations of salts and other pollutants when compared to natural runoff. The proposed strategy for the management of surface water at the Project is based on the separation of water from different sources based on anticipated water quality.

Definitions of the types of water generated within the Project are shown in Table 5.1.

5.2 PROPOSED WATER MANAGEMENT INFRASTRUCTURE

The operational period of mining is expected to run for four years from 2021 to 2024.

Figure 1.2 and Figure 1.3 show indicative locations of the key features of the mine, including infrastructure related to the management of water on the Project site for two different stages of mining (Stages 1 and 2). The main components of water-related infrastructure include:

- diverted water drains to divert runoff from undisturbed catchments around areas disturbed by mining;
- a flood protection levee along the western side of the proposed Jupiter pit that may be formed by a haul road embankment;
- a flood protection levee along the eastern side of the proposed Matilda pit;
- a diversion drain and flood protection levee along the western side of the proposed Matilda pit;
- sediment dams and drains to collect and treat runoff from waste rock emplacement areas;
- mine-affected water drains and dams to store water pumped out of the open cut mining areas and to collect runoff from the infrastructure areas;
- culverts to convey flows through the proposed rail loop and haul road crossings of the existing drainage diversion; and
- minor works to the existing BMA levee (and spillway) and existing drainage diversion in the vicinity of the haul road crossings.

The catchment areas of each of the mine water storages, as well as the assumed landuse contributing to each catchment are also shown in Figure 1.2 and Figure 1.3. Details of proposed water storages, including indicative storage sizes and pumping rules are provided in Section 6.4.

5.3 WATER MANAGEMENT STRATEGY OVERVIEW

The water management system for the Project aims to protect the identified downstream EVs and comprises the following key objectives:

- separate diverted water from mine affected water to ensure that up-catchment water and mine affected water do not mix wherever practicable;

- capture of mine affected runoff (e.g. mine industrial area, haul road/ROM pad runoff), storage and priority reuse as mine water supply;
- divert up-catchment water runoff from upstream catchments around the active mining area;
- limit external catchment runoff draining into pits;
- manage sediment from disturbed catchment areas (e.g. ex-pit waste rock emplacements, cleared/pre-strip areas) by using erosion and sediment control (ESC) measures prior to release offsite;
- reuse onsite water (e.g. mine affected water) where possible to support mine operational water demands (and therefore limit mine affected water inventories under normal operating conditions); and
- manage any mine affected water releases to the receiving environment to meet environmental release conditions (not currently proposed).

The Project water management system will include mine water drainage, mine water storages, sediment dams, pit water storages and flood protection works (i.e. levees). Further details of the mine water management system are provided in Section 6.4.

Table 5.1 – Types of water managed within the Project

Water type	Definition
Mine affected water	In accordance with the DES *Guideline Model Mining Conditions* (2017), mine affected water means the following types of water: i) pit water, tailings dam water, processing plant water; ii) water contaminated by a mining activity which would have been an environmentally relevant activity under Schedule 2 of the *Environmental Protection Regulation 2008* if it had not formed part of the mining activity; iii) rainfall runoff which has been in contact with any areas disturbed by mining activities which have not yet been rehabilitated, excluding rainfall runoff discharging through release points associated with erosion and sediment control structures that have been installed in accordance with the standards and requirements of an Erosion and Sediment Control Plan to manage such runoff, provided that this water has not been mixed with pit water, tailings dam water, processing plant water or workshop water; iv) groundwater which has been in contact with any areas disturbed by mining activities which have not yet been rehabilitated; v) groundwater from the mine dewatering activities; and vi) a mix of mine affected water (under any of paragraphs i to v) and other water.
Surface water	Surface water runoff from areas that are disturbed by mining operations (including ex-pit waste rock emplacements). This runoff does not come into contact with coal or other carbonaceous material and may contain high sediment loads but does not contain elevated levels of other water quality parameters (e.g. electrical conductivity, pH, metals, metalloids, non-metals). This runoff must be managed to ensure adequate sediment removal prior to release to receiving waters.
Diverted water	Surface runoff from areas unaffected by mining operations. Diverted catchment water includes runoff from undisturbed areas and fully rehabilitated areas.
Raw water	Untreated water that has not been contaminated by mining activities.
Potable water	Treated water suitable for human consumption.
External water	Water supplied from a source that is external to Project area to make up water shortfalls for onsite water demands when site water sources cannot meet demand.

5.4 DIVERTED RUNOFF WATER MANAGEMENT

5.4.1 Flood protection levee

A flood levee is proposed along the western edge of the proposed Jupiter Pit mining operations to protect the site from potential floodwater that overflows from the existing drainage diversion. Part of the proposed flood levee may be formed by a haul road that will be located around the western side of the Jupiter Pit. The location of the proposed Jupiter Pit flood levee is shown in Figure 8.11.

Flood levees are proposed along the western and eastern edges of the proposed Matilda Pit to protect the proposed pit from potential floodwater ingress via the western upstream clean water catchment and overflows from the existing drainage diversion from the east. The proposed Matilda Pit western flood levee may be formed by the drainage diversion used to divert the western clean water catchment around the proposed pit. The location of the proposed Matilda Pit flood levees is shown in Figure 8.11.

It is proposed to cross BMA's existing drainage diversion and associated levee to the west of the Jupiter Pit (shown in Figure 1.2 and Figure 1.3). Under existing conditions, BMA's existing drainage diversion and levee is overtopped during large flood events. Minor modifications to BMA's existing drainage diversion and associated levee will be undertaken to maintain the existing flow characteristics in the vicinity of the haul road crossings.

The proposed levees will be regulated structures under the EP Act and will therefore be required to have crests above the 0.1% annual exceedance probability (AEP) event. An assessment of the levees against the requirements of the EP Act is given in Section 8.6.10.

5.4.2 Diverted water drains and dams

The water management system has been designed to divert undisturbed catchments around mining operations wherever practicable. The key features of the site diverted water management are:

- DD1 (operational in Stage 2) – a diverted water dam, located adjacent to the Jupiter Pit, which has been designed to provide the Jupiter Pit with flood immunity during a 0.1% AEP rainfall event. DD1 has a spillway at 247.0 mAHD located on the northern side of the dam. A pump transfers water which collects in DD1 to the existing drainage diversion. The dam will only collect direct rainfall and flood runoff which overtops the existing drainage diversion during flood events.
- MIA area diverted water bunds (operational in Stages 1 and 2) – diverted water bunds located around the northern side of the northern workshop area and the southern side of the workshop area. The northern bund diverts runoff from the catchment area to the north of the workshop to the east. The southern bund diverts runoff overflowing the haul road floodway to DD1.
- Northern diverted water drains (operational in Stage 2) - a diversion drain which has been designed to divert water around the northern side of the pit. This drain collects the undisturbed catchment to the north of the pit, as well as any overflows from DD1.
- Southern diversion drains (operational in Stages 1 and 2) – two drains on the western side of the ex-pit emplacement and rail loop which will drain the undisturbed catchment to the west of the mining area around the ex-pit waste rock dump and toward the existing drainage diversion, which drains to the receiving waters.
- The rail loop (operational in Stage 2) will be considered diverted runoff, diverting undisturbed catchments around the rail loop. Notwithstanding this, suitable construction erosion and sediment controls (ESCs) will be implemented in accordance with site's Erosion and Sediment Control Plan (ESCP) as part of the rail loop construction and will remain in place until disturbed soils have been suitably stabilised. This will ensure that the potential elevated risk of erosion and downstream sedimentation is minimised until the rail loop earthworks are complete.

DD1 will be constructed in Stage 2 to collect water from an undisturbed catchment (catchment area of approx. 56.8 ha) adjacent to the Jupiter Pit. In addition, DD1 may potentially provide some level of flood protection from undisturbed catchment runoff for the Jupiter Pit during the final year of operations.

Temporary drainage management measures including bunds, drains and re-contouring to the north of the pit progression may be constructed as required to prevent runoff and flood waters from flowing into the Jupiter pit. Note that these drainage management measures will be mined through as the Jupiter pit progresses to the north and may be implemented to delay the requirement for DD1. It is expected that temporary drainage measures will be designed to convey at least a 5% AEP (1 in 20-year ARI) flow event.

It is proposed to construct upstream diversion bunds to divert the upstream clean water catchment around the rail loop to the proposed culverts prior to runoff being affected by mine water/disturbance areas. Rainfall/runoff diverted through the rail loop culverts would be classified as clean water.

The appropriate ESCs will be determined prior to the commencement of construction activities. Management of runoff from these roads will be a combination of drainage control, erosion control and sediment control measures. The design of the measures will be undertaken during detailed design, but will likely include some of the following measures:

- Catch drains;
- Check dams;
- Grass swales;
- Rock lining/protection;
- Sediment traps; and
- Sediment basins

The erosion and sediment control measures proposed for the rail loop would likely be installed on or adjacent to the railway embankment and road. The internal area of the rail loop which will contain the active and newly rehabilitated waste rock dump within Matilda Pit will be managed through surface water management measures as per Section 5.5.

5.5 SURFACE WATER MANAGEMENT

The following areas of the site have been defined as surface water catchments, consistent with the Guideline Model Mining Conditions (DES, 2017) definitions (see Figure 1.2, Figure 1.3 and Figure 1.4):

- the ex-pit waste rock dump – the runoff from this dump is not expected to come into contact with coal or other carbonaceous materials. This runoff may contain high sediment loads but is not expected to contain elevated levels of other water quality parameters (e.g. electrical conductivity, pH, metals, metalloids, non-metals). This runoff will be managed to ensure adequate sediment removal prior to release to receiving waters. Consistent with DES (2017), this runoff is classified as surface water as it will drain to sediment dams installed in accordance with an Erosion and Sediment Control Plan and it will not be mixed with pit water, tailings water, processing plant or workshop water;
- topsoil stockpiles – this runoff has the potential to have a high sediment load but will not come into contact with coal or other carbonaceous material;
- the south-eastern portion of the northern mine infrastructure area (reporting to the sediment trap) - this area includes a warehouse, carpark and site offices. The runoff from this area is therefore expected to be relatively benign and will not come into contact with coal; and
- northern mine access road (reporting to SD3) – this road will link the northern mine infrastructure area with the ROM Pad. This road is not expected to have trucks

carrying ROM coal as the main internal haulage for the site will be undertaken on haul roads between the pit and southern infrastructure area (to transport coal from the pits to the stockpiles).

The above areas all drain to sediment dams (via overland flow and surface water drains) which will be installed in accordance with an Erosion and Sediment Control Plan. The ESCP will adopt the three cornerstones of erosion and sediment control:

- Drainage control – prevention or reduction of soil erosion caused by concentrated flows and appropriate management and separation of the movement of diverted and surface water through the area of concern.
- Erosion control – prevention or minimisation of soil erosion (from dispersive, nondispersive or competent material) caused by rain drop impact and exacerbated overland flow on disturbed surfaces.
- Sediment control – trapping or retention of sediment either moving along the land surface, contained within runoff (i.e. from up-slope erosion) or from windborne particles.

The Project will require a combination of the three control measures to effectively manage sediment and erosion at the site.

5.5.1 Sediment dam locations and sizing

Catchment runoff from both active and newly rehabilitated overburden dumps at the Project will be managed in accordance with an ESCP. The sediment dams have been sized in accordance with the IECA method (IECA, 2008), and have been based on the following design standards and methodology:

- 'Type D' sediment basins with a depth of 3m;
- total sediment basin volume = settling zone + sediment storage volume. The sediment storage volume is the portion of the basin storage volume that progressively fills with sediment until the basin is de-silted. The settling zone is the minimum required free storage capacity that must be restored within 5 days after a runoff event;
- sediment basin settling volume based on 85th percentile 5-day duration rainfall with an adopted volumetric event runoff coefficient for disturbed catchments of 0.45 (Group C soils – loamy clay); and
- solids storage volume = 50% of settling zone volume.

The adopted design standard does not provide 100% containment for runoff from disturbed areas. Hence, it is possible that overflows will occur from sediment dams several times during a wet season if rainfall exceeds the design standard.

A summary of the conceptual sediment dam capacities and surface areas (based on a depth of 3 m) is provided in Table 5.2.

Table 5.2 - Proposed sediment dams

Storage name	Latitude	Longitude	Max. catchment area (ha)	Total volume required (ML)	Dam surface area (ha)	5-day dewatering rate (ML/d)	Sediment dam water source	Receiving waters description
SD1	-22.29316	148.18773	19.5	4.3	0.19	6.6	Ex-pit waste rock dump	Drainage line 2 via the existing drainage diversion
SD2	-22.28714	148.18329	8.3	1.8	0.08	2.8	Ex-pit waste rock dump	
SD3	-22.27815	148.17893	12.7	2.8	0.12	4.3	Northern mine access road	Drainage line 1
SD4	-22.29451	148.18781	5.0	1.1	0.05	1.7	Topsoil stockpile south of the ex-pit waste rock dump	Drainage line 2 via the existing diversion drain
SD5	-22.29490	148.19300	8.5	1.9	0.08	2.9	Jupiter Pit, in-pit waste rock dump	Drainage line 2
SD6	-22.28710	148.18810	24.6	5.4	0.24	8.3	Jupiter Pit, in-pit waste rock dump	Drainage line 2 via the existing diversion drain
SD7	-22.29309	148.18911	14.9	3.3	0.14	5.0	Jupiter Pit, in-pit waste rock dump and topsoil stockpile	
SD8	-22.29542	148.18936	8.8	1.9	0.09	3.0	Jupiter Pit, in-pit waste rock dump and topsoil stockpile	
SD9	-22.28652	148.19337	3.5	0.8	0.03	1.2	Jupiter Pit, in-pit waste rock dump	Drainage line 1
SD10	-22.27970	148.1881	31.3	6.9	0.31	10.6	Jupiter Pit, in-pit waste rock dump	
SD11	-22.27810	148.18280	52.7	11.6	0.51	17.8	Jupiter Pit, in-pit waste rock dump, topsoil stockpiles and mine access road	Drainage line 1 via the final landform drain
SD12	-22.27728	148.18213	5.7	1.3	0.06	1.9	Jupiter Pit, in-pit waste rock dump	
SD13	-22.28590	148.17730	8.9	2.0	0.09	3.0	Matilda Pit, in-pit waste rock dump and mine access road	Drainage line 2 via the existing diversion drain
SD14	-22.28040	148.17740	7.0	1.5	0.07	2.4	Matilda Pit, in-pit waste rock dump and mine access road	Drainage line 2 via the existing diversion drain
SD15	-22.28430	148.17980	10.7	2.3	0.10	3.6	Matilda Pit, in-pit waste rock dump and mine access road	Drainage line 2 via the existing diversion drain
SD16	-22.28600	148.18001	6.9	1.5	0.07	2.3	Matilda Pit, in-pit waste rock dump	Drainage line 2 via the existing diversion drain

5.5.2 Haul road and access road sediment management

Runoff from haul roads and access roads will be managed through the site's Erosion and Sediment Control (ESC) Plan, which will be developed prior to the commencement of construction activities. The sizing of haul/access road sediment basins will be undertaken in accordance with the Best Practice Erosion and Sediment Control Guidelines (IECA,

2008). Any runoff captured within the sediment basins will be released to the downstream environment in accordance with the site ESCP or pumped back into the mine water system.

Management of runoff from these roads will be a combination of drainage control, erosion control and sediment control measures. The design of the measures will be undertaken during detailed design, but will likely include some of the following measures:

- Catch drains;
- Check dams;
- Grass swales;
- Rock lining/protection;
- Road surface gravelling;
- Sediment traps; and
- Sediment basins.

5.6 MINE AFFECTED WATER MANAGEMENT

5.6.1 Mine affected water dams

Table 5.3 shows the mine affected dam details for the Project, including the full supply volume (FSV) of each dam and the operating rules for each dam which are applied if the operating volume (OV) is exceeded.

The following areas of the site have been defined as mine water catchments, consistent with the definitions provided in the Guideline Model Mining Conditions (DES, 2017) (see Figure 1.2, Figure 1.3 and Figure 1.4):

- the Jupiter Pit and Matilda Pit (active in Stage 2);
- the southern mine infrastructure area – this area contains a number of coal stockpiles and the sorter/crusher and therefore will come into contact with coal;
- the TLO pad (operational in Stage 2) will contain the TLO dam and be considered mine affected water;
- the north-western section of the northern mine area (reporting to MWD3) – this area will contain a maintenance workshop, tyre fitting bay and wash bay;
- the proposed CHPP product pad area (reporting to MWD4);
- the proposed CHPP area (reporting to MWD5); and
- the proposed ROM pad area (reporting to MWD6).

The above areas all drain to mine water dams (via overland flow and mine water drains) or to the pit itself. The dams sizes have been determined based on the water balance model (see Section 7) to ensure that the Jupiter and Matilda pits can be adequately dewatered and limit the spill risk to the receiving waters.

The TLO dam is intended to be a mine-affected water dam, and will collect runoff from the train load out pad, direct rainfall and mine-affected water from the train loadout process. There is no external catchment runoff draining to the to the TLO dam. The TLO dam will only receive water as required for train loadout purposes.

The adopted full storage volumes (FSVs), surface areas and operating volumes (OVs) were refined using the water balance model and available space from site mapping. MWD1 has been designed to keep the Jupiter and Matilda pits dewatered for as long as practical. The remaining mine water dams have been sized to limit the risk of spills to the receiving waters.

To limit the risk of uncontrolled discharges from the mine water storages, OVs have been set for these water storages (as shown in Table 5.3) as follows:

- MWD1 has an operating volume (OV) of 73 ML. When the water inventory in MWD1 exceeds its OV, all transfers to MWD1 (i.e. pit dewatering and mine water transfers) cease; and
- MWD2, MWD3, MWD4, MWD5 and MWD6 have OVs. When the water inventory in these dams exceeds their respective OVs, these storages commence dewatering to MWD1.

Table 5.3 - Proposed mine affected water dams

Storage	FSV (ML)	OV (ML)	FSV surface area (ha)	FSV water depth (m)	Adopted dewatering rate (ML/d)	Operating rules
MWD1	107.4	73.0	2.42	9.0	1.0	Above the OV, pit dewatering and MWD3 to MWD6 dewatering to MWD1 ceases. In addition, during Stage 2, MWD1 commences dewatering to MWD2. If near FSV it will pump to the Jupiter Pit.
MWD2	321.2	300.0	6.35	5.0	1.0	Above the OV, pit dewatering to MWD2 ceases. If near FSV it will pump to the Jupiter Pit.
MWD3	5.4	1.1	0.23	5.0	1.0	Above the OV, MWD3 commences dewatering to MWD1
MWD4	22.0	16.4	0.59	5.0	4.4	Above the OV, MWD4 commences dewatering to MWD1
MWD5	52.0	38.9	1.39	5.0	10.4	Above the OV, MWD5 commences dewatering to MWD1
MWD6	34.7	25.9	0.93	5.0	7.0	Above the OV, MWD6 commences dewatering to MWD1

5.6.2 Preliminary consequence assessment

A preliminary consequence assessment of the mine affected water dams using the *Manual for assessing consequence categories and hydraulic performance of structures* (DES, 2016) suggests that the consequence category of mine water dams will be low. This is based on the following:

- The expected harm to humans consequence category is low. The expected population at risk is zero given that most of the mine affected water dams are constructed downstream of any mine infrastructure areas and in the event of failure, would spill to the pit via constructed drains. The proposed MWD locations are not adjacent to any planned buildings (except for MWD3 which is small), other places of occupation or public infrastructure (e.g., roads or rail) that would lie within the failure impact zone. The downstream receiving waters are unlikely to be used for water supply;
- The expected harm to general environment consequence category is low. The downstream receiving waters are heavily modified and have been diverted through the Peak Downs operations. Controlled releases of mine water are not proposed. Further, groundwater assessments predict there will negligible groundwater to manage in the mine water management system. The CHPP mine water runoff will be managed by MWD4, MWD5 and MWD6. Dump runoff quality is expected to be of a suitable quality to release to the receiving waters (following sediment removal). Hence any potential releases of contaminants to the receiving waters from mine water dams are unlikely to have an adverse effect; and

- The expected general economic loss or property damage consequence category is low. This is for similar reasons given for the expected harm to humans consequence category and remedial costs would likely be less than $1 million.

5.6.3 Pit dewatering rates

The timeframes required to dewater the Jupiter and Matilda pits will be governed by the available pumping capacity. For this assessment, a pit dewatering rate of 100 L/s to MWD1 and MWD2 has been adopted. Alternative pumping capacities based upon the required duration to dewater the pit following a 1% AEP 24 hour storm event (assuming a volumetric rainfall/runoff coefficient of 1.0) are outlined in Table 5.4.

Table 5.4 - 1% AEP 24 hour pit dewatering rates

Stage	Pit dewatering duration (days)	Jupiter Pit dewatering (L/s)	Matilda Pit dewatering (L/s)
1	5	73	-
	10	37	-
	30	12	-
2	5	190	37
	10	95	19
	30	32	6

The alternative dewatering pump rates shown above may be adopted by site depending upon available pumping infrastructure.

5.7 RELEASE OF WATERS TO THE RECEIVING ENVIRONMENT

There are four key mechanisms through which water from the Project can enter the receiving environment:

- dewatering and overflows from sediment dams;
- overflows from mine affected water dams and the open cut pit;
- runoff from diverted water catchments; and
- runoff from rehabilitated catchments.

Sediment dam/mine affected overflows are a point source. Model predictions of volumes from sediment dam and mine affected dam overflows are provided in Section 7.3.6. Runoff from rehabilitated catchments is likely to be both a point and diffuse source of water to the receiving environment. When a sediment dam catchment is completely rehabilitated, and water quality monitoring of the runoff has established that it is consistent with natural background conditions, the sediment dam and associated drainage infrastructure will be decommissioned. Surface runoff and seepage from the rehabilitated catchment will be allowed to shed directly to the receiving environment.

5.8 SEWAGE AND EFFLUENT DISPOSAL

Sewage will be trucked offsite by registered waste transport contractors.

5.9 POST-CLOSURE CONDITIONS WATER MANAGEMENT

Figure 1.4 shows the conceptual final landform water management plan for the Project under Post-closure Conditions. The final landform plan has been developed with an aim to use water infrastructure constructed during operations. The post-closure layout shown in Figure 1.4 is conceptual only and may be updated should the mine plan and final landform plans change over the mine life.

The key features of the final landform include the following:

- No final voids are proposed as part of the final landform. Both open cut pits will be backfilled with overburden material;
- Final landform batter slopes will be 15%;
- Contour banks will be constructed on batters to limit topsoil erosion until vegetation has been suitably established;
- Drainage structures will be constructed to direct runoff from disturbed areas to sediment dams;
- The plateau will be shaped to fall to the west with proposed drains and drop structures to drain the top of the landform to natural ground level;
- Mine water dams will be decommissioned following rehabilitation of infrastructure areas;
- A 10 m corridor between the Jupiter Pit shell crest and the toe of the final landform will be provided for drainage on the eastern side of the final landform;
- The constructed channel between SD6 and DD1 will be a permanent landform feature. A drainage corridor will be constructed through the northern side of the final landform;
- Sediment dams SD9, SD10, SD11 and SD12 will be implemented on the northern side of the Jupiter Pit in-pit waste rock dump, with specifications as outlined in Section 5.5.1;
- The diverted water drain upstream (west) of the rehabilitated landform at the former Matilda Pit will be a permanent landform feature to limit erosion of the landform toe until vegetation has been suitably established; and
- Sediment dams SD13, SD14, SD15 and SD16 will be implemented around the Matilda Pit in-pit waste rock dump, with specifications as outlined in Section 5.5.1.

When a sediment dam catchment is completely rehabilitated, and water quality monitoring of the runoff has established that it is consistent with EA release conditions, the sediment dam and associated drainage infrastructure will be decommissioned. Surface runoff and seepage from the rehabilitated catchment will be allowed to shed directly to the receiving environment.

When the Jupiter Pit drainage corridor is rehabilitated, DD1 will be decommissioned. DD1 will remain until this time to allow in-stream vegetation to establish before receiving upstream catchment flows.

6 Water balance model configuration

6.1 OVERVIEW

A computer-based operational simulation model (OPSIM) was used to assess the dynamics of the mine water balance under conditions of varying rainfall and catchment conditions throughout the development of the Project. The OPSIM model dynamically simulates the operation of the water management system and keeps account of all site water volumes and representative water quality on a daily time step.

The model has been configured to simulate the operations of all major components of the water management system. The simulated inflows and outflows included in the model are given in Table 6.1.

Table 6.1 - Simulated inflows and outflows to the water management system

Inflows	Outflows
Direct rainfall on water surface of storages	Evaporation from water surface of storages
Catchment runoff	Haul road dust suppression demand
Groundwater inflows to the open cut pit	Potable water demand
External water supply	Dam overflows
ROM Coal Moisture	CHPP/Moisture stored within products and rejects coal
	Train loadout (TLO) demand

6.2 SIMULATION METHODOLOGY

The Project water management system will change over the four-year mine life, including changes in catchment areas, production profile and site water demands. To represent the evolution of the mine layout over time, the Project was modelled in two discrete stages. Two representative years of the mine plan have been selected to reflect the average conditions over the mine stage.

The modelled mining stages are summarised in Table 6.2. Approved bulk sampling activities have not been included in the water balance modelling assessment.

Table 6.2 - Application of representative mine stages to full mine life

Mine stage	Representative year	Applied range of mine life	Stage duration
Stage 1	2022	1/1/2021 to 31/12/2022	2 years
Stage 2	2024	1/1/2023 to 31/12/2024	2 years

6.3 CATCHMENT YIELD PARAMETERS

The OPSIM model uses the Australian Water Balance Model (AWBM) (Boughton, 2003) to estimate runoff from rainfall. The AWBM is a saturated overland flow model which allows for variable source areas of surface runoff. The AWBM uses a group of connected conceptual storages (three surface water storages and one ground water storage) to represent a catchment. Water in the conceptual storages is replenished by rainfall and is reduced by evaporation (surface stores only). Simulated surface runoff occurs when the conceptual storages fill and overflow.

The model uses daily rainfalls and estimates of catchment evapotranspiration to calculate values of runoff using a daily water balance of soil moisture. The model has a baseflow component which simulates the recharge and discharge of a shallow subsurface store. Runoff depth calculated by the AWBM is converted into a runoff volume by multiplying the contributing catchment area.

The model parameters define the storage depths (C1, C2 and C3), the proportion of the catchment draining to each of the storages (A1, A2 and A3), and the rate of flux between them (K_{base}, K_{surf} and BFI). Catchments across the site have been characterised into the following land use types:

- Natural, representing areas in their undisturbed state;
- Open cut mining pit;
- In-pit waste rock dump representing uncompacted dumped overburden material within the pit shell;
- Ex-pit waste rock dump, representing dumped overburden material outside of the pit shell; and
- Disturbed/industrial, representing roads, hardstands and stripped areas.

The adopted AWBM parameters are shown in Table 6.3. The natural runoff parameter was calibrated to the Phillips Creek streamflow gauge. The other AWBM parameters have been based on parameters typical for coal mines in this part of the Bowen Basin. The landuse configurations for the mining areas over the two modelled stages are shown in Figure 1.2 and Figure 1.3.

Table 6.3 - Adopted AWBM parameters

Parameter	Natural	Disturbed/Industrial	Pit	In pit waste rock dump/Ex-pit waste rock dump
A1	0.07	0.1	0.134	0.07
A2	0.465	0.9	0.433	0.10
A3	0.465	-	0.433	0.83
C1	12.0	4	2.6	5
C2	100.0	16	26.7	10
C3	300.0	-	53.3	200
C_{avg}	186.8	14.8	35.0	167.4
BFI	0.05	0	0	0.5
k_{base}	0.70	0	0	0.9
k_{surf}	0.35	0	0	0.1
C_{v*}	6.2%	37.6%	28.3%	12.0%

* Long term volumetric runoff coefficient.

6.4 CONCEPTUAL WATER MANAGEMENT SYSTEM CONFIGURATION AND SCHEMATIC

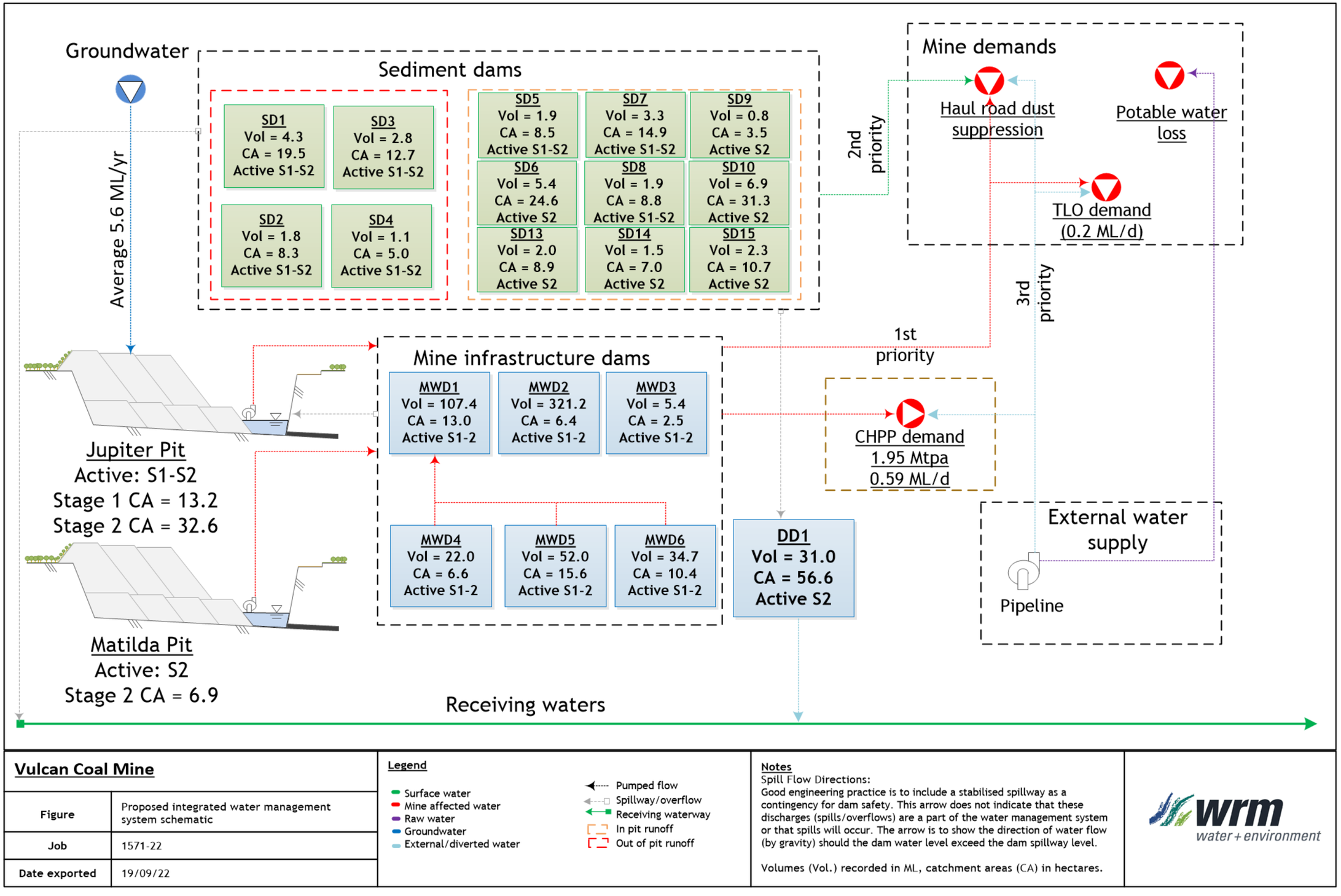
Figure 1.2 and Figure 1.3 show the conceptual Project water management system layout as well as catchment areas and land uses for Stage 1 and Stage 2 respectively. Figure 6.1 shows the schematised plan of the proposed water management system configuration. The modelled water management system configuration is outlined in Table 6.4.

Table 5.2 and Table 5.3 shows the sediment dam and mine water dam sizes respectively that were adopted for the water balance assessment.

Table 6.4 - Water management system operating rules for the Project

Item	Node Name	Operating Rules
1	***External water supply***	
1.1	External water	• Mine affected water can be imported (assumed to be from Peak Downs) to supplement mine water demands; • Supplies haul road dust suppression demands from MWD1 (3rd priority); and • Supplies raw water which is filtered for drinking water purposes and vehicle washdown.
2	***Supply to demands***	
2.1	Haul road dust suppression	• Sourced from the following: - 1st priority: MWD system; - 2nd priority: Sediment dams; and - 3rd priority: External water. • 100% loss assumed; and • Demand values outlined in Section 6.5.1.
2.2	CHPP demands	• CHPP makeup demands are supplied by the MWD system (1st Priority); • Supply from BMA pipeline if MWD system is low (2nd priority); and • Demand values outlined in Section 6.5.2.
2.3	TLO demands	• TLO demands are supplied by the TLO dam/MWD system (1st Priority); • Supply from BMA pipeline if MWD system is low (2nd priority); and • Demand values outlined in Section 6.5.3
2.4	Potable water demand	• Sourced from raw water via the external Bingebang pipeline and filtered at the onsite filtration plant; • 100% loss assumed; and • Assumed constant rate of 50 ML/yr (as outlined in Section 6.5.4).
3	***Pit water***	
3.1	Jupiter pit	• Proposed mining pit active during all stages; • Dewaters to MWD1 or MWD2 at 100 L/s (8.64 ML/d), provided there is available storage in MWD1 or MWD2; and • Receives groundwater inflows as outlined in Section 6.6.1.
3.2	Matilda Pit	• Proposed mining pit active during Stage 2; and • Dewaters to MWD1 or MWD2 at 100 L/s (8.64 ML/d), provided there is available storage in MWD1 or MWD2.

4	***Operation of mine affected dams***	
4.1	MWD1	• Proposed primary mine affected water storage; • Receives pump inflows from the Jupiter pit at 100 L/s (8.64 ML/d) until MWD1 reaches its max operating volume at 140 ML, at which point dewatering ceases. Pumped inflows recommence once the MWD1 inventory drops below its maximum operating volume; • Receives pumped inflows from MWD3, MWD4, MWD5 and MWD6 (refer to Table 5.3); • Transfer water to MWD2 at 11 L/s until MWD2 if the operating volume is exceeded (Stage 2 only).
4.2	MWD2	• Active in Stage 2; • Receives pumped inflows from the Jupiter pit at 100 L/s (8.64 ML/d) until MWD2 reaches its OV, at which point dewatering ceases. Pumped inflows recommence once the inventory drops below its OV; and • Supplies water to haul road dust suppression (1st priority).
4.3	MWD3	• Collect mine affected (potential) water from the mine workshop and laydown area; and • Transfer water to MWD1 at 11 L/s (1 ML/d) if MWD3 exceeds the operating volumes outlined in Table 5.3.
4.4	MWD4, MWD5 and MWD6	• Mine affected water storages that capture runoff from the product pad/ROM pad/CHPP area; • Supplies water to haul road dust suppression (1st priority); • Transfer water to MWD1 at 5 day pump rate (outlined in Table 5.3) if the operating volumes are exceeded; and • Overflows to the pit.
5	***Operation of sediment dams***	
5.1	Primary sediment dams (SD1, SD2, SD3, SD4, SD5, SD7, SD8, SD9, SD10, SD13, SD14, SD15)	• SD1 & SD2 collect water from the ex-pit waste rock dump; • SD3 and SD4 collect runoff primarily from topsoil stockpiles and mine access roads; • SD5, SD7, SD8, SD9 and SD10 collect runoff primarily from the Jupiter Pit in-pit waste rock dump; • Supplies water to the haul road dust suppression as 2nd priority; and • Overflow to Boomerang Creek via Drainage Line 1/Drainage Line 2/existing drainage diversion. • SD13, SD14 and SD15 collect runoff from in-pit waste rock dump from the Matilda Pit in Stage 2.
5.2	SD6	• Active in Stage 2; • Collects runoff from the Jupiter Pit in-pit waste rock dump; and • Overflows to SD10.
6	***Clean water storages***	
6.1	DD1	• Active in Stage 2; • Diverted water dam used as flood protection for the Jupiter Pit; • Transfers water to the existing drainage diversion at 100 L/s (8.64 ML/d) from empty; and • Overflows to Drainage Line 1 via a diverted water drain which runs around the northern edge of the pit.



Vulcan Coal Mine	
Figure	Proposed integrated water management system schematic
Job	1571-22
Date exported	19/09/22

Legend

- Surface water
- Mine affected water
- Raw water
- Groundwater
- External/diverted water
- Pumped flow
- Spillway/overflow
- Receiving waterway
- In pit runoff
- Out of pit runoff

Notes

Spill Flow Directions:
Good engineering practice is to include a stabilised spillway as a contingency for dam safety. This arrow does not indicate that these discharges (spills/overflows) are a part of the water management system or that spills will occur. The arrow is to show the direction of water flow (by gravity) should the dam water level exceed the dam spillway level.

Volumes (Vol.) recorded in ML, catchment areas (CA) in hectares.

wrm water + environment

Figure 6.1 - Water management system schematic for the Project

Table 6.5 - Water storage catchment areas (Stage 1)

Dam	Landuse area (ha)					Total
	Natural	Disturbed/ Industrial	In-pit waste rock dump	Ex-pit waste rock dump	Pit	
SD1	0.0	0.0	0.0	19.5	0.0	19.5
SD2	0.0	0.0	0.0	8.3	0.0	8.3
SD3	0.0	9.3	0.0	0.0	0.0	9.3
SD4	0.0	5.0	0.0	0.0	0.0	5.0
SD5	0.0	2.2	6.3	0.0	0.0	8.5
SD6	0.0	0.0	0.0	0.0	0.0	0.0
SD7	0.0	5.0	8.8	0.0	0.0	13.8
SD8	0.0	1.7	7.0	0.0	0.0	8.8
DD1	N/A	N/A	N/A	N/A	N/A	0
MWD1	0.0	13.0	0.0	0.0	0.0	13.0
MWD2	0.0	6.4	0.0	0.0	0.0	6.4
MWD3	0.0	2.5	0.0	0.0	0.0	2.5
MWD4	0.0	6.6	0.0	0.0	0.0	6.6
MWD5	0.0	15.6	0.0	0.0	0.0	15.6
MWD6	0.0	10.4	0.0	0.0	0.0	10.4
Jupiter Pit	0.0	2.7	0.0	0.0	10.5	13.2

Table 6.6 - Water storage catchment areas (Stage 2)

Dam	Landuse area (ha)					Total
	Natural	Disturbed/ Industrial	In-pit waste rock dump	Ex-pit waste rock dump	Pit	
SD1	0.0	0.0	0.0	19.5	0.0	19.5
SD2	0.0	0.0	0.0	8.3	0.0	8.3
SD3	0.0	12.7	0.0	0.0	0.0	12.7
SD4	0.0	5.0	0.0	0.0	0.0	5.0
SD5	0.0	1.2	4.3	0.0	0.0	5.5
SD6	0.0	1.3	23.3	0.0	0.0	24.6
SD7	0.0	4.5	10.4	0.0	0.0	14.9
SD8	0.0	2.0	3.7	0.0	0.0	5.7
SD9	0.0	0.5	3.1	0.0	0.0	3.5
SD10	0.0	1.1	30.2	0.0	0.0	31.3
SD13	0.0	0.9	8.0	0.0	0.0	8.9
SD14	0.0	0.9	6.1	0.0	0.0	7.0
SD15	0.0	1.0	9.7	0.0	0.0	10.7
DD1	48.5	8.13	0	0.0	0.0	56.6
MWD1	0.0	13.0	0.0	0.0	0.0	13.0
MWD2	0.0	6.4	0.0	0.0	0.0	6.4
MWD3	0.0	2.5	0.0	0.0	0.0	2.5
MWD4	0.0	6.6	0.0	0.0	0.0	6.6
MWD5	0.0	15.6	0.0	0.0	0.0	15.6
MWD6	0.0	10.4	0.0	0.0	0.0	10.4
Jupiter Pit	0.0	4.9	12.4	0.0	15.3	32.6
Matilda Pit	0.0	1.8	0.0	0.0	5.1	6.9

6.5 SITE WATER DEMANDS

6.5.1 Haul road dust suppression

Water for haul road dust suppression is primarily sourced from the mine dams (with the priorities outlined in Table 6.4). Haul road designs were provided by Vitrinite.

Haul road dust suppression demands are estimated using supplied haul road design plans and historical climate data as follows:

- Daily pan evaporation and rainfall rates are sourced from the SILO database;
- For a dry day (zero rainfall), the haul road watering rate is equal to the daily evaporation rate;
- For a rainy day when rainfall is less than the daily evaporation rate, the watering rate is reduced and is only required to make up the remaining depth to the daily evaporation rate; and
- For a rainy day when rainfall exceeds the daily evaporation rate, no haul road watering is required.

Assuming a haul road width of 30 m, an in-pit haul road length of 3 km and 1 km of haulage above surface (i.e. a total haul road length of 4 km), the estimated demand rates averaged over each month are summarised in Table 6.7. These rates were adopted for Stages 1 and 2.

Table 6.7 - Forecast Haul Road Dust Suppression usage

Month	Haul road demand (kL/d)
January	691.2
February	608.1
March	636.7
April	548.9
May	417.9
June	340.5
July	376.0
August	486.5
September	667.6
October	775.4
November	789.5
December	761.3
Annual	591.6

6.5.2 CHPP demand

The projected annual coal production schedule for the Project (provided by Vitrinite), incorporating the Matilda pit operations, is summarised in Table 6.8. The amount of washed coal for each stage was derived from the average value over the stage period. In addition, Vitrinite indicated that all coking coal would be processed and an initial estimate of 20% of thermal coal would bypass the CHPP. The assumed volumes of washed coal and bypass coal per stage are also provided in Table 6.8.

Table 6.8 - Forecast annual production data

Stage	Year	Total ROM coal (tpa)	Total anticipated product coal (tpa)
	2021*	-	-
1	**2022**	1,950,000	1,170,000
	2023	1,950,000	1,170,000
2	**2024**	1,865,000	1,118,000

* Note that CHPP is online in Stage 2 and ROM coal is processed offsite in Stage 1.

Key parameters regarding the CHPP process (provided by DRA Global and also derived from coal physicals) are outlined in Table 6.9.

Table 6.9 – Key CHPP parameters

Parameter	Value
ROM coal moisture	5%
Product coal moisture	9.4%
Coarse reject moisture	14.8%
Tailings moisture	25.4%
Plant efficiency (ROM:Product)	56.5%
Feed rejects (ROM:Coarse reject)	21.5%
Plant tailings (ROM:Tailings)	22.0%

The key CHPP parameters (Table 6.9) and stage washed coal values (Table 6.8) were input to the model to produce water makeup requirements over the mine life. The makeup requirements are supplied by the dams as outlined in Table 6.4.

The average CHPP water makeup requirement for Stage 2 is provided in Table 6.10.

Table 6.10 – Estimated CHPP makeup requirements

Stage	CHPP makeup requirement (ML/d)
1	-
2	0.59

6.5.3 TLO demand

Water for the TLO demand is sourced from the mine dams (with the priorities outlined in Table 6.4). A nominal TLO demand of 0.2 ML/d (200 kL/d) was assumed.

6.5.4 Potable water demand

Raw external water is supplied to the site via the Bingebang pipeline and is filtered at the onsite filtration plant for drinking water purposes and for vehicle washdown via the onsite washdown plant. Potable water demand was assumed at 50 ML/annum (137 kL/d).

6.6 WATER SOURCES

6.6.1 Groundwater

Groundwater inflow estimates to the Jupiter open cut pit were provided by Hydrogeologist.com.au and have been provided as a daily rate for six-monthly periods over the mine life. A summary of the predicted groundwater inflows provided by Hydrogeologist.com.au are provided in Table 6.11. Also shown in Table 6.11 is the assumed modelled groundwater inflow for each stage of operations. The estimated groundwater inflow rates are small and will likley have a negligible impact on the Mine water balance. Notwithstanding this, groundwater inflows have been included in the water balance model for completeness. Groundwater estimates to the Matilda open cut pit are estimated to be up to 3 m^3/day in the first year of mining (2023) and reducing after this period. The predicted inflow is equivalent to a maximum cumulative groundwater inflow of 1.1 ML/a to the Matilda Pit and Section 7 of this report shows that these inflows will have a negligible impact on the Mine water balance.

Table 6.11 - Estimated groundwater inflows

Stage	Period start/end	Groundwater inflow (m^3/day)	Modelled groundwater inflow per stage (m^3/day)
1	1/01/2021	0	4.31
	1/07/2021	10.41	
	1/01/2022	5.91	
	1/07/2022	0.91	
2	1/01/2023	8.9	26.22
	1/07/2023	34.75	
	1/01/2024	39.79	
	1/07/2024	21.42	

6.6.2 External water

A key objective of the mine site water management system is to reuse surface water runoff captured within the mine affected water system. Recycling mine water will minimise the volume of water from external sources that is required to satisfy site demands. However, the volume of water captured on site is highly variable and dependent upon climatic conditions. Hence, under dry conditions there is a requirement to source water from external sources.

For the purposes of the assessment, it has been assumed that Vitrinite will source external mine water (likely from BMA's Peak Downs operation) to provide water as required via a pipeline for the life of the Project. Vitrinite are currently investigating other possible sources of water for the Project. The assessment of other sources of water, if utilised, will be undertaken if required.

The pipeline will transfer mine affected water to be stored in MWD1 when mine affected water inventories are low.

6.7 WATERCOURSE FLOW MODELLING

As outlined in Section 4.4 and 4.5, Boomerang Creek streamflow and water quality data was not available for this assessment.

Flows in the surrounding natural watercourses have therefore been simulated using the calibrated AWBM parameter set previously derived for Philips Creek (WRM, 2012) (as shown in Table 6.12). Phillips Creek is a tributary of the Isaac River and is located approximately 25 km south of the Project area. Phillips Creek drains primarily undisturbed land to the west of the Norwich Park Branch Railway through Saraji Mine to the Isaac River. Phillips Creek drains into the Isaac River approximately 4 km downstream of Boomerang Creek. The undisturbed catchment which drains to Phillips Creek is similar in nature to the undisturbed catchment to the west of the Project which drains to Boomerang Creek.

The catchment area of Boomerang Creek directly downstream of the Project (i.e. approximately where Drainage Line 1 meets Drainage Line 2) is approximately 4,300 ha. This catchment area has been adopted for assessing the potential mixing within the downstream receiving waters.

Table 6.12 - Phillips Creek AWBM parameters

Parameter	Phillips Creek Value
A1	0.013
A2	0.444
A3	0.543
BFI	0.21
C1	15.0
C2	100.0
C3	651.0
C_{av}	398.1
Kbase	0.914
Ksurf	0.502
Average annual runoff co-efficient (C_v)	4.5%

6.8 WATER QUALITY MODELLING

RGS Environmental have undertaken an assessment of the overburden and potential coal reject materials at the Vulcan Coal Mine. RGS (2022) presented initial results from the Jupiter Pit area. A series of geochemical tests were completed on samples from the Jupiter Pit to assess the risk of potential oxidation of sulphides, acid and metalliferous drainage, potential presence and potential leaching of soluble metals/metalloids and other salinity/erosion issues. RGS (2022) made the following findings regarding the geochemical characterisation of the potential overburden and potential coal rejects material:

- all samples tested had a high factor of safety and negligible risk of generating acid mine drainage;
- assay of the multi-element concentration present in selected representative samples indicates that there are no elements (metals/metalloids) enriched in the sample materials compared to median crustal abundance in unmineralised soils;
- the initial static and kinetic test results indicate that surface runoff and seepage from the sample materials are likely to be pH neutral with moderate excess alkalinity, and low levels of salinity;
- the initial geochemistry results are consistent with the larger data set of results obtained from geochemical characterisation of 139 samples from 21 drill holes across the broader Jupiter and Vulcan prospect areas in the VCM; and
- the results represent an 'assumed worst case' scenario as the samples are pulverised (to minus 75 micrometres) prior to testing. Therefore, samples have a very high surface area compared to materials in the field. This process provides a greater potential for dissolution and reaction and represents an assumed initial 'worst case' scenario for geochemical testing of these materials.

In consideration of the RGS (2022) findings from the preliminary geochemical characterisation, salinity is considered the key contaminant for assessment purposes. Assessment of other contaminants has not been undertaken as part of this surface water assessment. If subsequent monitoring data indicates that there are other contaminants of concern, the assessment can be updated to include additional water quality parameters.

6.8.1 Adopted salinity parameters

The water balance model is configured to use salinity as an indicator of water quality using electrical conductivity (EC) values of runoff for each landuse type and other sources of water. Salinity is used as the adopted indicator of water quality as it is typically the key

limiting contaminant of concern for coal mines and is historically of most interest for agricultural and domestic use.

The proposed EC values are shown in Table 6.13. EC values have been sourced from previous water balance models for mines in similar areas of the Bowen Basin.

Table 6.13 - Adopted salinity concentrations

Water source/land use	EC (µS/cm)	Comment
Natural/ undisturbed	300	Value adopted for Olive Downs SWA and Lake Vermont Northern Extension SWA.
Disturbed	500	Runoff value typical for cleared/stripped areas.
Mining pit	4,500	Value adopted for Lake Vermont Northern Extension SWA.
In pit waste rock dump/ex-pit waste rock dump	350	Value adopted for Olive Downs SWA.
External water (pipelines from BMA Peak Downs)	10,000	Salinity of mine water unknown, conservatively high value adopted.
Industrial area	900	Salinity of ROM coal unknown, conservatively high value adopted.
Groundwater	9,520	Average groundwater salinity reading from historical groundwater monitoring undertaken at site (Hydrogeologist.com.au, 2020).

7 Water management system assessment

7.1 OVERVIEW

The Project OPSIM model was used to assess the performance of the water management system, using the following key performance indicators:

- overall water balance – the average inflows and outflows of the water management system based on all model realisations (Section 7.3.1);
- mine water inventory – the risk of accumulation (or reduction) of the overall mine water inventory (Section 7.3.2);
- in-pit storage – the risk of accumulation of water in the mining pits, and the associated water volumes (Section 7.3.3);
- external water demand – the volumes of imported external water required to supplement site mine water supplies (Section 7.3.4);
- uncontrolled spillway discharges – the risk and associated volumes of uncontrolled discharge from the mine affected water storages and sediment dams to the receiving environment (Section 7.3.6);
- overall salt balance – the average salt loads in and out of the water management system based on all model realisations (Section 7.3.7);
- potential receiving water impacts - predicted water quality in the receiving environment during predicted 'worst case' release scenarios (Section 7.3.8 and 7.3.9); and
- sensitivity analysis - varying the assumed haul road dust suppression over the mine life and the potential impacts of climate change (Section 7.4).

The use of a large number of climate sequences reflecting the full range of historical climatic conditions provides an indication of the system performance under very wet, very dry and average climatic conditions. It is important to note that the results of the water balance modelling are dependent on the accuracy of input assumptions. There is inherent uncertainty with respect to some key site characteristics (e.g. catchment yield/runoff, groundwater inflows etc.).

7.2 INTERPRETATION OF MODEL RESULTS

In interpreting the results of the water balance assessment, it should be noted that the results provide a statistical analysis of the water management system's performance over the 4 years of mine life, based on 125 stochastically generated climatic rainfall sequences and historical average monthly evaporation. The model results are presented as a probability of exceedance. For example, the 10%ile represents 10% probability of exceedance and the 90%ile represents 90% probability of exceedance. There is an 80% chance that the result will lie between the 10%ile and 90%ile traces.

Whether a percentile trace corresponds to wet or dry conditions depends upon the parameter being considered. For site water storage, where the risk is that available storage capacity will be exceeded, the lower percentiles correspond to wet conditions. For example, there is only a small chance that the 1%ile storage volume will be exceeded, which would correspond to very wet climatic conditions. For off-site site water supply volumes (for example), where the risk is that insufficient water will be available, there is only a small chance that more than the 1%ile water supply volume would be required. This would correspond to very dry climatic conditions.

It is important to note that a percentile trace shows the likelihood of a particular value on each day and does not represent continuous results from a single model realisation. For example, the 50%ile trace does not represent the model time series for median climatic conditions.

7.3 WATER BALANCE MODEL RESULTS

7.3.1 Overall water balance

Water balance results for all of the 125 model realisations are presented in Table 7.1.The results presented in Table 7.1 are the average of all realisations and will include wet and dry periods distributed throughout the mine life. Rainfall yield and evaporation for each stage is affected by the variation in climatic conditions within the adopted climate sequence.

Table 7.1 provides an indication of the long-term average annual inflows and outflows. Key outcomes from the overall water balance are as follows:

- Average annual inflows from rainfall runoff for mine affected and surface water dams increase from Stage 1 to Stage 2, as the pit progresses, and more catchment runoff is collected in mine affected water dams and sediment dams.
- The proposed water management system is in negative balance under 'average' climate conditions. This indicates that the Project will require significant volumes of external water to meet mine water demands.
- External water requirements are greater in Stage 2 when compared to Stage 1 due to the demand required for the CHPP.

It should be recognised that the following items are subject to climatic variability:

- Rainfall runoff;
- Evaporation;
- External water requirement;
- Dust suppression demand; and
- Dam overflows.

Whilst it provides an indication of the long-term average annual inflows and outflows, application of the nominated values for other purposes should only be undertaken with due consideration of the suitability of the nominated value and any potential implications.

In particular, the "average" sediment dam overflows do not necessarily mean that discharges occur under median climatic conditions. It means that there was a discharge in at least one of the 125 model realisations. A more detailed analysis of the performance of the various components of the water management system is provided in the following sections.

Table 7.1 - Average annual water balance - all realisations

Description	Stage 1	Stage 2
Inflows (ML/year)		
Rainfall Runoff		
Mine affected water	146.1	164.8
Surface water	82.0	148.4
Diverted water	0.0	27.7
Groundwater inflow	1.6	9.6
ROM coal moisture	0.0	97.5
External water	192.7	334.5
Total Inflows	422.4	782.4
Outflows (ML/year)		
Evaporation	28.2	33.6
Dam overflows		
Mine affected water	0.0	0.0
Surface water	45.7	75.4
Diverted water	0.0	16.0
CHPP		
Product moisture	0.0	108.6
Coarse rejects moisture	0.0	69.2
Fine rejects moisture	0.0	138.8
Haul road dust suppression	216.1	216.1
TLO demand	73.1	73.1
Potable water demand	50.0	50.0
Total Outflows	413.0	780.7
Change in volume (ML/year)		
Change in stored volume	9.4	1.7

7.3.2 Mine affected water inventory

7.3.2.1 MWD1 inventory

Figure 7.1 shows the forecast inventory for MWD1 which is the key out-of-pit mine affected water storage, controlling the dewatering of the pit. Figure 7.2 shows the annual maximum forecast inventory for MWD1 over the mine life.

These results show the 1%ile (wettest climatic conditions), 5%ile, 10%ile, 25%ile and 50%ile traces.

As outlined in Section 5.6.1, to prevent uncontrolled discharges from MWD1 a OV is required. If the OV is exceeded, all transfers to the storage cease (i.e. pit dewatering and mine water dam dewatering). The MWD1 OV, in addition to the FSV are shown in Figure 7.1 and Figure 7.2.

The model results show the following:

- The MWD1 inventory is maintained below the FSV for all climatic conditions assessed and therefore is not predicted to spill under any modelled climate sequence;
- The MWD1 inventory is maintained below its OV for 10%ile and drier conditions in Stage 1 and 5%ile and drier conditions in Stage 2. This means pit and mine dam dewatering is restricted under 5%ile in Stage 1 and 1%ile and wetter conditions in Stage 2;
- Under the 50%ile trace, the MWD1 inventory is maintained below 27 ML for the entire mine life;
- Under very wet (1%ile) conditions, MWD1 has an inventory of up to 105 ML during both Stage 1 and Stage 2; and
- Under wet (10%ile conditions), MWD1 has a maximum inventory of approximately:
    - up to 76 ML during Stage 1; and
    - up to 75 ML during Stage 2.

7.3.2.2 Mine water dam inventories

MWD1, MWD2, MWD3, MWD4, MWD5 and MWD6 are the mine affected water dams on site. MWD1 and MWD2 dewater the pit following rainfall events. The OVs of these dams have been designed to keep the pit as dry as possible while also limiting the requirement to transfer water back to the pit. MWD3 collects runoff from the northern mine workshop area and dewaters to MWD1 when it rises above its OV. MWD4, MWD5 and MWD6 collect runoff from the proposed CHPP/ROM area and dewaters to MWD1 when they accumulate water above their OV.

The mine affected water dams are not predicted to spill under any of the 125 modelled realisations.

Figure 7.3 shows the annual maximum forecast combined inventory for MWD2, MWD3, MWD4, MWD5 and MWD6. The model results show that:

- the combined water inventories remain below the combined FSV under all climatic conditions assessed and therefore are not predicted to spill under any modelled climate sequence;
- under 50%ile and drier conditions, the maximum mine water inventory is maintained below the combined OV for all years; and
- under 10%ile conditions, the maximum mine water inventory is generally below the combined OVs for Stage 1 and Stage 2.

The results indicate that the mine water dams are predicted to store water, to some extent, under the majority of conditions. However, they are not at risk of surpassing their FSVs, even under extremely wet (<1%ile) conditions, due to the proposed dewatering of dams to MWD1 and MWD2 and reuse of water for operational requirements.

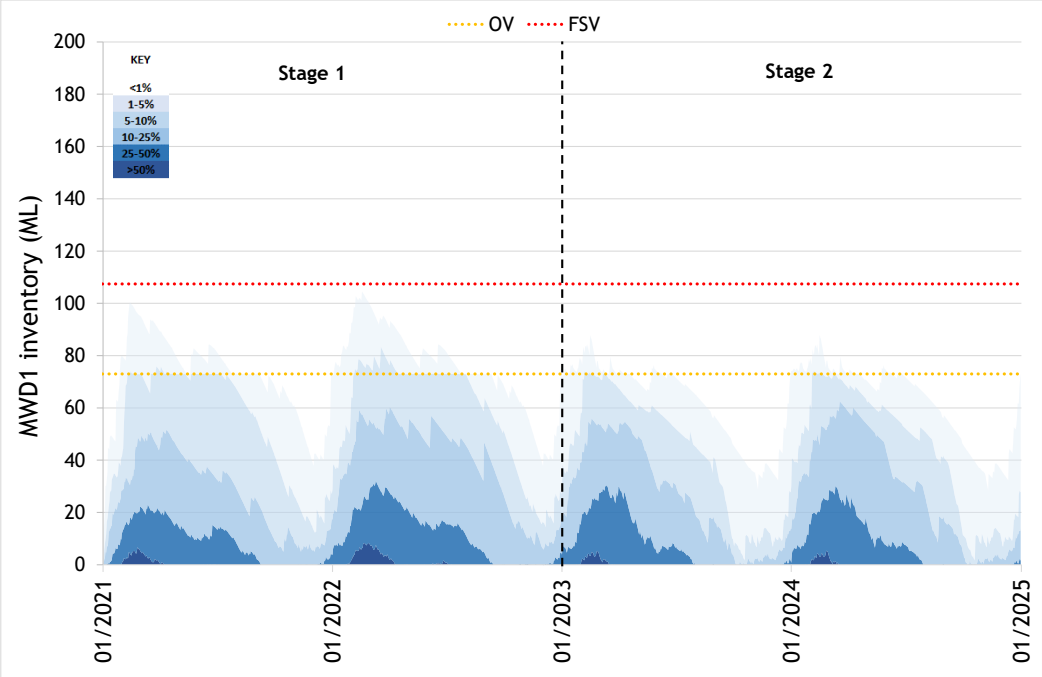


Figure 7.1 - Forecast MWD1 inventory

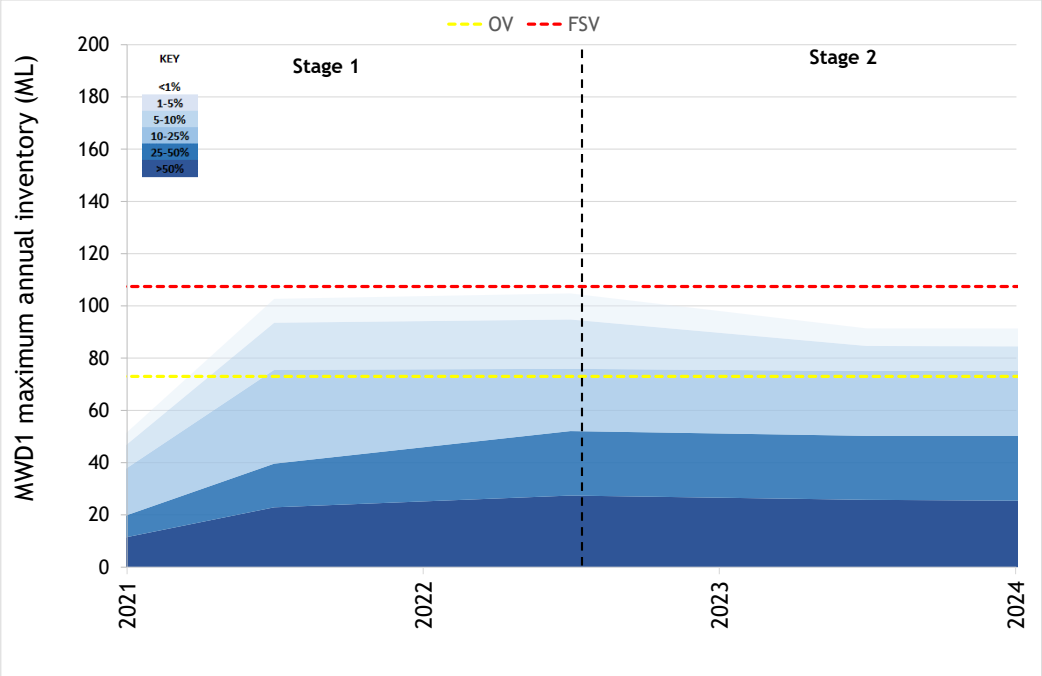


Figure 7.2 - Forecast annual maximum MWD1 inventory

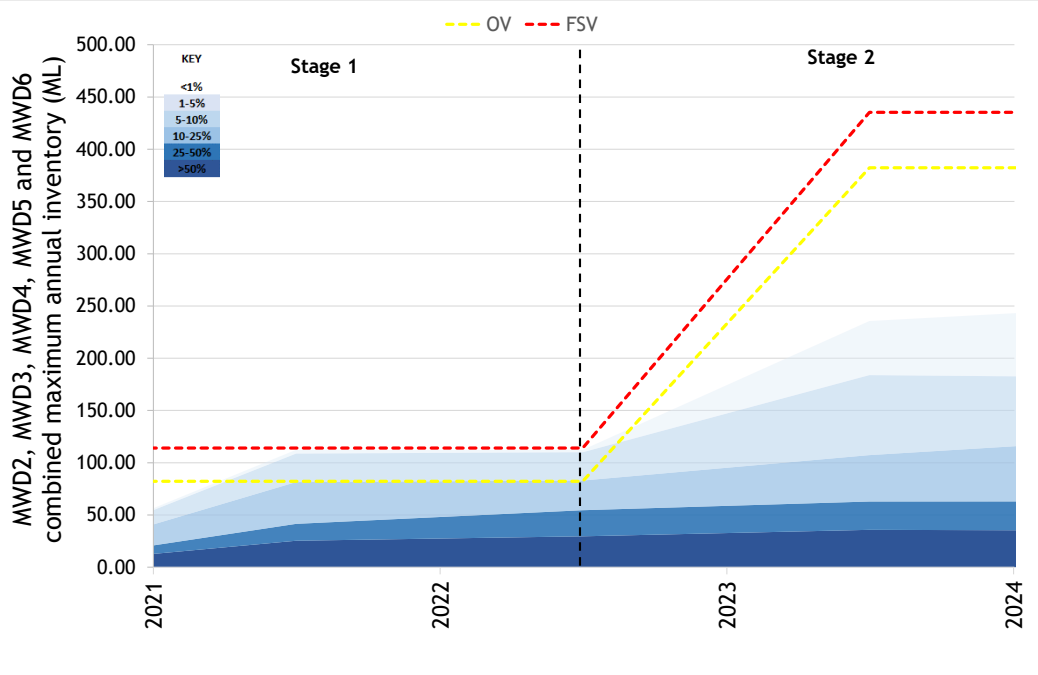


Figure 7.3 – Forecast annual combined maximum water inventory in MWD2, MWD3, MWD4, MWD5 and MWD6

7.3.3 Jupiter pit water inventory

7.3.3.1 In pit storage

Figure 7.4 shows the forecast inventory of the Jupiter pit and Figure 7.5 shows the forecast annual maximum Jupiter pit inventory during the 4-year operational period.

The 1%ile (wettest climatic conditions), 5%ile, 10%ile, 25%ile and 50%ile percentile traces are shown. As outlined in Section 5.6.1, the pit is continuously dewatered into MWD1 and MWD2 in Stage 2, as long as the mine dams are maintained below their OV. MWD1 and MWD2 have been sized to keep the pit dewatered as long as practical given sizing constraints.

The model results show the following:

- Under very wet (1%ile) conditions, the Jupiter pit will have a forecast inventory of approximately:
    - up to 45 ML during Stage 1;
    - up to 7 ML during Stage 2; and
- Under wet (10%ile conditions) and 50%ile conditions, the pit remains empty during Stage 1 and Stage 2.

The results suggest that pit dewatering may be constrained under very wet (between 1%ile and 10%ile) conditions in Stages 1 and 2, accumulating (on average) up to 45 ML. The addition of MWD2 in Stage 2 allows the pit to be dewatered under the majority of climate conditions for Stage 2 and is therefore expected to accumulate water under only the wettest (1%ile – 5%ile) conditions.

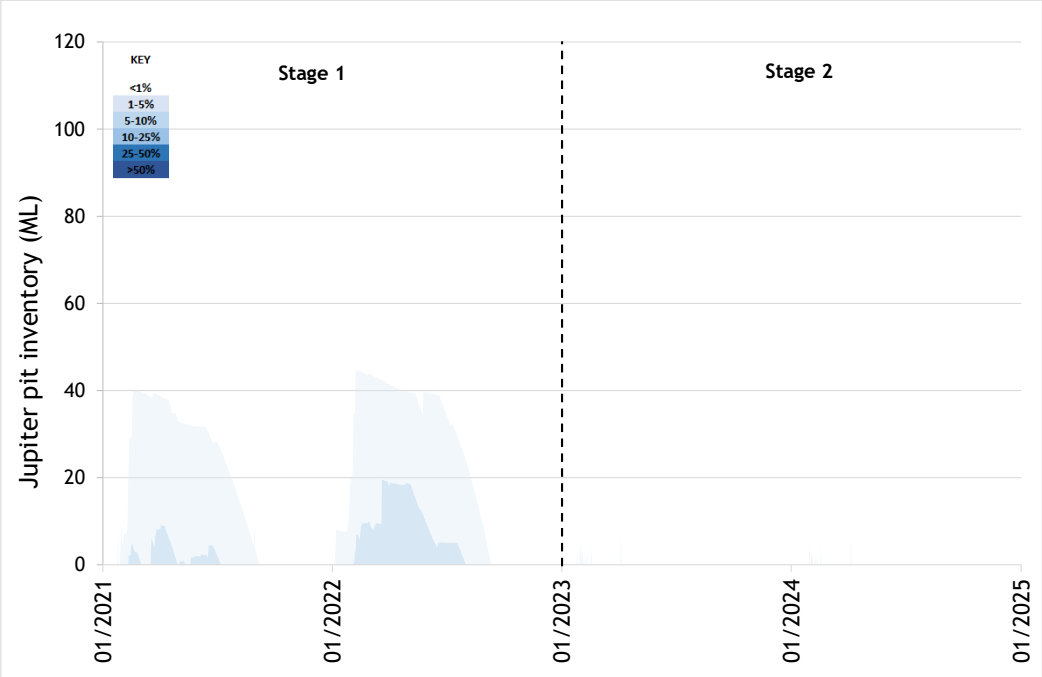


Figure 7.4 - Jupiter forecast mine pit inventory

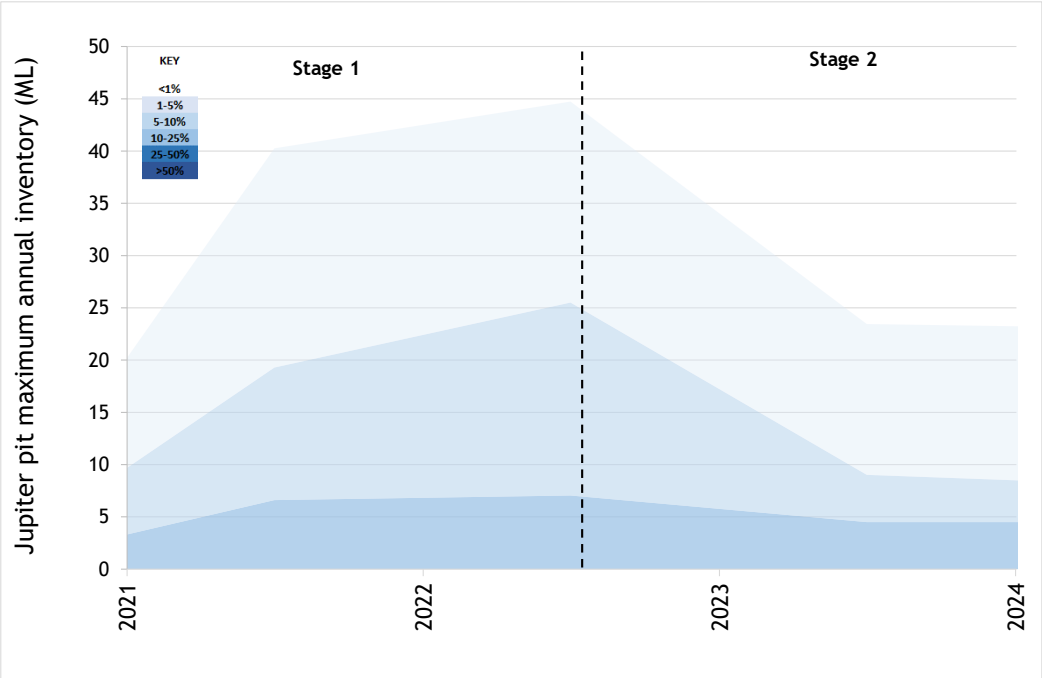


Figure 7.5 - Jupiter forecast annual maximum pit inventory

7.3.4 Matilda Pit

7.3.4.1 In pit storage

The Matilda Pit (operational in Stage 2) will dewater to MWD1 and MWD2 during operations. The results of the forecast water balance model show that the pit can be

dewatered under the majority of climate conditions during Stage 2 and would not accumulate water for long periods within the pit.

7.3.5 External water requirements

Figure 7.6 shows the total annual modelled external water required to meet predicted dust suppression, CHPP and TLO demands. The 1%ile (driest climatic conditions), 5%ile, 10%ile, 25%ile and 50%ile percentile traces are shown.

The modelling results show the following:

- During the driest (1%ile) climatic conditions, the predicted external water requirement is:
    - up to approximately 272 ML/annum during Stage 1; and
    - up to 477 ML/annum during Stage 2.
- During 50%ile conditions, the predicted external water requirements is:
    - up to approximately 161 ML/annum during Stage 1; and
    - up to approximately 302 ML/annum during Stage 2.

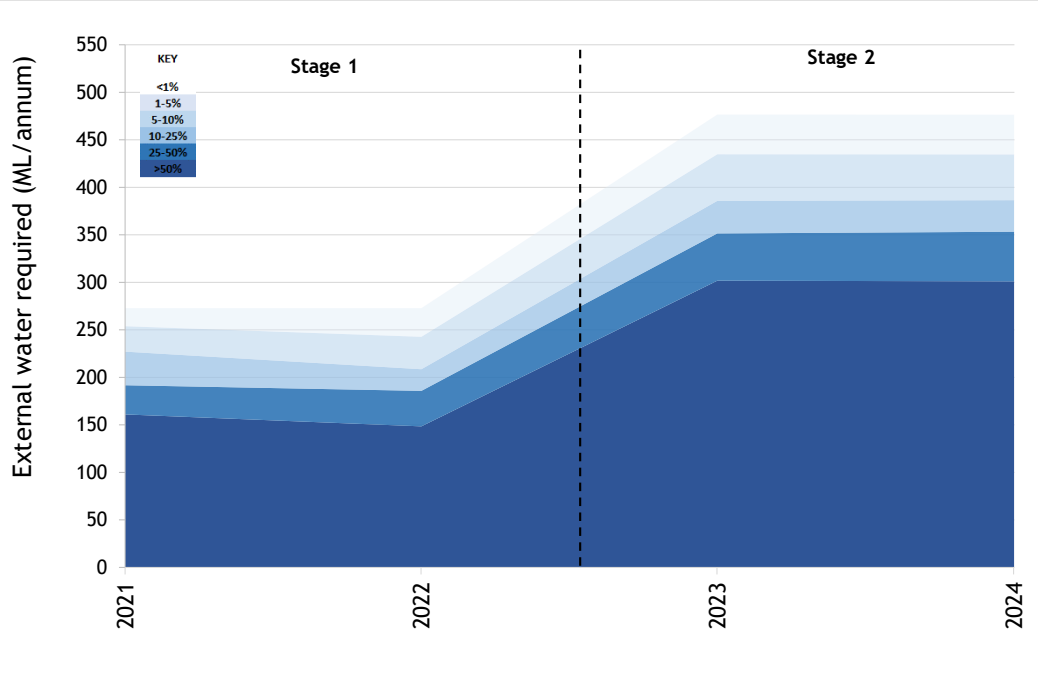


Figure 7.6 – Forecast external water requirement for dust suppression, CHPP and TLO use

7.3.6 Spillway water discharges

7.3.6.1 Mine Affected Water Dams

As outlined in Section 7.3.2, no spills are predicted from any of the mine affected water dams (i.e. MWD1, MWD2, MWD3, MWD4, MWD5 and MWD6) under any of the climate sequences modelled.

7.3.6.2 Sediment Dams

Consistent with the IECA guidelines (2008), sediment dams do not provide 100% containment for captured runoff. Hence releases will occur from sediment dams when rainfall exceeds the design standard.

The potential for releases from the proposed sediment dam has been modelled using a passive overflow rather than active release (to regain storage capacity within 5 days).

Figure 7.7 shows the forecast annual sediment dam releases to the receiving waters which indicates that:

- Under wet (10%ile) conditions, the annual volume of sediment dam releases to the receiving waters are approximately:
    - up to 227 ML/yr during Stage 1; and
    - up to 442 ML/yr during Stage 2.
- Under 50%ile conditions, the annual volume of sediment dam releases to the receiving waters are approximately:
    - up to 25 ML/yr during Stage 1; and
    - up to 29 ML/yr during Stage 2.

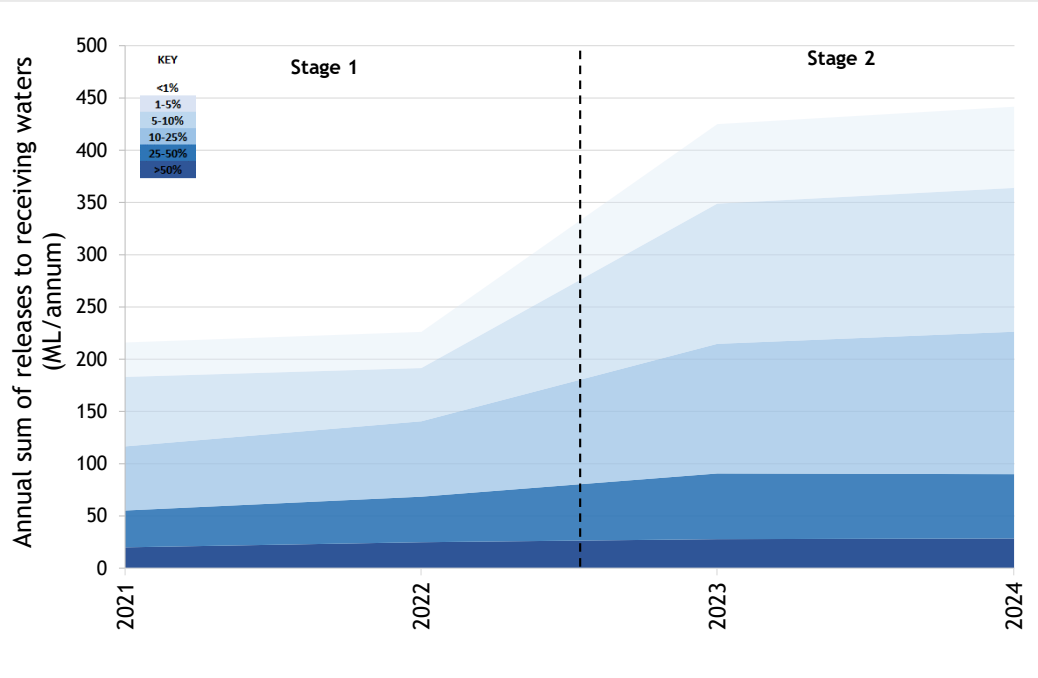


Figure 7.7 - Forecast annual sediment dam releases to the receiving waters

7.3.6.3 DD1

DD1 will be constructed in Stage 2 and will collect water from an undisturbed catchment to the northwest of the Project. All water stored in DD1 will be dewatered to the existing drainage diversion at 100 L/s. If the capacity of DD1 is exceeded, water will spill to Drainage line 1 via the northern diversion drain.

Figure 7.8 shows the annual total pumped flows from DD1 to the existing drainage diversion. The 1%ile (wettest climatic conditions), 5%ile, 10%ile, 25%ile and 50%ile percentile traces are shown.

The model results predict the following:

- Under 10%ile conditions, DD1 dewaters up to approximately 31 ML/year to the existing drainage diversion in Stage 2;
- Under 1%ile conditions (wettest climatic conditions), DD1 dewaters up to approximately 41 ML/year to the existing drainage diversion; and

- DD1 does not spill when receiving runoff from its own catchment however there may be a spill risk during large events when external catchments overflow into DD1.

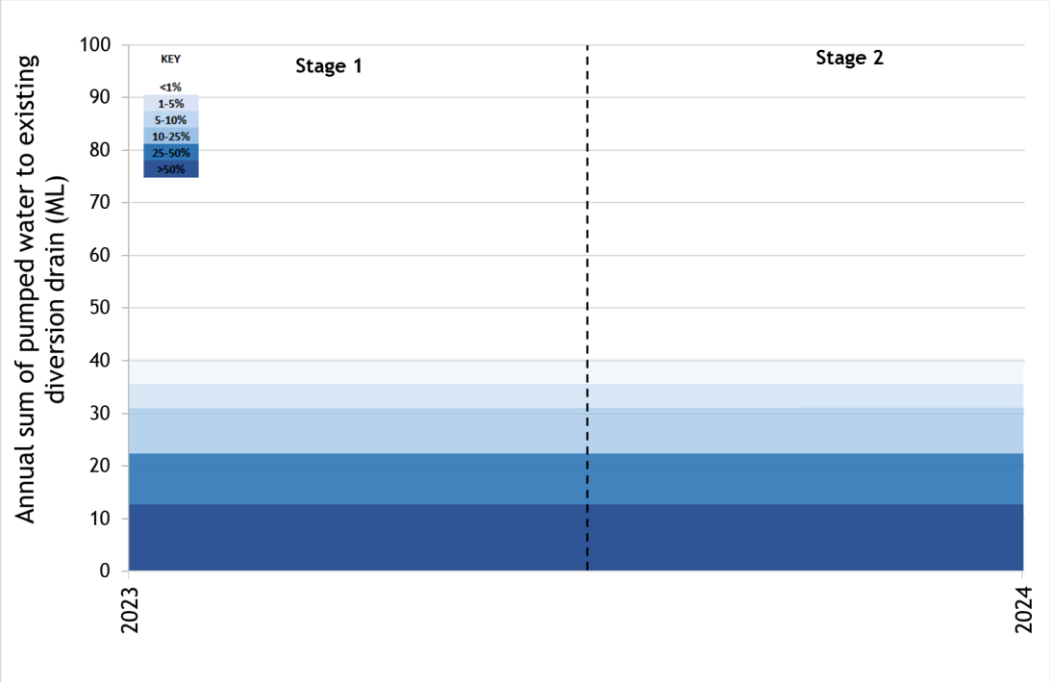


Figure 7.8 – Forecast total annual pumped transfers from DD1 to the existing drainage diversion

7.3.7 Overall salt balance

Table 7.2 shows the average annual salt balance for the Project for each stage.

Salt inputs to the Project include salts in the groundwater inflow, catchment runoff and external water. Salt inputs from direct rainfall was assumed to be zero.

Salt outputs from the Project include site demands and offsite (spillway) discharges from the water management system.

The results indicate the following:

- The largest contributor to the Project salt load is due to external water assuming it is sourced from BMA's operations. This is due to the high assumed salinity of the BMA water (Section 6.8.1);
- The largest outflow in the salt balance from the Project is haul road dust suppression demands; and
- The change in stored salt load is generally low in comparison to the total inputs and outputs, which suggests that salt will not accumulate within the site water management system.

Note that the salt balance is reported in annual tonnes of total dissolved solids (TDS) based on an EC to TDS conversion factor of 0.7.

Table 7.2 - Average annual salt balance (based on TDS)

Description	Stage 1	Stage 2
Inputs (t/year)		
Rainfall Runoff		
Mine affected water	104.9	144.0
Surface water	24.7	42.1
Diverted water	0.0	3.4
Groundwater inflow	10.5	63.8
ROM coal moisture	0.0	682.5
External water	998.8	1,991.3
Total Input	1,138.9	2,927.1
Outputs (t/year)		
Evaporation	0.0	0.0
Dam overflows		
Mine affected water	0.0	0.0
Surface water	14.3	22.3
Diverted water	0.0	3.4
CHPP		
Product moisture	0.0	570.2
Coarse rejects moisture	0.0	484.3
Fine rejects moisture	0.0	728.6
Haul road dust suppression	794.5	741.9
TLO demand	323.9	375.4
Potable water demand	0.0	0.0
Total Output	1,132.7	2,926.0
Change in salt (t/year)		
Change in stored salt	6.2	1.1

7.3.8 Receiving waters water quality

The three potential sources of receiving waters contamination from the water management system are releases from the sediment dams, releases from the mine affected dams and pumped releases from DD1. As outlined in Section 7.3.2, the mine affected dams are not predicted to spill under any of the modelled climate sequences. Releases from DD1 are expected to be of a water quality that is similar to the default WQO trigger values as it primarily collects water from a rural catchment.

Potential impacts to EC in the receiving environment were assessed at a point directly downstream of the Project (where Drainage Line 1 meets Drainage Line 2, approximately 1 km downstream of the Project boundary). The default WQO trigger levels for EC outlined in Section 3 have been used for this assessment.

Figure 7.9 shows the predicted annual maximum EC in the receiving waters over the mine life. Note that most of the time, EC concentrations will be lower due to dilution with natural flows. The 1%ile, 5%ile, 10%ile, 25%ile and 50%ile (median climatic conditions) traces are shown. The results predict that:

- Under 1%ile conditions the maximum EC in the receiving waters is approximately 480 µS/cm in Stage 1 and 435 µS/cm in Stage 2; and
- Under 50%ile conditions the maximum EC in the receiving waters is approximately 398 µS/cm in Stage 1 and 381 µS/cm in Stage 2.

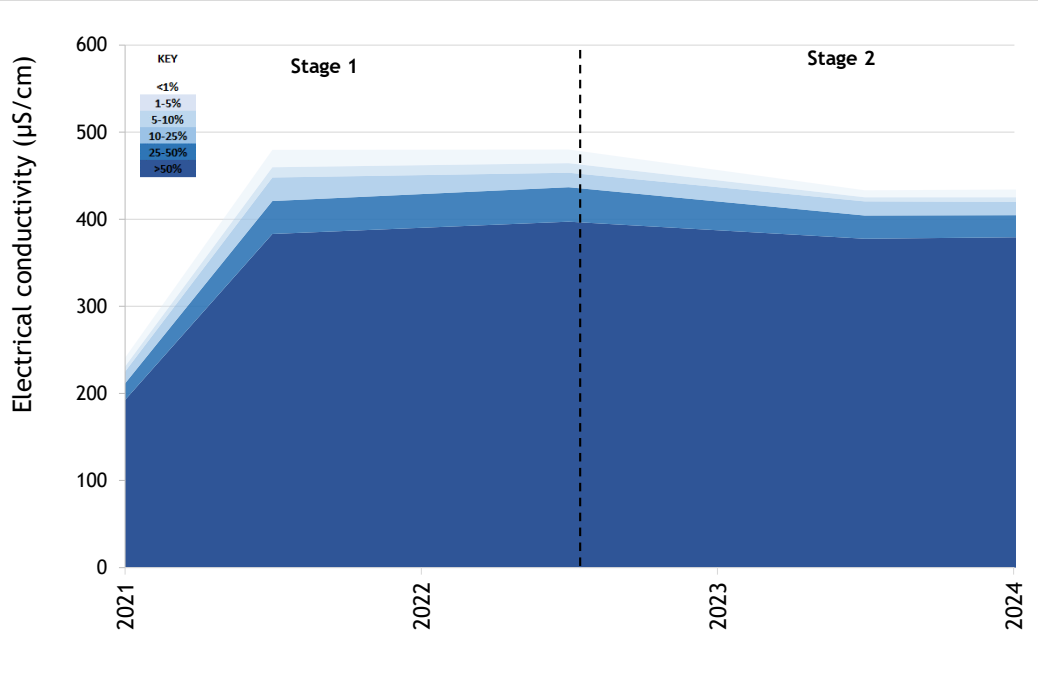


Figure 7.9 - Predicted Boomerang Creek annual maximum EC variation downstream of the Project

7.3.9 Release scenarios

The OPSIM model was used to assess the release (spill or transfer) from sediment dams and DD1. No other dams or storages are predicted to release to the receiving waters. The release scenarios that were investigated include:

- Scenario 1 – The highest EC release from the sediment dams; and
- Scenario 2 – The highest flow rate release from the sediment dams.

The release events were compared to the WQO levels outlined in Section 3.

7.3.9.1 Scenario 1 - Sediment dams highest EC release

The cumulative release with the highest EC from the Project occurs during Stage 2 at approximately 646 µS/cm with a flow rate of approximately 0.54 ML/d. Figure 7.10 and Figure 7.11 show the release rate and EC compared to the rates in the receiving waters. The WQO levels outlined in Section 3 are also shown.

The OPSIM model predicts that during the Scenario 1 release, the release causes a minor increase to EC levels in the receiving waters. This is due to the low flow rate of the release in comparison to the high flows within the receiving waters. The model predicts that during the event both the EC levels of the release, and receiving waters remain above the high flow WQO but below the baseflow WQO. It is noted that for this assessment, the assumed receiving waters EC level (300 µS/cm) is greater than the high flow WQO of 250 µS/cm.

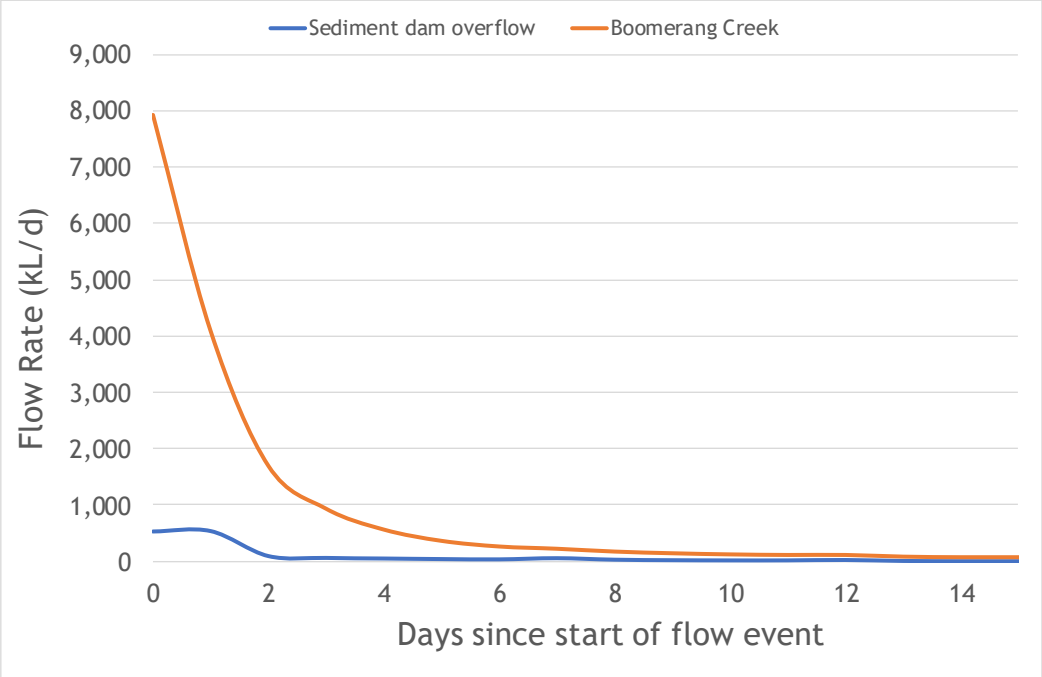


Figure 7.10 - Project release rate compared to flow rate in the receiving waters - Scenario 1

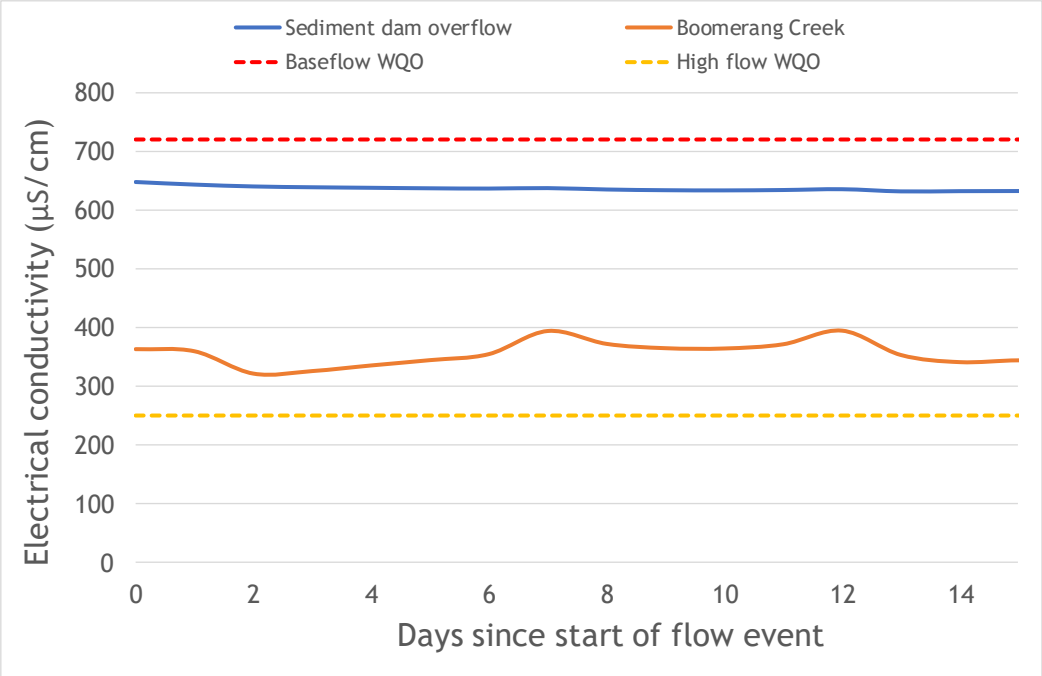


Figure 7.11 - Project release EC levels compared to EC levels in the receiving waters and corresponding water quality criteria - Scenario 1

7.3.9.2 Scenario 2 – Sediment dam highest flow rate

The Scenario 2 highest release rate occurs during Stage 1 with a cumulative release of approximately 39 ML/d. Figure 7.12 and Figure 7.13 shows the Scenario 2 release rate and EC from the cumulative release compared to the flow rate and EC in Boomerang Creek during and following the release event.

The OPSIM model predicts that during the Scenario 2 release, Boomerang Creek will already have a very large flow. The cumulative release has a negligible effect on the Boomerang Creek EC levels due to the already high flows present. The model predicts that during the event both the EC levels of the release, and within Boomerang Creek remain above the high flow WQO but below the baseflow WQO. It is noted that for this assessment, the assumed Boomerang Creek EC is greater than the high flow WQO of 250 µS/cm.

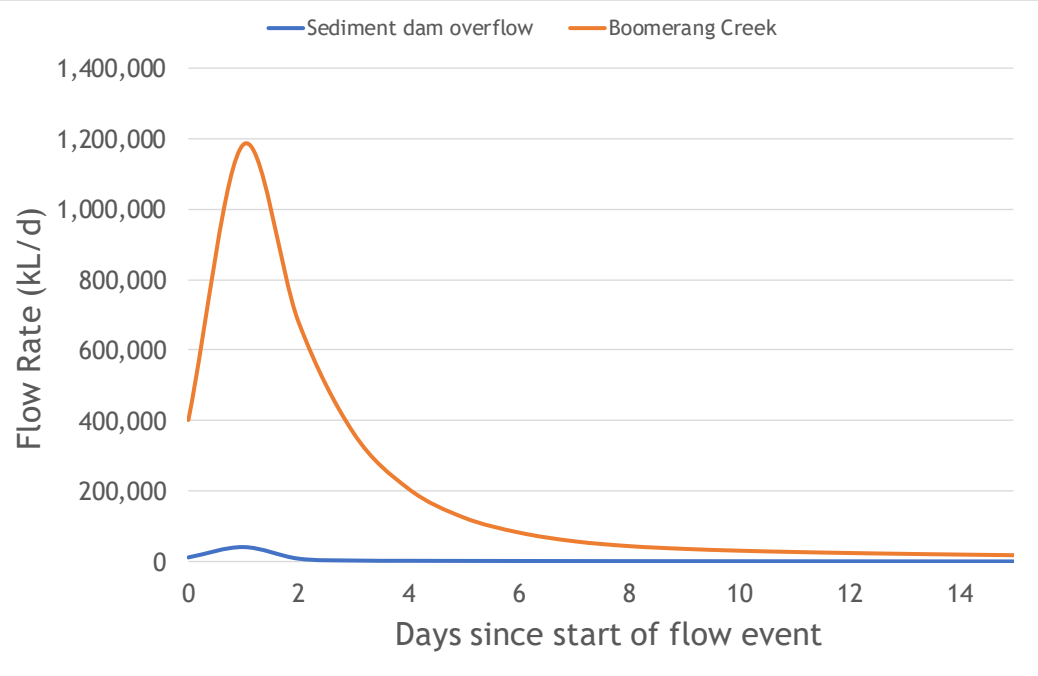


Figure 7.12 – Project release rates compared to flow rates in the receiving waters- Scenario 2

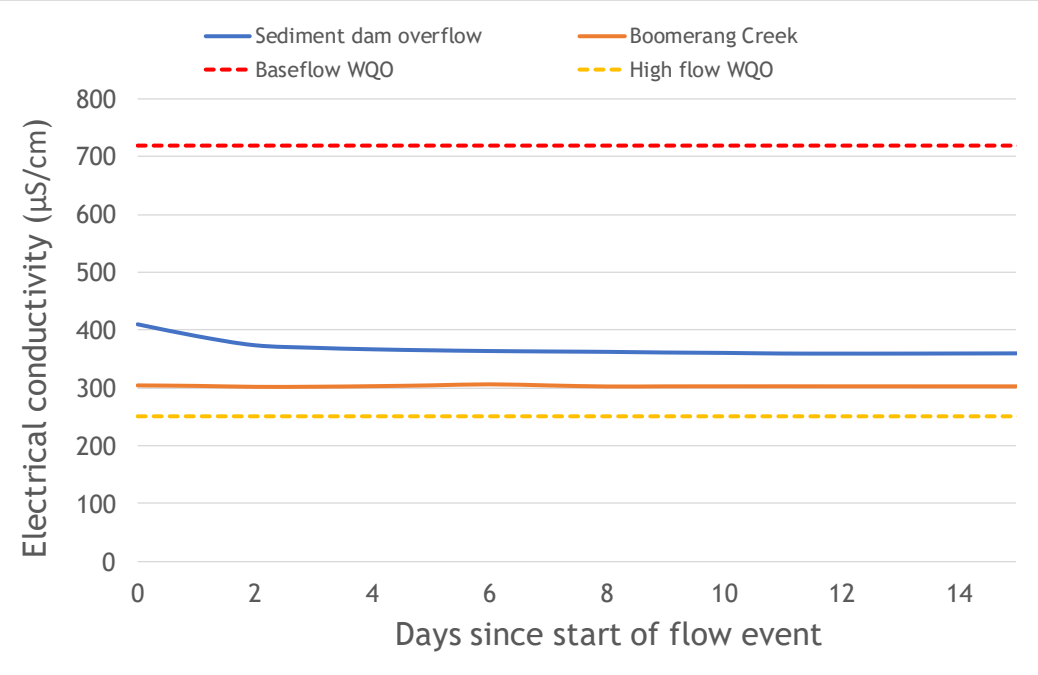


Figure 7.13 – Project release EC levels compared to EC levels in the receiving waters as well as the corresponding water quality criteria – Scenario 2

7.4 SENSITIVITY ANALYSIS

7.4.1 Haul road dust suppression

A sensitivity analysis was undertaken by varying the haul road dust suppression demand to assess the potential impacts on the overall water balance and MWD spill risk.

As outlined in Section 7.3, haul road dust suppression has the biggest influence on the Project water and salt balance. The haul road dust suppression demand has been estimated using the methodology outlined in Section 6.5.1. It is likely that the dust suppression demand will vary over the mine life as operations progress, as well as climatic and seasonal conditions. The haul road dust suppression is therefore likely the largest uncertainty for the water balance model and will have the greatest effect on the overall water balance.

A preliminary haul road dust suppression demand estimate of 1.33 ML/d was adopted for the sensitivity assessment based on preliminary rates adopted for the bulk sample project.

Figure 7.14 shows the annual maximum MWD1 inventory, Figure 7.15 shows the annual maximum Jupiter mine pit inventory and Figure 7.16 shows the forecast annual total external water requirement for the sensitivity assessment.

The results of the sensitivity analysis indicate that:

- Less water would accumulate in onsite water storages and the Jupiter Pit when compared to the base case:
    - Under 10%ile conditions, MWD1 would store up to 97 ML in Stage 1 and 86 ML in Stage 2 when compared with 105 ML and 92 ML respectively in the base case;
    - During Stage 1, MWD1 would only be filled to capacity in wettest (1%ile) conditions when compared with the 5%ile condition in the base case;
    - During Stage 2, under 1%ile conditions the Jupiter pit would store up to 19 ML compared to 24 ML in the base case; and

- More external water would be required to meet site water demands. During the driest climatic conditions (1%ile), external water demand would be up to 542 ML/annum in Stage 1 and 746 ML/annum in Stage 2. The maximum predicted base case external water demand is up to 272 ML/annum during Stage 1 and 477 ML/annum during Stage 2; and
- No mine affected water dam spills to the environment occur for this sensitivity assessment and the base case.

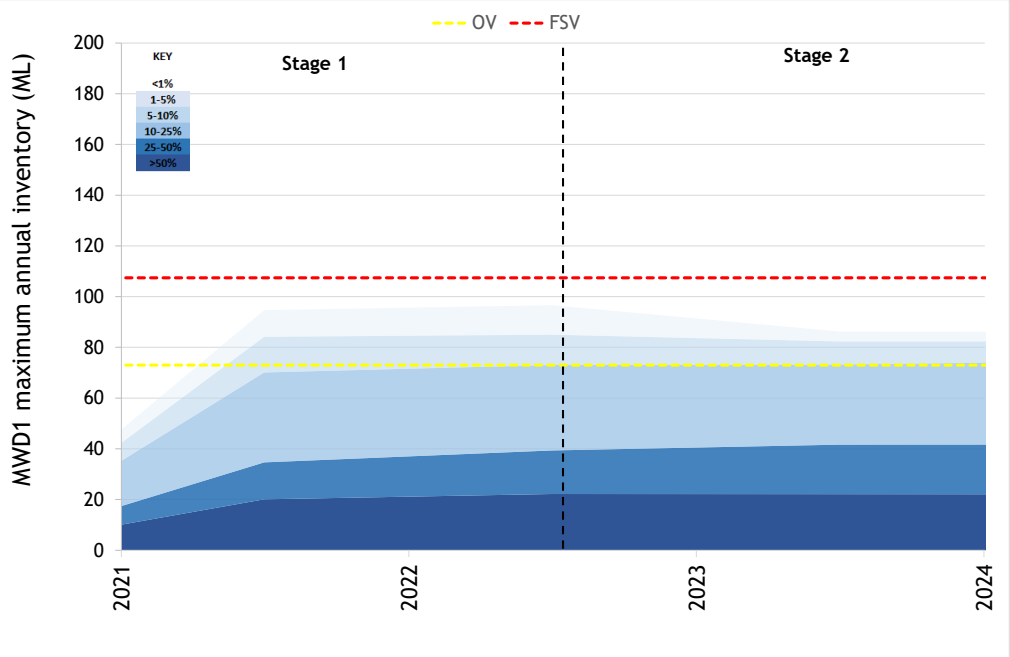


Figure 7.14 - Forecast annual maximum MWD1 inventory - dust suppression sensitivity analysis

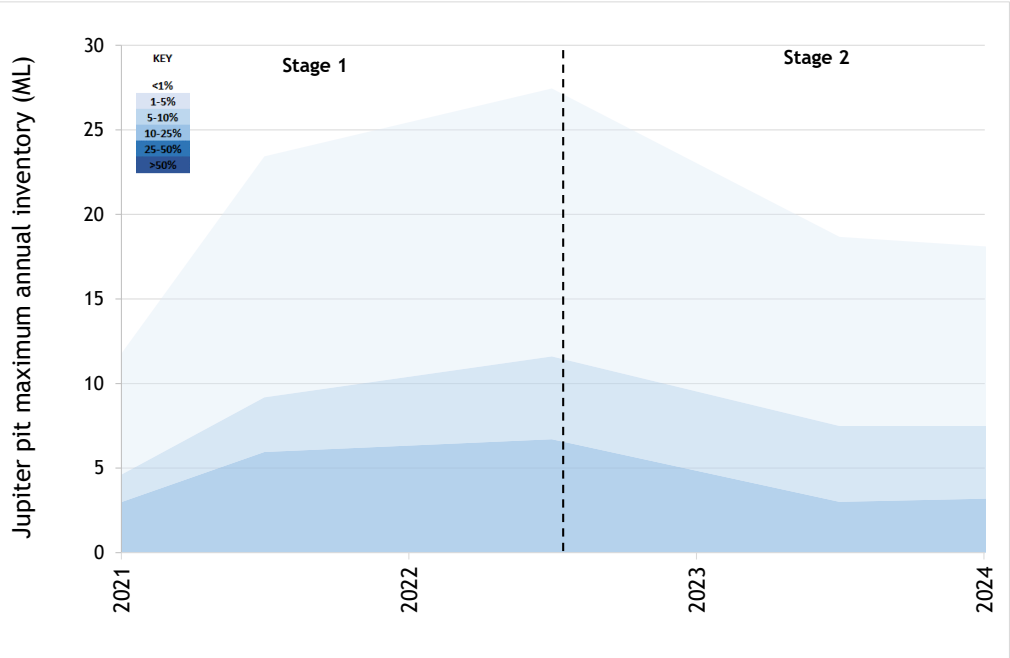


Figure 7.15 - Jupiter forecast annual maximum mine pit inventory - dust suppression sensitivity analysis

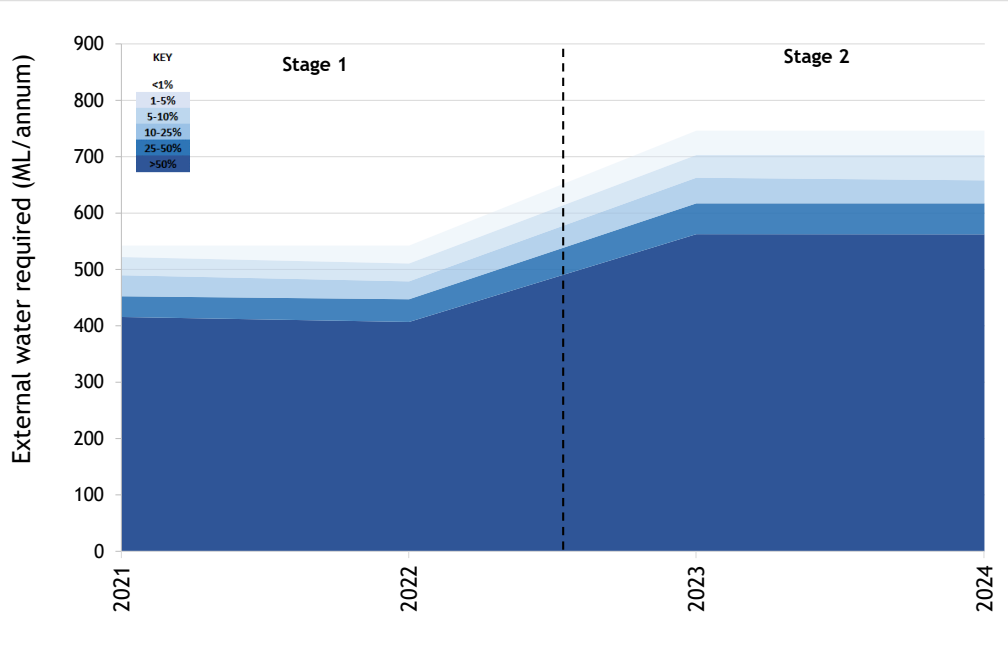


Figure 7.16 – Forecast annual total external water requirement - dust suppression sensitivity analysis

7.4.2 Climate change

The potential changes to climate within the operational life of the Project were assessed using the projections and methodologies given in the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Commonwealth Bureau of Meteorology (BoM) report entitled "Climate Change in Australia Technical Report" (CSIRO, 2015). This report provides guidance on the possible projections of future climate for the Australian East Coast based on a current understanding of the climate system, historical trends and model simulations of the climate response to changing greenhouse gas and decreasing aerosol emissions.

Projections are given for a number of climatic variables including (but not limited to) temperature, rainfall, wind speed and potential evapotranspiration. CSIRO (2015) presents a number of possible approaches to quantify risks associated with climate change impacts.

For this assessment, the Representative Concentration Pathway 4.5 (RCP4.5) emissions scenario has been adopted. Potential changes in climate have been obtained using the projection builder tool provided in the Climate Change Australia website. Climate variable inputs for the 'best case', 'maximum consensus' case 'and 'worst case' RCP4.5 climate change scenarios are provided in Table 7.3.

Temperatures are expected to increase by approximately 1°C, rainfall is expected to decline by between 3% and 10% and evapotranspiration is expected to increase by between 3% and 4%.

The climate variable inputs (rainfall and evaporation) to the Project water balance model were adjusted to undertake the climate change impact assessment. Table 7.3 shows the adopted climate projections for the 'best case' and 'worst case' RCP4.5 climate change scenarios. The 'maximum consensus' scenario has not been run as it falls between 'best case' and 'worst case' scenarios.

Table 7.3 – Projections of changes to climate

Scenario	Climate model	Mean surface temperature	Rainfall	Evapotranspiration
		Annual change	Annual change	Annual change
Best case	MIROC5	1.02°C	-3.1%	3.2%
Maximum consensus	MIROC5	1.02°C	-3.1%	3.2%
Worst case	GFDL-ESM2M	1.07°C	-10.4%	3.9%

Figure 7.17 and Figure 7.18 show the forecast annual modelled demand for water from external sources for the 'best' and 'worst' case climate scenarios in comparison to the base case results.

The model results are summarised as follows:

- 'Best' case climate scenario (Figure 7.17):
  - For the 1%ile results (very dry climatic conditions), the 'best' case modelled annual external water demands are up to 7.0 ML/a higher than the base case results; and
  - For the 50%ile results the 'best' case modelled annual external water requirement be up to 13.0 ML/a higher than the base case results.
- 'Worst' case climate scenario (Figure 7.18):
  - For the 1%ile results (very dry climatic conditions), the 'worst' case modelled annual external water demands are up to 12 ML/a higher than the base case results; and
  - For the 50%ile conditions, the 'worst' case modelled annual external water requirements are up to 39 ML/a higher than the base case.

There is an increase in external water demand requirements under both the 'best' and 'worst' climate scenarios, when compared with the base case results. This is due to the increase in evaporation and decrease in rainfall under both scenarios.

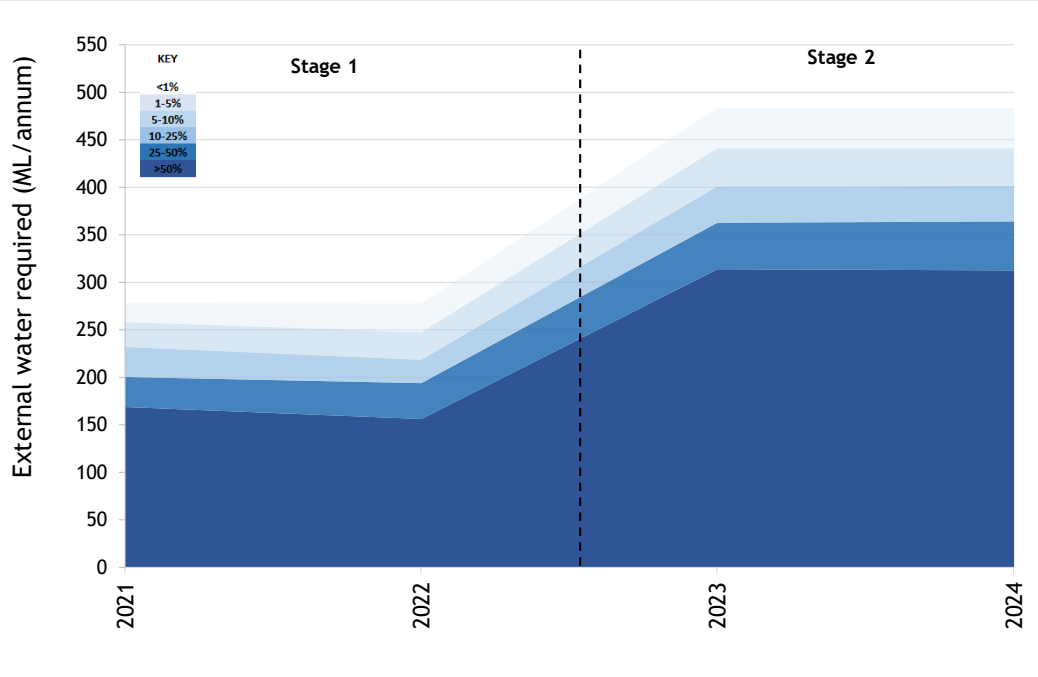


Figure 7.17 - Forecast annual total external water requirement - climate change 'best case' sensitivity analysis

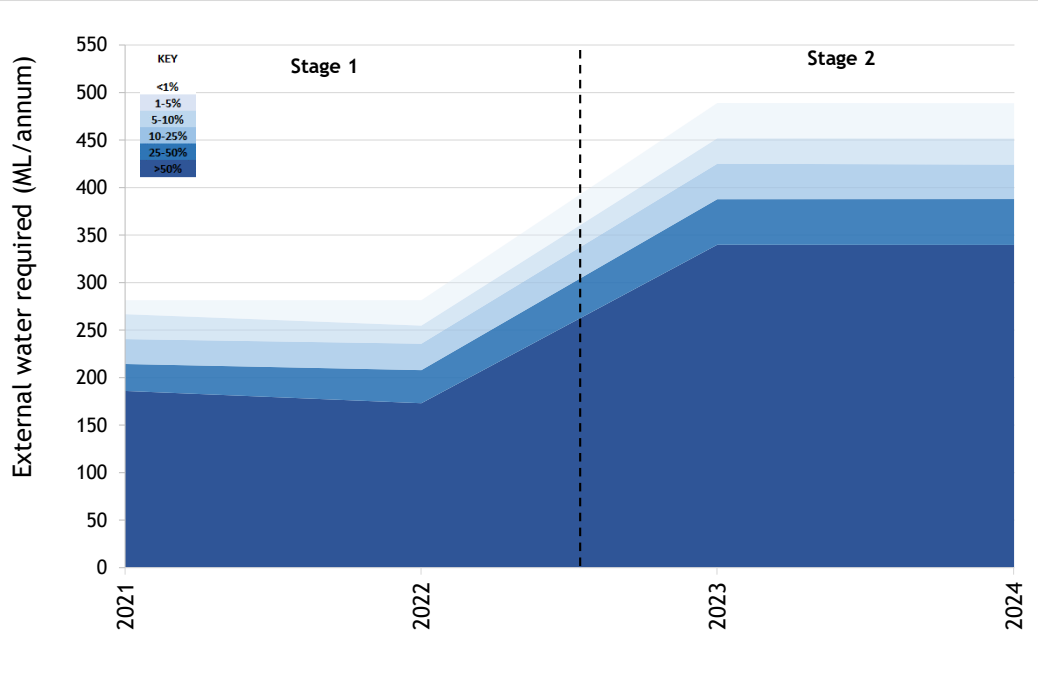


Figure 7.18 - Forecast annual total external water requirement - climate change 'worst case' sensitivity analysis

7.5 ADAPTIVE MANAGEMENT OF THE WATER MANAGEMENT SYSTEM

The model results presented above represent the application of the proposed water management system rules over the mine life, regardless of climatic conditions. There are numerous options for adaptive management of the mine water system to respond to climatic conditions and the current site water inventory in a way that will reduce the risks of impacts to surface water resources.

A site water balance model will be developed once the mine is operational and will be updated regularly (annually or biennially) using site monitoring data.

8 Flood modelling and impact assessment

8.1 OVERVIEW

The drainage features that cross the Project have been assessed to determine the potential impact of the Project on flood behaviour including:

- The potential to impact on flood levels;
- The potential to increase the extent of flooding;
- The potential to increase erosion and/or sedimentation of the impacted waterways;
- The potential to impact on the morphology of the adjacent floodplains; and
- The potential loss of flow from the catchment.

8.2 ADOPTED METHODOLOGY

8.2.1 Hydrological model

A hydrological model was developed for the Boomerang Creek and Hughes Creek catchments, including the features that cross the Project area, using the XP-RAFTS runoff-routing software (Innovyze, 2019). Section 8.2 describes the development, configuration and calibration of the hydrological model.

There was no publicly available recorded streamflow data in the drainage lines that cross the proposed Project area to calibrate the model. As a result, the XP-RAFTS design discharges estimated for Boomerang Creek and Hughes Creek catchments were validated against the Rational Method for the 10% and 1% AEP design flood event.

The Phillips Creek catchment was also included in the hydrologic model because of the availability of recorded water levels and flows. The peak 10% and 1% AEP design discharges estimated for Phillips Creek by the XP-RAFTS model were validated against a Flood Frequency Analysis (FFA) of the annual series peak discharges recorded at the (now closed) Phillips Creek at Tayglen streamflow gauge.

Design flood hydrographs estimated using the calibrated XP-RAFTS model were adopted as inflows in the hydraulic model.

8.2.2 Hydraulic model

The TUFLOW model was used to estimate design flood levels, velocities and extents in Boomerang Creek and its tributaries across the Project area for the 10% (1 in 10) AEP, 1% (1 in 100) AEP and 0.1% (1 in 1000) AEP design flood events for the Pre-mining Conditions, Operational Conditions and the proposed Final Landform Conditions. The model results were used to assess the potential impacts on flood levels, velocities and extents along Boomerang Creek for the Operational and Final Landform Conditions. Section 8.3 and Section 8.4 describe the development and configuration of the hydraulic model and Section 8.5 and Section 8.6 provide the flood modelling results and impact assessment.

8.3 CONDITIONS ASSESSED

8.3.1 General

The potential flood impacts of the Project were assessed for the following two conditions:

- Pre-mining (2019) Conditions;
- Operational Conditions; and

- Post-closure Conditions.

The Project proposes to modify BMA's existing drainage diversion and levee as part of the EA amendment. The Operational Conditions were assessed against the Pre-mining Conditions assuming that the levee would remain operational over the life of the project. Two haul road crossing options of the existing drainage diversion and BMA levee were assessed as part of the Operational Conditions.

For Post-closure Conditions, two possible levee scenarios were considered for the existing drainage diversion and levee to ensure that the Project could cater for future modification/removal of this structure by others. The two scenarios assessed for the Post-closure flood impact assessment were:

- The existing drainage diversion and levee remains operational after the completion of the Project; and
- The existing drainage diversion and levee is removed by others at some time in the future after the completion of the Project.

8.4 EXISTING CONDITIONS HYDROLOGIC MODEL CONFIGURATION

8.4.1 General

Figure 8.1 shows the configuration of the XP-RAFTS model of the Boomerang, Hughes and Phillips Creek catchments. The model consists of a total of 94 sub-catchments, ranging in size from 0.1 km^2 to 59.8 km^2. This includes 50 sub-catchments for Boomerang Creek, 30 sub-catchments for Hughes Creek, 3 sub-catchments for Barrett Creek and 11 sub-catchments for Phillips Creek.

The XP-RAFTS model uses a single sub-catchment approach to determine runoff hydrographs, based on the overall sub-catchment parameters (fraction impervious, slope and roughness). All sub-catchments were assigned a fraction impervious of 0%, catchment slope based on the available topographic data and a Manning's n (roughness) of 0.04. Channel routing was modelled using the Muskingum-Cunge method, based on the channel length and average channel slope for each "link" between catchment nodes.

8.4.2 Design rainfall depths, intensities and temporal patterns

Design rainfall depths and intensities for the design events were derived using intensity-frequency duration (IFD) data obtained from the Bureau of Meteorology's (BOM's) 2019 Rainfall IFD Data System.

The East Coast North temporal patterns were adopted for events up to the 1% AEP as per recommendations in Australian Rainfall and Runoff (AR&R) Data Hub (Geoscience Australia, 2019). For the 0.1% AEP event, one temporal pattern was applied to each storm duration. The 0.1% AEP temporal patterns were adopted from the Generalised Short Duration Method (GSDM) (BOM, 2003) for storm durations of 6 hours and less.

8.4.3 Design rainfall losses

The initial (IL) and continuing loss (CL) method of accounting for rainfall losses was adopted for this assessment. The recommended regional IL and CL values for the Boomerang Creek and Hughes Creek catchments from the AR&R Data Hub (Geoscience Australia, 2019), were 45 mm (prior to adjustment for preburst rainfall) and 1.9 mm/hr respectively. The IL and CL adopted for the 0.1% AEP was 0.0 mm and 1.9 mm/h respectively.

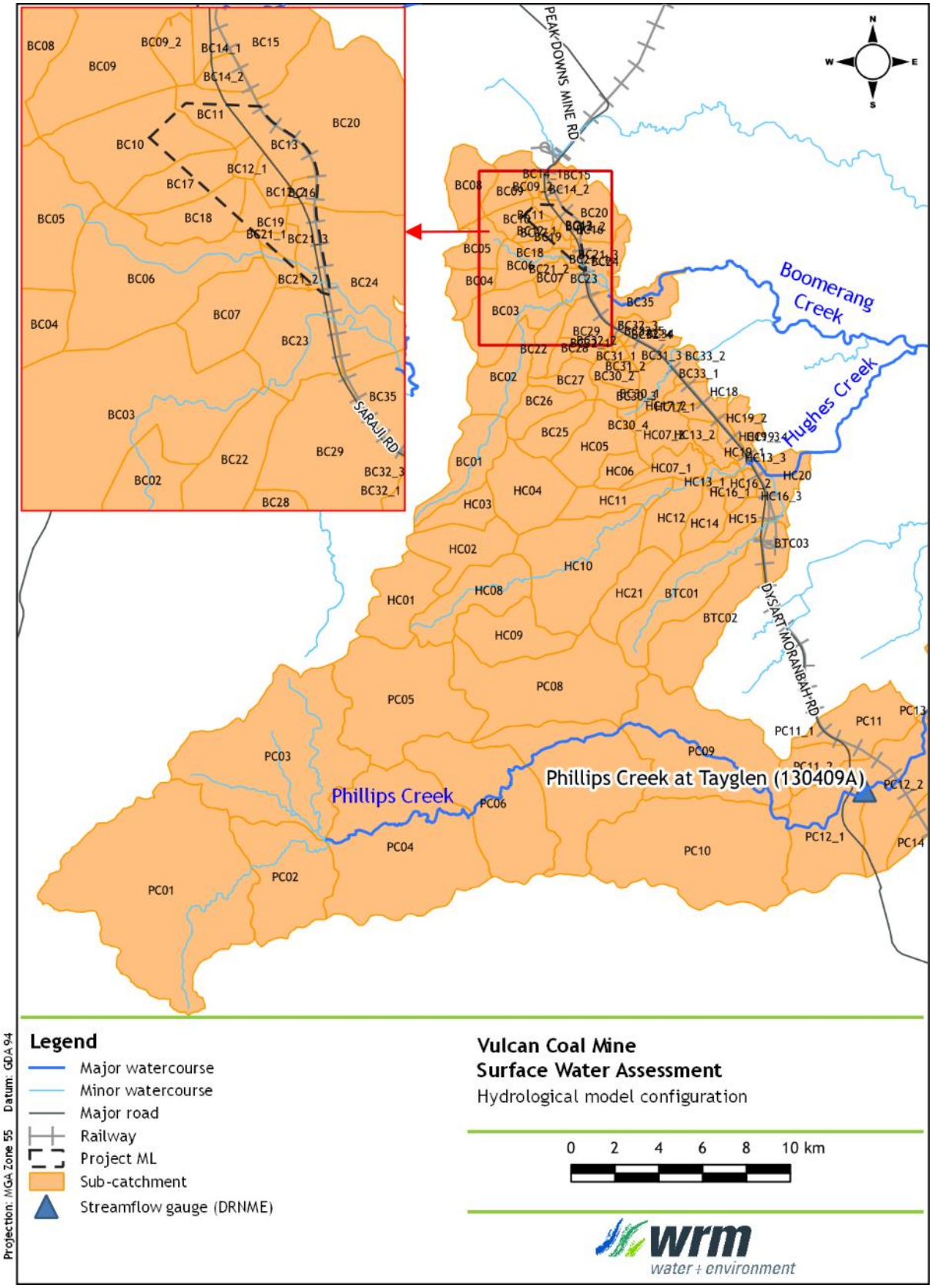


Figure 8.1 – XP-RAFTS model configuration

8.4.4 Peak flow validation

8.4.4.1 Boomerang Creek catchment

The Rational Method was used to validate the 10% and 1% AEP design flood discharges in Boomerang Creek estimated by XP-RAFTS. Table 8.1 compares the XP-RAFTS design discharge estimates for Boomerang Creek at BC11 and BC17 against the Rational Method estimates. The table shows that the design discharges derived by the XP-RAFTS model are generally within 15% of the Rational Method estimates.

Table 8.1 - Peak design discharge comparison between XP-RAFTS and Rational Method

Sub-catchment ID (see Figure 8.1)	Sub-catchment area (ha)	AEP event (%)	Design Discharge (m^3/s)		
			Rational Method	XP-RAFTS	Difference
BC11	61	10%	3.8	3.3	-0.5
		1%	6.7	7.2	0.5
BC17	107	10%	8.1	7.2	-0.9
		1%	14.0	15.5	1.5

8.4.4.2 Phillips Creek catchment

The results of the XP-RAFTS model for Phillips Creek were validated by comparing the peak design discharges from XP-RAFTS to the results of a FFA undertaken to the annual flood peak series from RDMW's Tayglen gauge (gauge no. 130409A), which operated between 1968 and 1988. The catchment to the gauge is approximately 344 km^2.

The results compared in Table 8.2 show that the XP-RAFTS 1% AEP peak discharge compares reasonably well with the FFA expected result. The 10% AEP XP-RAFTS peak discharge overestimates the FFA peak discharge, however it is within the 90th percentile confidence limits.

Table 8.2 - FFA at Tayglen gauge compared to XP-RAFTS peak discharge

Design event	XP-RAFTS design peak discharge (m^3/s)	FFA design peak discharges (m^3/s)			% Difference
		Expected result	Lower confidence limit	Upper confidence limit	
10%	490	376	227	622	23%
1%	1,109	1,083	402	2,922	2%

8.4.4.3 Summary

Overall, the XP-RAFTS hydrological model is considered satisfactorily validated and acceptable for estimating design hydrographs for input into the hydraulic model.

8.4.5 Adopted design discharges

Table 8.3 shows the adopted peak design discharges estimated by the XP-RAFTS model at key locations in the vicinity of the Project area for the 10%, 1% and 0.1% AEP design flood events. Table 8.3 also shows the critical storm durations and representative temporal patterns producing the peak discharge at each location.

Table 8.3 - Adopted design discharges, critical storm durations and temporal pattern

Key location	AEP event (%)	XP-RAFTS Ensemble mean peak discharge (m^3/s)	XP-RAFTS adopted design peak discharge (m^3/s)[1]	Critical storm duration (hours)	Temporal pattern number
Boomerang Creek at Peak Downs (BC35)	10%	236.1	236.8	6	7*
	1%	520.5	520.9	6	6
	0.1%	NA	1,037.1	3	NA
Drainage Line 2 upstream of Saraji Road (BC06)	10%	50.9	51.5	3	4*
	1%	102.4	102.8	2	8*
	0.1%	NA	233.4	2	NA
Drainage Line 3 at Saraji Road (BC23)	10%	69.4	71.0	6	7
	1%	164.7	166.8	6	2*
	0.1%	NA	323.9	3	NA
Drainage Line 4 at Saraji Road (BC29)	10%	68.5	70.2	6	4
	1%	143.1	145.2	4.5	2
	0.1%	NA	342.4	2	NA

NA – not applicable; Note that the 1 hour to 6 hour storm durations were all run in the hydraulic model for the 0.1% AEP event.
[1]Adopted design peak discharge calculated from the temporal pattern which generated a peak discharge closest to, but higher than, the ensemble mean.

*Indicates the selected temporal pattern run in the hydraulic model.

8.5 HYDRAULIC MODEL DEVELOPMENT

The two-dimensional TUFLOW hydraulic model (BMT, 2018a) was used to simulate the flow behaviour of Boomerang Creek and its tributaries in the vicinity of (and through) the proposed Project area.

TUFLOW represents hydraulic behaviour on a fixed grid by solving the full two-dimensional depth averaged momentum and continuity equations for free surface flow (BMT, 2018b). The model automatically calculates breakout points and flow directions within the study area. A 2 m grid cell size was adopted to obtain the best representation of flow distributions between the drainage channels, drainage diversions, hydraulic structures (e.g., culverts) and floodplains.

8.5.1 Topographic data

The TUFLOW model used topographic aerial survey data (LiDAR) supplied by Aerometrex Pty Ltd via Vitrinite. The ground surface data was obtained by LiDAR capture on 7, 8 and 27 May 2019. Aerometrex Pty Ltd quote that the LiDAR data has a vertical root mean squared error of 0.0755 m.

8.5.2 Inflow and outflow boundaries

Figure 8.2 shows the locations of the 2D inflow and outflow boundaries used in the TUFLOW model. The discharge hydrographs estimated using the XP-RAFTS runoff-routing model were adopted as inflows to the TUFLOW model.

Normal depth outflow boundaries were adopted at Peak Downs's Boomerang Creek diversion, located 3.5 km downstream of the Project area to ensure that the boundary assumptions have no material impact on peak flood levels in the study area. The adopted tailwater slope for the Boomerang Creek diversion was set at 0.0025 m/m.

8.5.3 Manning's 'n' values

The TUFLOW model uses Manning's 'n' values to represent hydraulic resistance. Manning's 'n' values were adopted based on typical published values (e.g. Chow (1959)) and

consistent with Manning's 'n' value adopted in nearby flood studies. Manning's 'n' values were mapped within the study area based on aerial photography taken on 27 May 2019. The following Manning's 'n' values were adopted:

- Vegetated channels: 'n' = 0.060;
- Rocky channels: 'n' = 0.045;
- Light vegetation: 'n' = 0.050;
- Dense vegetation: 'n' = 0.080;
- Exposed soil / unsealed roads: 'n' = 0.025;
- Water bodies / dams: 'n' = 0.015;
- Sealed roads: 'n' = 0.020; and
- Buildings: 'n' = 0.300.

8.5.4 Hydraulic structures

There are 21 culvert structures modelled as 1d structures in the 2d domain. The culvert locations are shown in Figure 8.2 and include the culverts beneath Saraji Road and the Norwich Park Branch Railway.

The culvert structures within the Peak Downs and Saraji mining leases were modelled as gaps or openings to represent the culverts as information on these structures was not available for this study.

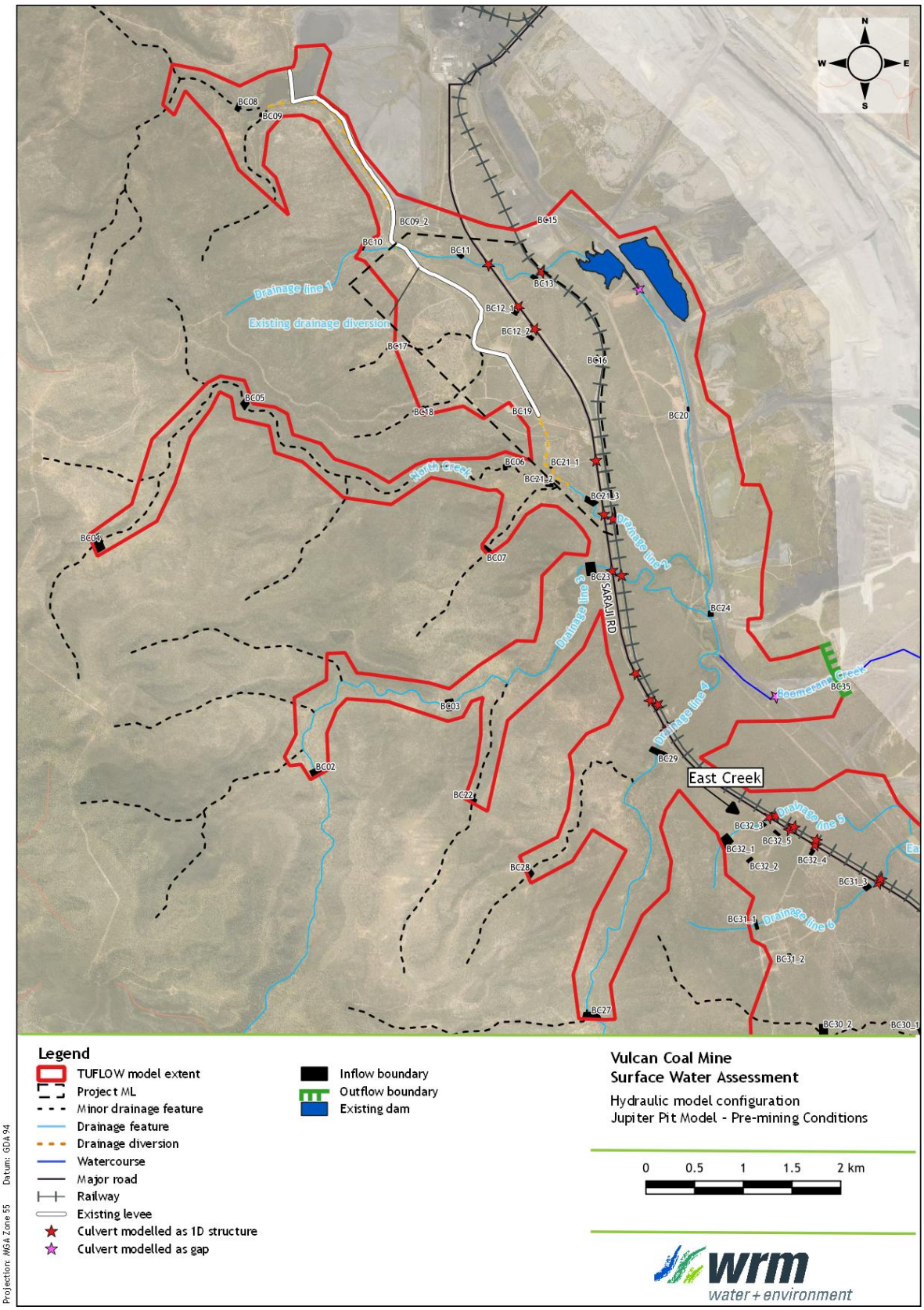


Figure 8.2 – Jupiter Pit Pre-mining Conditions hydraulic model configuration

8.6 CHANGES TO PRE-MINING CONDITIONS

8.6.1 Operational Conditions model changes

The Pre-mining Conditions TUFLOW model developed for the Project was modified were updated to include mine water infrastructure required during operations. The model updates representing the Operational Conditions configuration is shown in Figure 8.3 and include:

- Proposed life-of-mine landforms and open cut pits;
- Modified inflow boundary locations to represent Operational Conditions catchment areas;
- Proposed haul road, haul road crossing and haul road culverts;
- Proposed modifications to BMA's existing drainage diversion and levee;
- Proposed rail loop and associated rail loop drainage infrastructure;
- Proposed Matilda Pit drainage diversion and levees;
- Proposed CHPP infrastructure area;
- Proposed DD1 dam and diversion drains/bunds;
- Realignment of Saraji Road; and
- Saraji Road culverts.

8.6.2 Post-closure Conditions model changes

The Pre-mining Conditions TUFLOW model developed for the Project was modified (for both levee scenarios) to include the proposed final landforms including drainage channels and the realignment of Saraji Road. The model updates shown in Figure 8.5 include:

- The proposed drainage corridor through backfilled waste rock dump at Jupiter Pit;
- The proposed clean water diversion drain around the Matilda Pit final landform;
- Ex-pit waste rock dump;
- Modified inflow boundary locations to represent Post-closure Conditions catchment areas;
- Realignment of Saraji Road; and
- Saraji Road culverts.

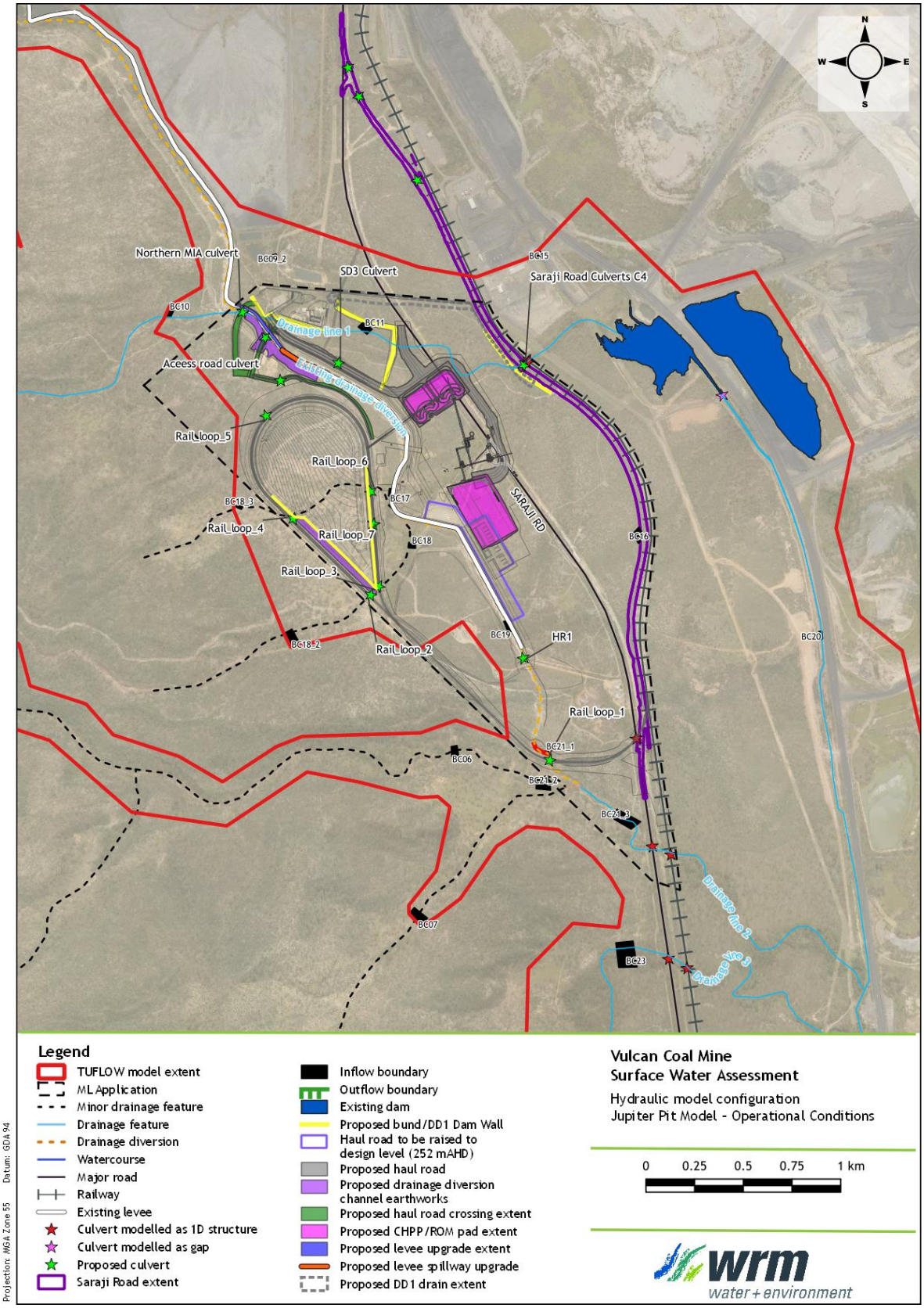


Figure 8.3 – Jupiter Pit Operational Conditions hydraulic model configuration

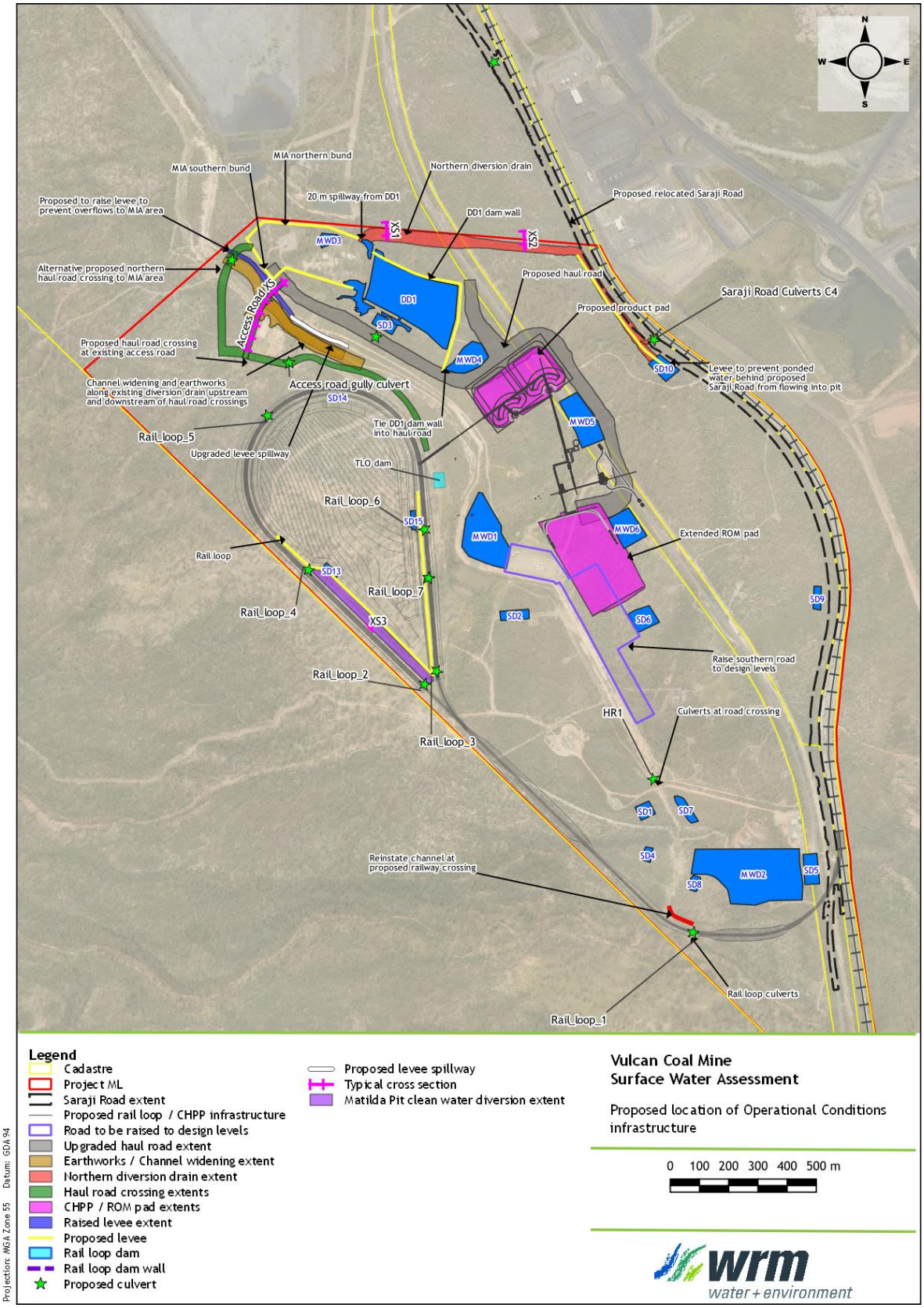


Figure 8.4 - Location and extent of Operational Conditions infrastructure changes

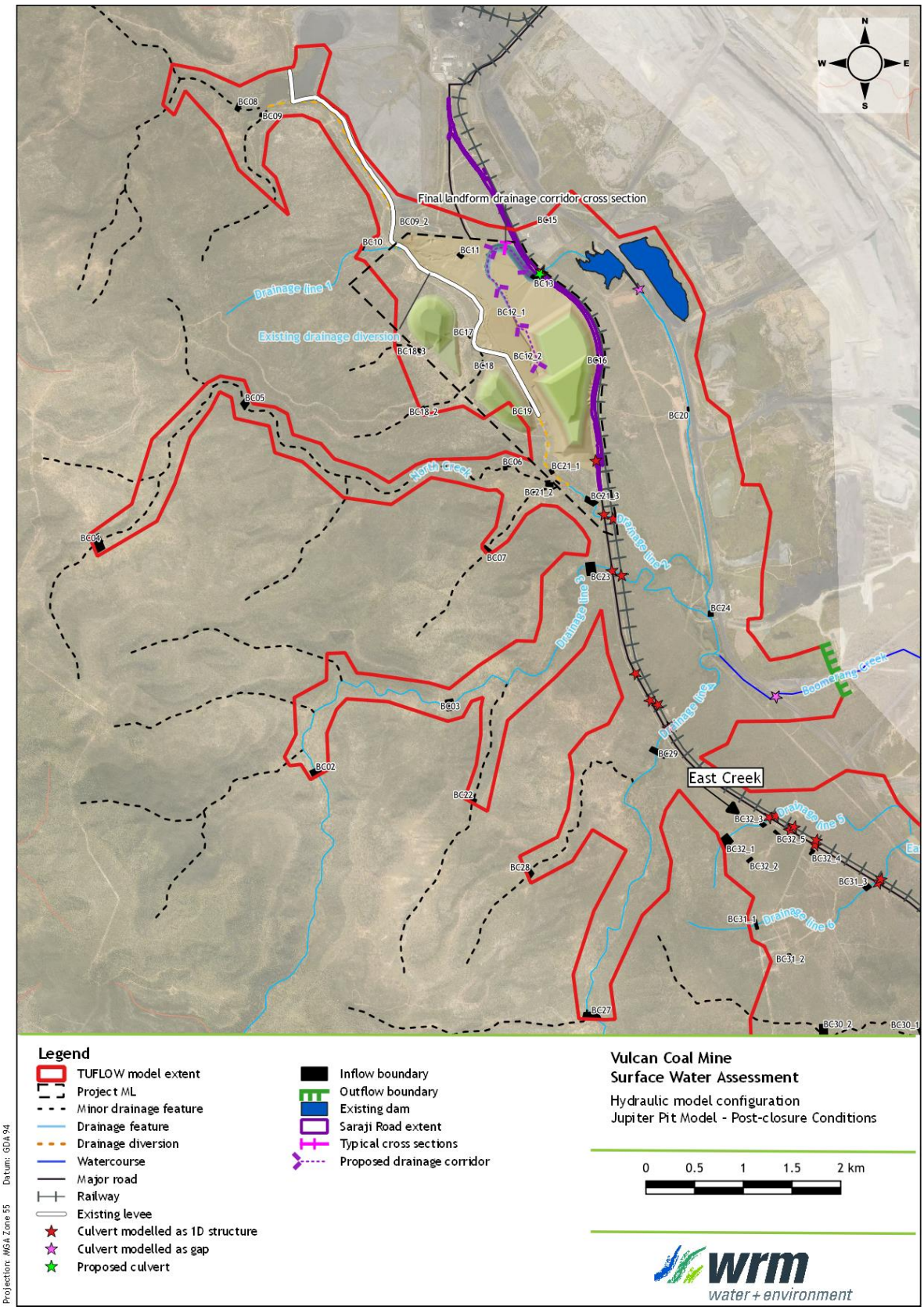


Figure 8.5 – Jupiter Pit Final Landform (Post-closure Conditions) hydraulic model configuration

8.6.3 Proposed haul road crossings and upgraded haul road

Two crossing locations shown in Figure 8.3 and Figure 8.4 were assessed under Operational Conditions as part of the EA amendment:

- Proposed haul road crossing at the existing access road; and
- Proposed haul road crossings at the northern MIA.

The proposed crossings were assessed independently as only one crossing option will be constructed. Notwithstanding this, the two options were assessed. The design surfaces of the haul road crossings were provided by JukesTodd in October and November 2021.

The haul road culvert configuration for each option was preliminarily sized by JukesTodd and confirmed using the TUFLOW model.

Additional culvert crossings were input to the TUFLOW model

Table 8.4 – Adopted culvert configuration for the proposed haul road crossings

Crossing	Type	Diameter (m)	Width (m)	No. of barrels	US invert level (mAHD)	DS invert level (mAHD)
Access road	RCBC	2.1	1.2	5	252.61	252.57
Northern MIA	RCBC	2.1	1.2	5	253.94	253.69

8.6.4 Proposed modifications to the BMA levee and existing drainage diversion

Figure 8.3 and Figure 8.4 shows the location and extent of the levee and drainage diversion modifications and Figure 8.6 shows a typical cross section proposed road crossing and channel. The Project proposes to raise a section of the existing BMA levee and undertake earthworks and channel widening along the existing drainage diversion at the northern end of the ML boundary. The proposed works would be undertaken to mitigate flood impacts of the proposed crossing of the existing drainage diversion which connects the rail loop to the upgraded haul road on the eastern side of the levee. The levee and channel upgrades were iteratively designed to mitigate the impacts of the crossing and include:

- Raising the northern section of the levee (by up to 1 m);
- Widening the existing drainage diversion channel to a base width of 30 m with a batter slope of 1V:6H on the left bank and 1V:20H on the right bank. The widened channel extends from the ML boundary to the end of the spillway (up to 550 m in length); and
- Extending the existing levee spillway width (spillway height of 253.7 mAHD) from 40 m to 200 m.

The existing drainage diversion upstream of the proposed culverts Rail_Loop_1 (see Figure 8.3 and Figure 8.4) was modified to reinstate the existing drainage diversion channel through the rail loop embankment. A similar channel width and channel slope to existing conditions was used and it is recommended that detailed design will undertake suitable erosion and scour protection at the crossing.

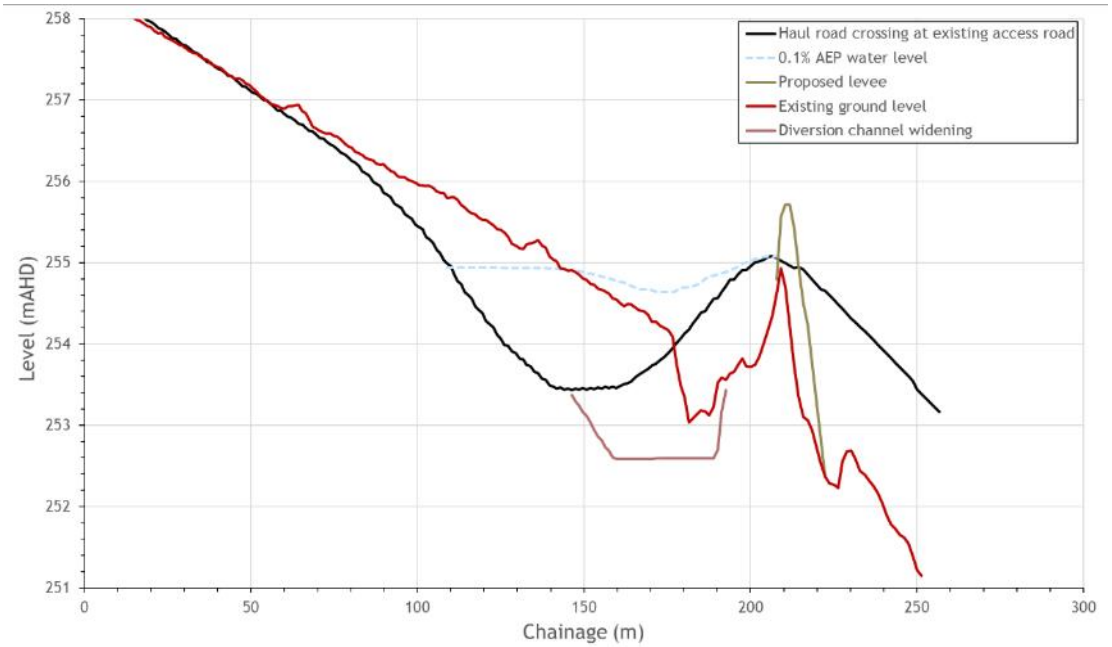


Figure 8.6 – Typical cross section (Access road XS in Figure 8.3) of the proposed levee and drainage diversion modifications at the existing access road haul road crossing upgrade

8.6.5 Proposed rail loop and culverts

Figure 8.3 and Figure 8.4 shows the proposed rail loop design which was undertaken by JukesTodd and the design surface (provided 11 November 2021) was input to the TUFLOW model. Proposed rail loop culverts were sized for the 1% AEP design event using standard culvert nomographs under *Hydraulic design manual: Hydraulics of precast concrete conduits* (CPAA, 2012). Table 8.5 shows the adopted rail loop culverts included in the model.

Table 8.5 – Adopted culvert configuration for the proposed rail loop

Culvert ID	Type	Diameter (m)	No. of barrels	US invert level (mAHD)	DS invert level (mAHD)
Rail_loop_1	CSP	4.05	2	228.7	228.1
Rail_loop_2	CSP	2.4	1	257.4	255.7
Rail_loop_3	CSP	2.7	2	255.7	254.0
Rail_loop_4	CSP	2.7	1	258.2	256.9
Rail_loop_5	CSP	1.5	1	265.3	263.7
Rail_loop_6	CSP	2.7	1	252.1	251.5
Rail_loop_7	CSP	2.7	1	251.7	250.7

8.6.6 Proposed CHPP infrastructure area

Figure 8.3 shows the design strings of the proposed CHPP infrastructure area, including the product stockpile, TLO, CHPP and extended ROM pad. The design was undertaken by Sedgman and provided in November 2021. The design surface was input to the Operational Conditions TUFLOW model.

8.6.7 Proposed DD1 dam, northern diversion drain and bunds

Figure 8.3 shows the proposed DD1 dam and dam wall which were designed to provide flood protection for the Jupiter Pit during a 0.1% AEP flood event (in conjunction with other drainage infrastructure). Overflows from the BMA levee are drained to two floodway crossings along the haul road into DD1. The DD1 dam wall is proposed to be constructed at least 0.5 m above the 0.1% AEP flood event across the spillway.

DD1 overflows via a 20 m wide spillway on the northern corner of the dam into a 20 m wide northern drain and 10 m wide northeastern/eastern drain adjacent to the Jupiter Pit (see typical cross sections in Figure 8.7 and Figure 8.8). A flood protection levee is proposed for construction on the eastern side of the Jupiter Pit. The proposed eastern levee will prevent floodwater ingress to the Jupiter Pit from floodwater potentially building up behind the realigned Saraji Road and the railway embankment.

The DD1 dam wall, DD1 spillway, northern diversion drain and eastern levee form part of the flood protection levee alignment as discussed in Section 8.6.10.

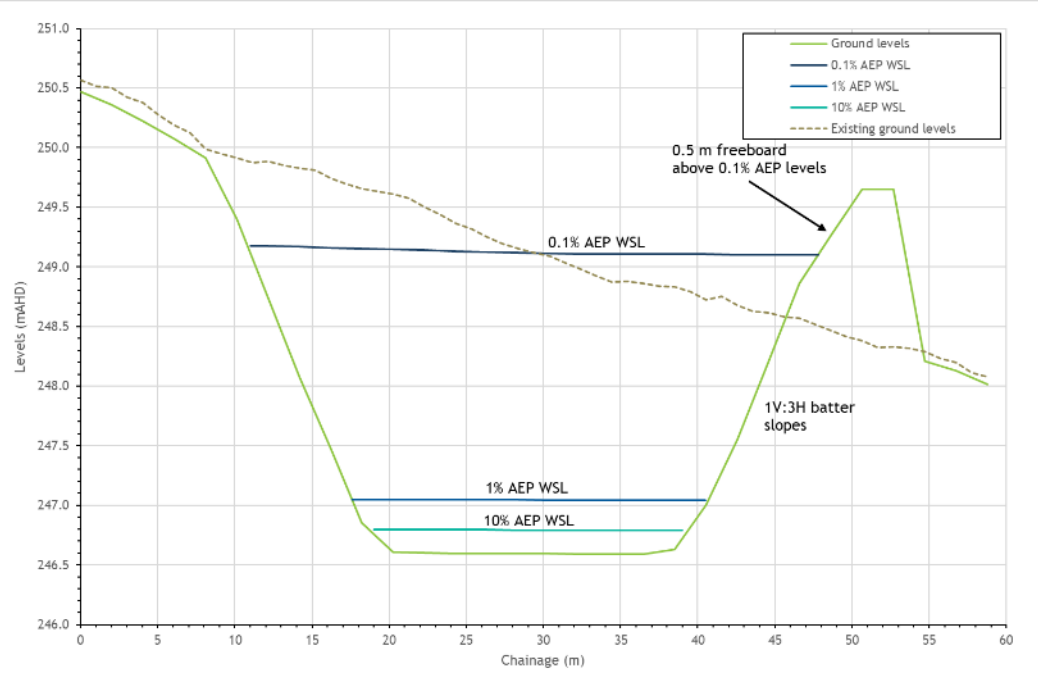


Figure 8.7 – Typical cross section (XS1 in Figure 8.3) of proposed northern diverison drain around Jupiter Pit

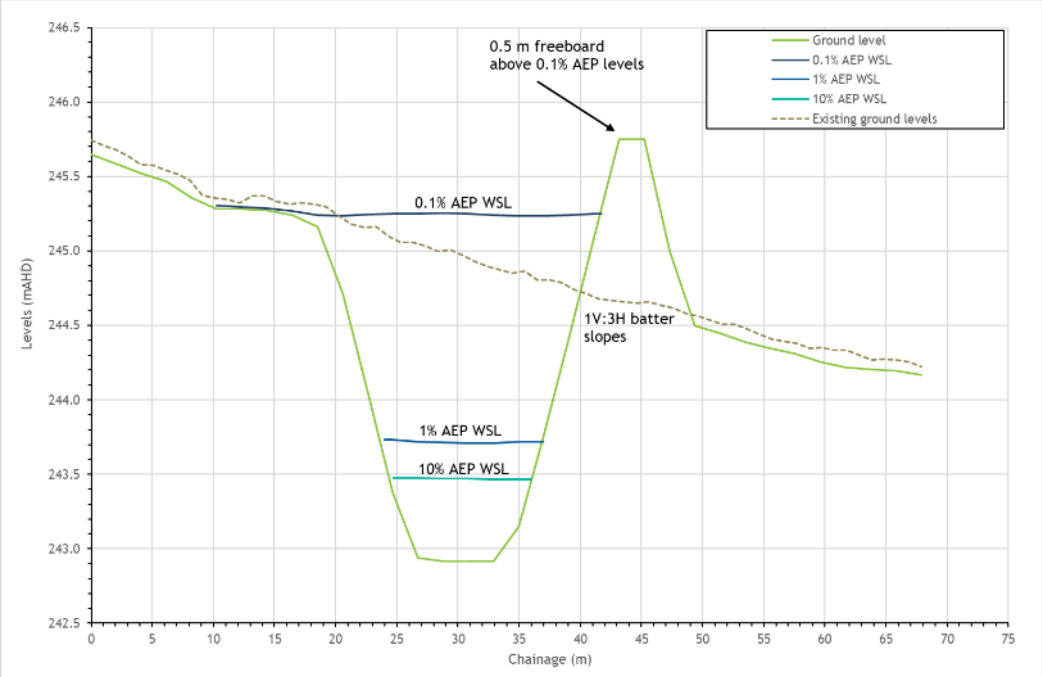


Figure 8.8 – Typical cross section (XS2 in Figure 8.3) of proposed northern/eastern diverison drain around Jupiter Pit

8.6.8 Proposed Matilda Pit diversion drain

Figure 8.9 shows the proposed western diversion drain which was designed to divert the upstream clean water catchment around the pit into the existing diversion drain and to provide flood protection for the Matilda Pit during a 0.1% AEP flood event (in conjunction with other drainage infrastructure). The diversion drain will be suitably lined to manage channel erosion and prevent scour until the Matilda Pit landform is rehabilitated and suitable vegetation is established.

A flood protection levee is constructed on the western side of the Matilda Pit adjacent to the diversion drain to prevent floodwaters from the upstream clean water catchment from entering the Matilda Pit as discussed in Section 8.6.10.

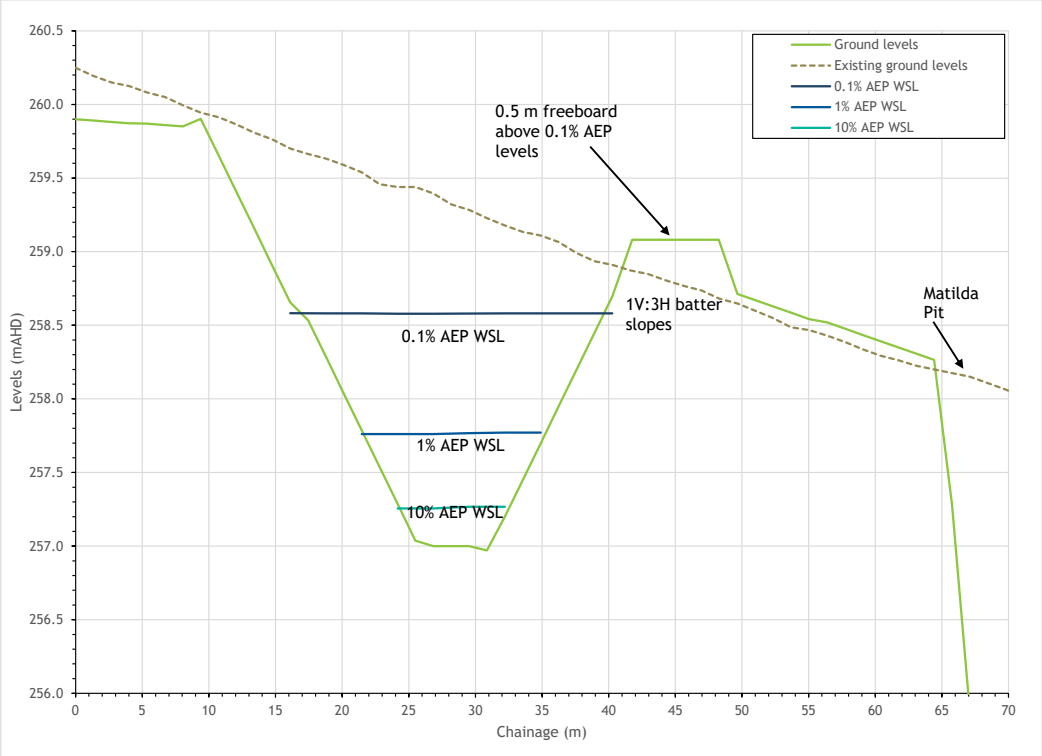


Figure 8.9 – Typical cross section (XS3 in Figure 8.3) of proposed western diverison drain around Matilda Pit

8.6.9 Saraji Road and culverts

The Saraji Road design was undertaken by Cozens Regan and the design surface provided by Vitrinite (dated 20 July 2021) was input to the hydraulic model. Figure 8.10 shows the design of the Saraji Road culverts (Culverts C4 in Figure 8.3 and Figure 8.4) (undertaken by Cozens Regan), which includes invert levels, scour protection and crossing details at the Drainage Line 1 crossing. The culverts included in the TUFLOW model were four (4) 2.4 m diameter corrugated steel pipes (CSPs).

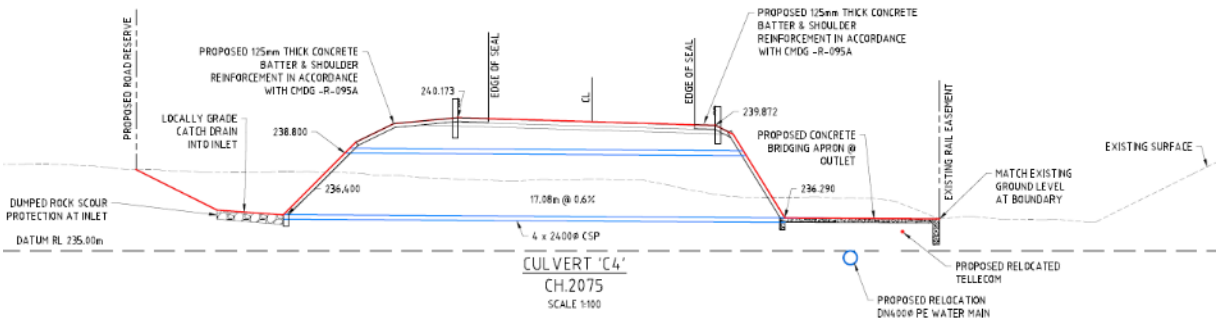


Figure 8.10 – Conceptual design of Saraji Road culverts along Drainage line 1

8.6.10 Proposed flood protection levee

Figure 8.11 shows the proposed flood protection levees, which are required to act as protection from ingress of floodwaters to the mining pits for a 0.1% AEP event during the Operational Conditions of the Project. Six flood protection levees are proposed as part of the Project, with some of the infrastructure proposed for operations to act in place of a levee structure:

- The proposed haul road alignment west of the pit;
- The proposed DD1 dam wall;
- The proposed DD1 spillway and drain;
- The proposed levee on the eastern side of the pit adjacent to the Saraji Road realignment;
- The proposed levee on the western side of the Matilda Pit which may be formed by the batters of the proposed clean water diversion drain (Section 8.6.8); and
- The proposed levee on the eastern side of the Matilda Pit.

The levels shown in Table 8.6 are the recommended required levee crest levels determined by applying a freeboard of at least 0.5 m above the peak 0.1% AEP levels. These levels were based on the maximum of the Operational Conditions haul road crossing options (the crossing at the existing access road of the northern MIA). Figure 8.11 shows the reported chainage along the proposed flood protection levee. The results show that the proposed flood protection levees will range between 1 m and 6 m (DD1 dam wall) high.

The proposed flood protection levee configurations are preliminary only. The final horizontal and vertical alignment will be confirmed in conjunction with the proposed drainage requirements and potential existing drainage diversion failure assessments during the design phase.

Table 8.6 – 0.1% AEP flood levels adjacent to the proposed flood protection levees required for operations

Chainage (m)	Required minimum crest levee level with 0.5 m freeboard requirement included (mAHD)					
	Haul road levee	DD1 dam wall levee	DD1 drain levee	Eastern pit levee	Matilda Pit western levee	Matilda Pit eastern levee
0	250.6	249.7	249.5	242.8	-	-
50	251.6	249.7	249.4	242.5	-	225.8
100	251.6	249.7	248.8	241.9	-	253.1
150	251.7	249.7	248.6	241.5	-	253.1
200	251.7	249.7	248.4	241.3	259.3	253.0
250	251.7	249.7	248.3	241.2	259.2	253.0
300	251.7	249.7	248.2	241.2	259.2	253.0
350	251.7	249.7	248.1	241.2	259.2	253.0
400	251.7	249.7	247.7	241.2	259.2	253.0
450	251.7	249.7	247.3	241.2	259.1	254.3
500	251.7	249.7	246.6	241.2	259.1	255.6
550	251.7	249.7	246.0	-	259.1	255.6
600	251.7	249.7	245.3	-	259.1	256.3
650	251.7	249.7	244.7	-	259.1	-
700	251.7	-	244.0	-	259.1	-
750	251.7	-	243.1	-	-	-
800	252.4	-	-	-	-	-
850	252.4	-	-	-	-	-
900	252.4	-	-	-	-	-
950	252.5	-	-	-	-	-
1000	252.5	-	-	-	-	-
1050	252.5	-	-	-	-	-
1100	252.5	-	-	-	-	-
1150	252.4	-	-	-	-	-
1200	252.4	-	-	-	-	-
1250	252.4	-	-	-	-	-
1270	252.9	-	-	-	-	-

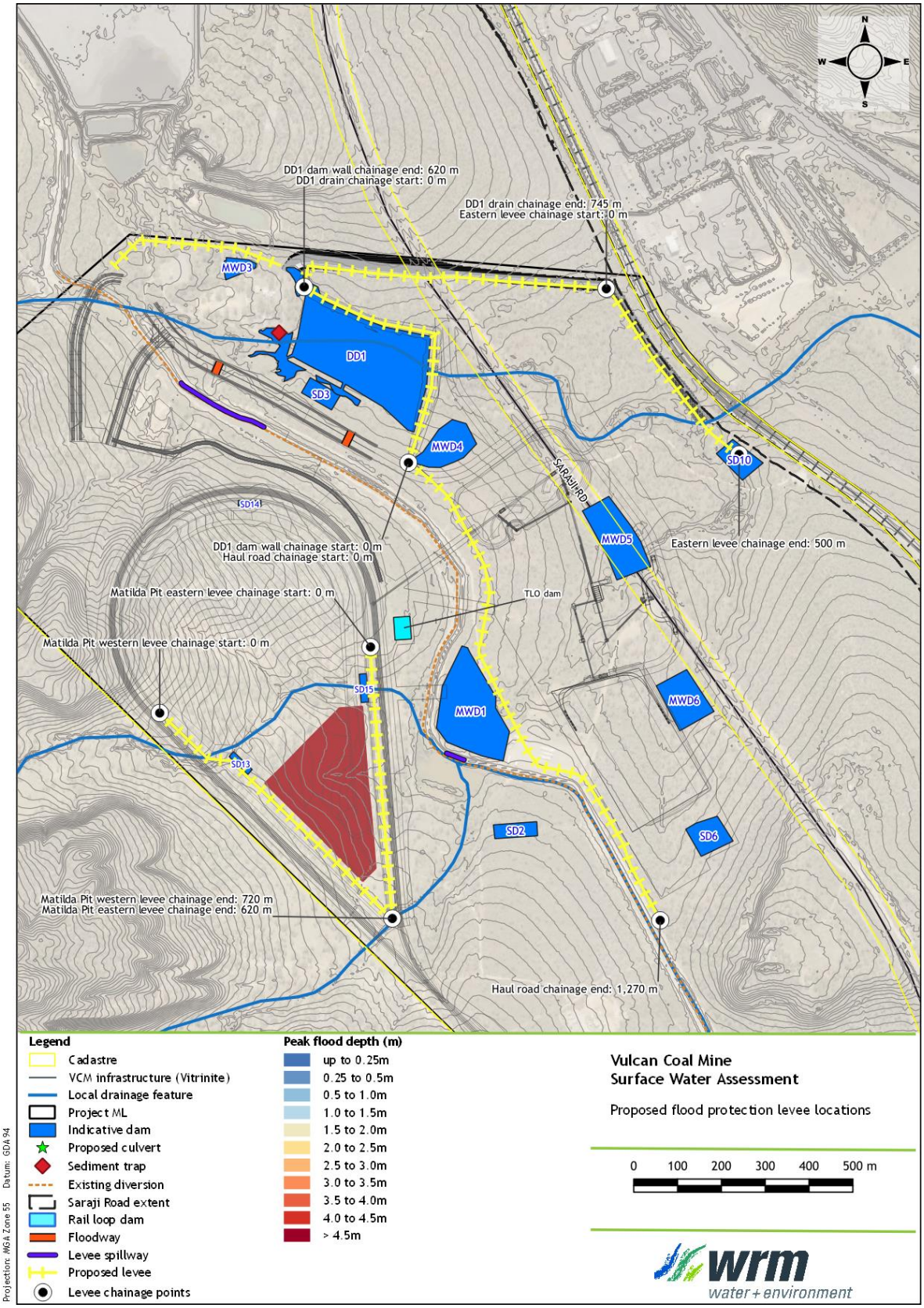


Figure 8.11 - Proposed flood protection levee alignment

8.6.11 Proposed drainage corridor

The proposed drainage corridor was designed to divert runoff from Post-closure Conditions catchments around the proposed Jupiter Final Landform to the existing Drainage Line 1 rail culverts. Figure 8.12 shows a cross-section of the proposed drainage corridor approximately 500 m upstream of the existing Norwich Park Branch Railway culverts under Post-closure Conditions (see Figure 1.4 for cross-section location). Figure 8.12 and Table 8.7 show the modelled flood levels and velocities within the proposed drainage corridor.

The preliminary sizing of the proposed drainage corridor was 40 m wide with 17% batter slopes that grade up to existing ground levels. The results show that the drainage corridor has sufficient capacity under both levee scenarios to convey flood events up to the 0.1% AEP. Refinements to the design will be required to incorporate a meandering low flow channel within the drainage corridor and will be undertaken prior to undertaking detail design. Also, careful consideration of scour protection will be required at the upstream and downstream ends of the drainage corridor as well as at tributary inflow locations.

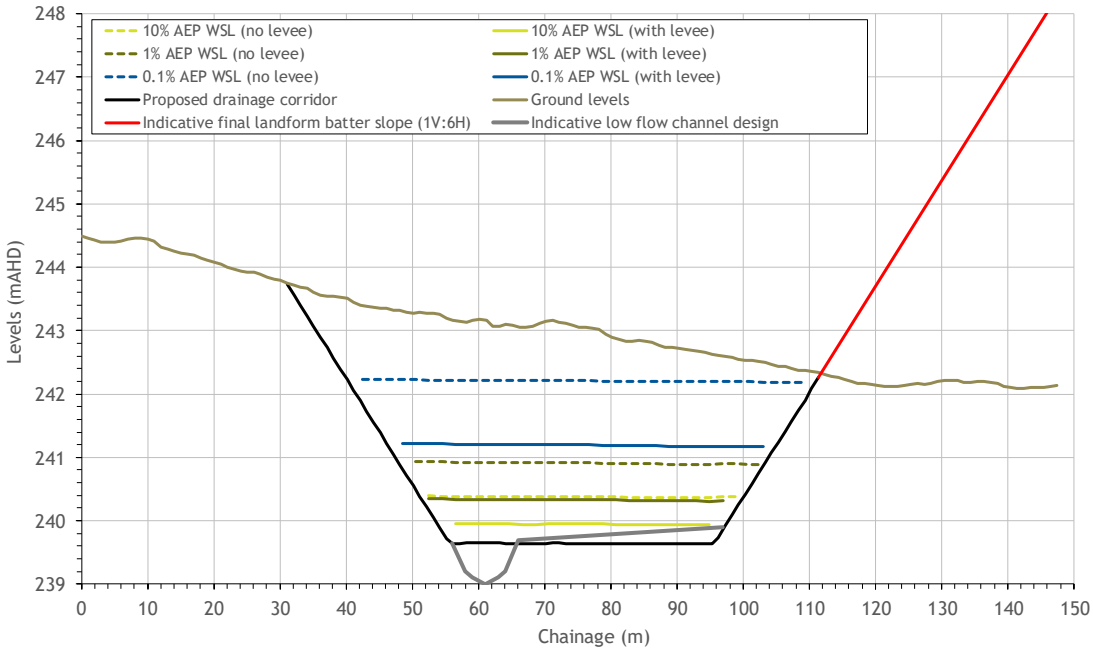


Figure 8.12 – Conceptual cross section of the proposed drainage corridor and the 10%, 1% and 0.1% AEP event water surface elevations for both levee scenarios

Table 8.7 – Indicative drainage corridor depths and velocities during Post-closure Conditions

AEP event (%)	Scenario 1 (with levee)		Scenario 2 (no levee)	
	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)
10%	0.3	0.7	0.75	1.2
1%	0.7	1.1	1.3	1.6
0.1%	1.6	1.7	2.6	1.9

8.7 PRE-MINING CONDITIONS DESIGN FLOOD LEVELS AND EXTENTS

8.7.1 Pre-mining Conditions modelling results

The TUFLOW model was used to determine the Pre-mining Conditions 10%, 1% and 0.1% AEP design flood levels, depth, extents and velocities in the vicinity of the Project for the two levee scenarios. Figure A.1 to Figure A.6 in Appendix A show the predicted flood depth and flood velocity profiles under Pre-mining Conditions (with levee) for the 10%, 1% and 0.1% AEP events. Figure A.7 to Figure A.12 show the predicted flood depth and flood velocity profiles under Pre-mining Conditions (no levee) for the 10%, 1% and 0.1% AEP events.

8.7.2 Scenario 1 – Pre-mining Conditions (with levee)

Key findings on flooding within the Boomerang Creek catchment and its tributaries are summarised below:

- For the 10% AEP event (see Figure A.1 and Figure A.4):
    - floodwaters through the Project area are generally conveyed within the channel banks of natural drainage lines. Saraji Road is overtopped at some crossing locations. The Norwich Park Branch Railway culverts have sufficient flow capacity to convey the 10% AEP event;
    - peak flood velocities along natural drainage channels are typically elevated in the vicinity of the Project area (greater than 2.0 m/s in localised areas);
    - overbank flood depths adjacent to natural drainage lines are generally shallow (less than 0.5 m); and
    - the existing drainage diversion and levee to the west of the Jupiter Pit diverts all upstream flows to Drainage Line 2. Flood depths within the existing drainage diversion are up to 2.2 m.
- For the 1% AEP event (see Figure A.2 and Figure A.5):
    - floodwaters through the Project area are generally conveyed within the channel banks of natural drainage lines with limited overbank flooding. Saraji Road is overtopped at most crossing locations. The Norwich Park Branch Railway culverts have sufficient flow capacity to convey the 1% AEP event;
    - peak flood velocities in natural drainage channels are typically elevated (greater than 2.0 m/s in localised areas). Overbank velocities are generally up to 1 m/s;
    - flood widths and depths adjacent to natural drainage lines are greatest upstream of Saraji Road and Norwich Park Branch Railway where floodwaters are impounded behind the constructed embankments; and
    - floodwaters overtop the existing drainage diversion and levee to the west of the Jupiter Pit at several locations and drain east across the proposed Jupiter Pit footprint before flowing towards the rail culverts. Flood depths within the existing drainage diversion are up to 2.7 m.
- For the 0.1% AEP event (see Figure A.3 and Figure A.6):
    - floodwaters through the Project area are generally conveyed within the channel banks of natural drainage lines with confined overbank flooding;
    - flood velocities along natural drainage channels are typically elevated (greater than 2.5 m/s in localised areas). Overbank velocities are generally up to 1 m/s;
    - peak flood widths and depths along the eastern side of the Project area increase as natural drainage lines drain towards Saraji Road and Norwich Park Branch Railway where floodwaters are impounded behind the constructed

embankments. Overbank flood depths range from about 2 m at the western boundary of the Project area to greater than 4 m at the eastern boundary; and

- floodwaters overtop the existing drainage diversion at a number of locations.

8.7.3 Scenario 2 – Pre-mining Conditions (no levee)

- For the 10% AEP event (see Figure A.7 and Figure A.10):
  - floodwaters previously diverted by the existing drainage diversion and levee drain east to the existing Saraji Road crossings. Floodplain depths are generally less than 1 m upstream of Saraji Road. The existing crossings at Saraji Road and the Norwich Park Branch Railway culverts have sufficient flow capacity to convey the 10% AEP event; and
  - floodwaters draining east towards Saraji Road have peak flood velocities which are typically less than 1.5 m/s.
- For the 1% AEP event (see Figure A.8 and Figure A.11):
  - floodwaters previously diverted by the existing drainage diversion and levee drain to the existing Saraji Road crossings. The northernmost Saraji Road crossing is overtopped by 0.1 m during the 1% AEP event, however, all other existing crossings at Saraji Road and the Norwich Park Branch Railway culverts have sufficient flow capacity to convey the 1% AEP event; and
  - floodwaters draining east towards Saraji Road have peak flood velocities which are typically less than 2 m/s upstream of Saraji Road.
- For the 0.1% AEP event (see Figure A.9 and Figure A.12):
  - floodwaters previously diverted by the existing drainage diversion and levee drain to the existing Saraji Road crossings, where the existing road is overtopped by up to 0.25 m. Floodwaters are impounded behind the constructed Norwich Park Branch Railway embankment, with flood extents up to 500 m; and
  - floodwaters draining east have peak flood velocities which reach up to 2.5 m/s upstream of Saraji Road within the Project area.

8.8 OPERATIONAL CONDITIONS DESIGN FLOOD LEVELS AND EXTENTS

8.8.1 General

Figure 8.5 shows the proposed Operational Conditions configuration used in the TUFLOW model. The TUFLOW model results show that the proposed Operational Conditions configuration may cause potential flow constraints and flood impacts within the Project area. These include:

- Changed flow conditions between the Norwich Park Branch Railway and the realigned Saraji Road realignment;
- Proposed infrastructure as part of the EA amendment, including the rail loop, CHPP, haul road crossing and upgraded haul road; and
- Diversion of Drainage Line 1 around the proposed pit.

Figure B.1 to Figure B.12 show the change in peak water levels and the change in peak velocities for the 10%, 1% and 0.1% AEP events for Operational Conditions compared to Pre-mining Conditions across the Project.

Table 8.8 and Table 8.9 summarise the changes in peak water levels and peak velocities respectively for the 10%, 1% and 0.1% AEP events at the reporting location points shown in Figure B.1 to Figure B.12.

In general, the results show that impacts created by the Project as a result of the proposed infrastructure during Operational Conditions are within the ML boundary for the 10%, 1% and 0.1% AEP events. The impacts for both the proposed crossing at the existing access road and the proposed crossing at the northern MIA are similar for all events assessed, with minor differences surrounding the respective crossing locations.

Areas that will require erosion control measures include the haul road crossing locations, the levee spillway upgrade, where existing natural drainage paths enter constructed drains and at the upstream and downstream ends of constructed drains.

Hence, the proposed surface water drainage infrastructure for the Project will result in a very low risk of changes to the existing erosion and sedimentation process in the receiving environment.

8.8.2 Operational Conditions impacts

Key findings on potential Operational Conditions (for both haul road crossing options) flooding impacts in the vicinity of the project include:

- For the 10% AEP event (see Figure B.1, Figure B.4, Figure B.7 and Figure B.10):
    - there are no increases in peak water levels and peak velocities within the Norwich Park Branch Railway corridor;
    - downstream of the railway corridor, there are no modelled increases in peak water levels and peak velocities; and
    - within the Project ML, there are localised increases in peak water levels and peak velocities in the immediate areas upstream and downstream of the new rail loop embankments and haul road crossing embankment.
- For the 1% AEP event (see Figure B.2, Figure B.5, Figure B.8 and Figure B.11):
    - there are negligible increases in peak water levels and peak velocities within the Norwich Park Branch Railway corridor;
    - downstream of the railway corridor, there are no increases in peak water levels;
    - within the Project area, peak water levels increase within the existing drainage diversion and immediately upstream/downstream of the new rail loop embankments and haul road crossing embankments.
    - within the Project area, peak velocities increase within the existing drainage diversion upstream of the rail loop embankments by up to 3 m/s (near afflux reporting location 6) where the channel is diverted around the embankment. However, peak velocities within the minor channel diversion are similar to the peak velocities within the existing drainage diversion under Pre-mining Conditions. Additional erosion protection may be required to limit scour and erosion within the embankment crossing.
- For the 0.1% AEP event (see Figure B.3, Figure B.6, Figure B.9 and Figure B.12):
    - similar to the existing Saraji Road, the realigned Saraji Road is inundated as the culverts have insufficient capacity to convey the 0.1% AEP event flows and floodwaters are impounded behind the constructed Norwich Park Branch Railway embankment;
    - there are negligible increases in peak water levels and velocities at the Norwich Park Branch Railway culverts; and
    - there are increases in peak water levels and peak velocities within the Norwich Park Branch Railway corridor and the Jupiter pit northern/eastern diversion drain of up to 0.5 m and 2.3 m/s.

Table 8.8 – Changes in peak water levels and peak velocities under Operational Conditions (for crossing location at existing access road) compared to Pre-mining Conditions

Location ID	Modelled change for Operational Conditions compared to Pre-mining Conditions					
	Change in peak water level (m)			Change in velocities (m/s)		
	10%	1%	0.1%	10%	1%	0.1%
1	0.00	-0.96	-0.17	0.00	0.33	0.46
2	-0.50	-1.06	-0.39	-0.08	-0.12	0.01
3	-0.49	-0.93	-0.05	0.03	0.08	-0.22
4	-0.72	-0.61	-0.27	0.17	0.37	0.46
5	0.00	0.06	0.02	0.08	0.14	-0.01
6	0.17	0.18	0.10	-2.05	-2.43	-2.48
7	0.10	0.02	-0.03	-0.33	-0.13	-0.14
8	-0.09	-0.06	-0.01	-0.04	-0.01	0.00
9	-0.01	0.00	-0.01	-0.01	-0.01	0.00

Table 8.9 – Changes in peak water levels and peak velocities under Operational Conditions (for crossing location at northern MIA) compared to Pre-mining Conditions

Location ID	Modelled change for Operational Conditions compared to Pre-mining Conditions					
	Change in peak water level (m)			Change in velocities (m/s)		
	10%	1%	0.1%	10%	1%	0.1%
1	0.00	-0.89	-0.10	0.00	0.33	0.46
2	-0.50	-1.00	-0.30	-0.08	-0.11	0.03
3	-0.49	-0.86	-0.04	0.03	0.08	-0.17
4	-0.43	-0.38	-0.21	0.21	0.42	0.51
5	0.00	0.04	0.00	0.08	0.14	-0.01
6	0.17	0.17	0.09	-2.05	-2.43	-2.48
7	0.10	0.02	-0.03	-0.33	-0.13	-0.15
8	-0.07	-0.06	-0.01	-0.04	-0.01	0.00
9	-0.01	0.00	-0.01	-0.01	-0.01	0.00

8.9 POST-CLOSURE CONDITIONS POTENTIAL FLOOD IMPACTS

8.9.1 General

Figure 8.5 shows the proposed Post-closure Conditions configuration used in the TUFLOW model. The TUFLOW model results show that the proposed Post-closure Conditions configuration may cause potential flow constraints and flood impacts when compared to the Pre-mining Conditions results within the Project area for the events assessed. These include:

- Changed flow conditions between the Norwich Park Branch Railway and the realigned Saraji Road realignment;
- Changed catchment areas due to the final landform configuration; and

- Diversion of Drainage Line 1 around the proposed Jupiter Pit via the northern diversion drain.

Figure C.1 to Figure C.6 show the change in peak water levels and the change in peak velocities for the 10%, 1% and 0.1% AEP events for Post-closure Conditions compared to Pre-mining Conditions (with levee) across the Project.

Figure C.7 to Figure C.12 show the change in peak water levels and the change in peak velocities for the 10%, 1% and 0.1% AEP events for Post-closure Conditions compared to Pre-mining Conditions (no levee) across the Project.

Table 8.10 and Table 8.11 summarise the changes in peak water levels and peak velocities respectively for the 10%, 1% and 0.1% AEP events at the reporting location points shown in Figure C.1 to Figure C.12.

In general, the results show that there are negligible impacts along Drainage Line 1 with the levee for the 10% and 1% AEP events and small impacts for the 0.1% AEP event. Drainage Line 1 impacts without the levee are greater and may require additional erosion protection to cater for the increase flooding potential. The Post-closure Conditions configuration will not impact on peak water levels or velocities along Drainage Line 2, Drainage Line 3, Drainage Line 4 or Boomerang Creek under both levee scenarios for the 10% to 0.1% AEP events.

There will be some minor areas that will require erosion control measures such as where existing natural drainage paths enter constructed drains and at the upstream and downstream ends of constructed drains.

Hence, the proposed surface water drainage infrastructure for the Project will result in a very low risk of changes to the existing erosion and sedimentation process in the receiving environment.

8.9.2 Scenario 1 – Post-closure Conditions impacts (with levee)

Key findings on potential Post-closure Conditions (with levee) flooding impacts in the vicinity of the project include:

- For the 10% AEP event (see Figure C.1 and Figure C.4):
    - there are no increases in peak water levels and peak velocities within the Norwich Park Branch Railway corridor;
    - downstream of the railway corridor, there are no modelled increases in peak water levels and peak velocities; and
    - within the Project ML, peak water levels and peak velocities generally do not change significantly.
- For the 1% AEP event (see Figure C.2 and Figure C.5):
    - there are negligible increases in peak water levels and peak velocities within the Norwich Park Branch Railway corridor;
    - downstream of the railway corridor, there are no increases in peak water levels;
    - within the Project area, peak water levels generally do not increase. Peak velocities at the upstream end of the proposed drainage corridor are up to 1.4 m/s. This highlights the need to construct and revegetate the drainage corridor prior to removing DD1 and allowing upstream inflows into the drainage corridor. If vegetation is not allowed to establish, additional erosion protection may be required to limit scour and erosion within the drainage corridor.
- For the 0.1% AEP event (see Figure C.3 and Figure C.6):
    - similar to the existing Saraji Road, the realigned Saraji Road is inundated as the culverts have insufficient capacity to convey the 0.1% AEP event flows and floodwaters are impounded behind the constructed Norwich Park Branch Railway embankment;

- there are increases in peak water levels and peak velocities within the Norwich Park Branch Railway corridor of up to 0.25 m and 0.4 m/s;
- downstream of the Norwich Park Branch Railway there are minor increases in peak water levels of 0.08 m; and
- within the Project ML, there are generally no increases in peak water levels and peak velocities along Drainage Line 1, except where it connects with the proposed drainage corridor, where maximum velocities are up to 1.9 m/s.

8.9.3 Scenario 2 – Post-closure Conditions impacts (no levee)

Key findings on potential Post-closure Conditions (no levee) flooding impacts in the vicinity of the project include:

- For the 10% AEP event (see Figure C.7 and Figure C.10):
  - within the Norwich Park Branch Railway corridor, there are minor increases in peak water levels of 0.08 m and increases in peak velocities of up to 0.3 m/s;
  - downstream of the railway corridor, there are localised increases in peak water levels and peak velocities of 0.2 m and 0.5 m/s, respectively;
  - within the Project area, there are generally no increases in peak water levels and peak velocities. Typical peak velocities along the proposed drainage corridor are 1.2 m/s. Maximum velocities of up to 1.8 m/s occur at the inlet to the drainage corridor.
- For the 1% AEP event (see Figure C.8 and Figure C.11):
  - the realigned Saraji Road is overtopped during the 1% AEP event under the no levee scenario;
  - within the Norwich Park Branch Railway corridor, there are minor increases in peak water levels of up to 0.09 m and there are increases in peak velocities of up to 0.45 m/s;
  - downstream of the railway corridor, there are negligible increases in peak water levels and increases in peak velocities are 0.3 m/s along the existing dirt road downstream of the railway culverts; and
  - Typical peak velocities along the proposed drainage corridor are 1.6 m/s. Maximum velocities of up to 2.6 m/s occur at the inlet to the drainage corridor.
- For the 0.1% AEP event (see Figure C.9 and Figure C.12):
  - floodwaters are impounded behind the constructed embankment of the Norwich Park Branch Railway with extents spanning 600 m upstream of the railway;
  - within the Norwich Park Branch Railway corridor, there are increases in peak water levels and peak velocities of 0.35 m and 0.35 m/s, respectively;
  - downstream of the railway corridor, there are increases in peak water levels of 0.15 m and increases in peak velocities of 0.75 m/s;
  - there are minor impacts of up to 0.11 m downstream of the Project, however, these impacts do not extend downstream of the railway; and
  - Typical peak velocities along the proposed drainage corridor are 1.9 m/s. Maximum velocities of up to 2.8 m/s occur at the inlet to the drainage corridor.

Table 8.10 - Changes in peak water levels under Post-closure Conditions compared to Pre-mining Conditions

Location ID	Modelled change in peak water level (m) for Post-closure Conditions compared to Pre-mining Conditions					
	Scenario 1 (with levee)			Scenario 2 (no levee)		
	10%	1%	0.1%	10%	1%	0.1%
1	0.00	0.05	0.22	0.08	0.23	0.06
2	-0.21	-0.18	0.13	-0.20	-0.09	0.04
3	-0.19	-0.12	0.01	-0.11	-0.02	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	-0.01	0.53	0.75	1.12
6	0.00	-0.02	0.00	-0.01	0.01	0.13
7	0.00	0.00	0.00	0.03	0.17	0.25
8	-0.01	-0.01	0.00	0.00	0.00	0.09
9	0.00	0.00	0.00	0.00	0.02	0.02

Table 8.11 - Changes in peak velocities under Post-closure Conditions compared to Pre-mining Conditions

Location ID	Modelled change in peak velocity (m/s) for Post-closure Conditions compared to Pre-mining Conditions					
	Scenario 1 (with levee)			Scenario 2 (no levee)		
	10%	1%	0.1%	10%	1%	0.1%
1	0.00	0.18	0.07	0.14	0.08	0.08
2	-0.06	-0.01	0.03	-0.06	-0.03	0.01
3	-0.11	0.05	0.07	0.04	-0.04	0.02
4	0.00	0.00	0.00	0.00	0.00	0.01
5	0.06	0.05	0.01	0.27	0.30	0.52
6	0.00	0.01	0.00	-0.01	0.00	-0.01
7	0.00	0.00	-0.01	0.08	0.40	0.70
8	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00

9 Surface water monitoring

9.1 OVERVIEW

Monitoring of surface water quality both within and external to the mine site will form a key component of the surface water management system. Monitoring of upstream, onsite and downstream water quality will assist in demonstrating that the site water management system is effective in meeting its objective of minimal impact on receiving water quality and will allow for early detection of any impacts and appropriate corrective action.

Further details regarding the monitoring program, including the sampling methodology and analysis process of the monitoring program, is described in the REMP (Vitrinite, 2021).

Details of the receiving water quality monitoring, mine affected water quality monitoring and sediment dam water monitoring program are outlined in Section 9.2, Section 9.3 and Section 9.4 respectively. Locations of the proposed surface water monitoring locations and mine affected dam monitoring locations are shown in Figure 4.16 and Figure 9.1 and summarised in Table 9.1. Note that the mine water release points are the same as the mine water monitoring locations (i.e. at the spillway).

Table 9.1 – Proposed surface water and mine water dam quality monitoring locations

Station ID	Catchment Area	Easting*	Northing*	Description
Receiving water monitoring sites				
Upstream sites				
VSW1	Boomerang Ck	621,003	7,536,086	Diversion bund approximately 3.1 km upstream of Drainage Line 2. Used as an upstream monitoring site for all site dams.
VSW3	Boomerang Ck	623,053	7,532,780	Drainage line 3 upstream of Saraji Road.
VSW5	Hughes Ck	626,062	7,522,834	Hughes Creek approximately 5.0 km upstream of Saraji Road.
VSW6	Hughes Ck	630,659	7,521,084	Barrett Creek upstream of Saraji Road.
VSW11	Boomerang Ck	622,541	7,533,675	Minor drainage line, upstream of confluence of Drainage Line 2.
VESW2[1]	Harrow Ck	610,183	7,546,136	Harrow Creek approximately 8.3 km upstream of Peak Downs Highway.
VESW3	Harrow Ck	615,316	7,528,175	Harrow Creek upstream of the Project.
VESW4	Boomerang Ck	623,621	7,531,088	Drainage line 4 upstream of Saraji Road.
Downstream sites				
VSW2	Boomerang Ck	623,117	7,533,362	Drainage Line 2 upstream of the railway. Used as a downstream monitoring site for MWD2, SD1, SD2, SD4, SD5, SD7, SD8, SD13, SD14, SD15 and SD16.
VSW4[1]	Hughes Ck	630,357	7,524,021	Hughes Creek upstream of Saraji Road.
VSW7[1]	Hughes Ck	626,767	7,528,677	Drainage line 7 upstream of Saraji Road.
VSW8	Boomerang Ck	622,370	7,535,855	Drainage Line 1 upstream of the railway. Used as a downstream site for MWD1, MWD3, MWD4 MWD5, and MWD6 as well as SD3, SD6, SD9, SD10, SD11 and SD12.
VESW1[1]	Harrow Ck	614,134	7,543,160	Harrow Creek approximately 8.7 km upstream of Peak Downs Highway.

Station ID	Catchment Area	Easting*	Northing*	Description
Mine water dam monitoring locations/release points				
MWD1	13.0 ha	621,787	7,535,320	MWD1 spillway
MWD2	6.2 ha	622,650	7,533,934	MWD2 spillway
MWD3	4.5 ha	621,264	7,536,200	MWD3 spillway
MWD4	6.6 ha	621,782	7,535,826	MWD4 spillway
MWD5	15.6 ha	622,173	7,535,590	MWD5 spillway
MWD6	10.4 ha	622,311	7,535,222	MWD6 spillway

* Projection – MGA94 (Zone 55)
[1] Remote logger location

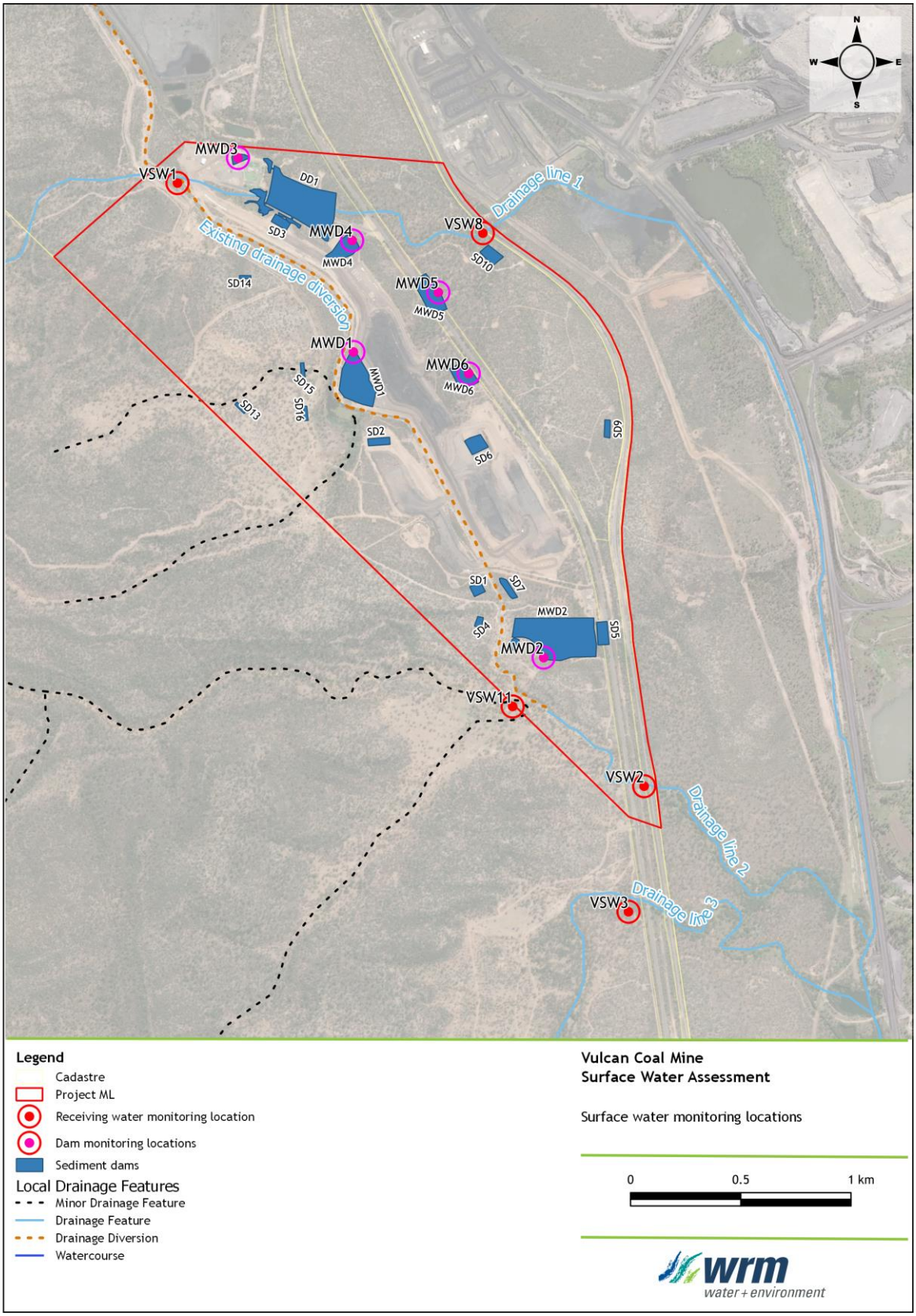


Figure 9.1 - Proposed mine water dam quality monitoring locations

9.2 RECEIVING WATER QUALITY MONITORING

The proponent has undertaken a round of baseline monitoring at a number of surface water locations in the Project vicinity (as detailed in Section 4.5.2). In accordance with condition F10 of the Project EA, Vitrinite will monitor the receiving water locations shown in Figure 4.16 and Figure 9.1 and summarised in Table 9.1. These locations will be monitored during natural flow events and release events (i.e. releases from sediment or mine dams) to achieve at least 24 sampling events over a 2-year period. Vitrinite will submit the results of the receiving waters monitoring to DES no more than 2 years from the commencement of activities to evaluate whether the site-specific trigger values prescribed in the Project EA are suitable.

In addition, in accordance with condition F7 of the Project EA, Vitrinite will ensure streamflow gauging stations are operated and maintained at the receiving water locations to determine and record streamflows. The receiving water monitoring points are required to be monitored for the parameters specified in Table 9.2.

The receiving water locations will be monitored against the WQOs for the Project (outlined in Table 9.2). In addition, preliminary release contaminant trigger investigation levels have been proposed for downstream monitoring sites.

- Receiving waters monitoring locations are classified as upstream or downstream sites to assist with trigger investigations. The sites are classified as follows:
- VSW3, VSW5, VSW6, VSW11, VESW2, VESW3 and VESW4 are upstream monitoring points;
- VSW2, VSW4, VSW7, VSW8 and VESW1 are downstream monitoring points. VSW2 and VSW8 are classified as downstream sites corresponding to particular storages, as outlined in Table 5.2.

Table 9.2 – Receiving water contaminant trigger investigation levels

Parameter	Interim dam release point trigger value		Interim downstream monitoring point trigger value		Frequency
pH (pH units)	6.5 - 8.5		6.5 - 8.5		Upon commencement (the first sample must be taken within 2 hours of commencement of release), daily during release, and within 2 hours after cessation of release.
Electrical Conductivity (µS/cm)	Low Flow[1]	<864	Low Flow[1]	<720	
	Medium Flow[2]	<600	Medium Flow[2]	<500	
	High Flow[3]	<300	High Flow[3]	<250	
Total suspended solids (mg/L)[4]	234.2		195.2		
Turbidity (NTU)[4]	606		505		
Dissolved oxygen	64% - 132% saturation		80% - 110% saturation		
Sulphate (mg/L)	924		770		
Filtered metals and metalloids					
Filtered Lead (µg/L)	4.8		4		Upon commencement (the first sample must be taken within 2 hours of commencement of release), daily during release, and within 2 hours after cessation of release.
Filtered Mercury (µg/L)	0.72		0.6		
Filtered Arsenic (µg/L)	28.8		24		
Filtered Aluminium (µg/L)	864		720		
Filtered Molybdenum (µg/L)	40.8		34		
Filtered Selenium (µg/L)	13.2		11		

9.3 MINE AFFECTED WATER QUALITY MONITORING

The water quality monitoring program will also include monitoring at all dams which contain mine affected water with the potential to discharge to the receiving waters. This includes the following dams:

- MWD1;
- MWD2;
- MWD3;
- MWD4;
- MWD5; and
- MWD6

Locations of the proposed mine water monitoring locations are shown in Figure 9.1 and summarised in Table 9.1.

In accordance with condition F13 of the Project EA, in the event of an uncontrolled release from a mine affected water dam as a result of a rainfall event that exceeds design specifications, Vitrinite will:

1. notify the administering authority via WaTERS within 24 hours of the commencement of the release;
2. notify the administering authority via WaTERS within 24 hours of the cessation of the release; and
3. conduct an investigation within 20 business days of cessation of the release.

In accordance with condition F14 of the Project EA, the investigation required under condition 3 above must determine:

1. whether environmental harm has or may occur;
2. cause of the uncontrolled release;
3. where relevant, measures to address environmental harm; and
4. where relevant, measures to prevent recurrence of uncontrolled release(s).

Vitrinite will submit the results of the investigation to the administering authority within 28 days after completing the investigation. Water quality parameters which will be collected for the mine water dams are outlined in Table 9.2. Note that the metals listed in Table 9.2 will be analysed for both total and dissolved concentrations.

9.4 SEDIMENT DAM MONITORING

In accordance with condition F5 of the Project EA releases from sediment dams will be monitored at their release points for the water quality parameters specified in Table 9.2 The Project sediment dams are shown in Figure 9.1 and details regarding the sediment dams (including the location of release points) is outlined in Table 5.2.

9.5 TRIGGER INVESTIGATION

In accordance with condition F6 of the Project EA, Vitrinite will complete an investigation if water quality sampling identifies 3 consecutive exceedances of:

a) interim sediment dam release trigger values detailed in Table 9.2, at the sediment dams specified in Table 5.2; and

b) interim downstream monitoring point trigger values detailed in Table 9.2, at the receiving water locations specified in Section 9.1.

In accordance with condition F8 of the Project EA, where the quality characteristics of the release exceed any of the trigger values specified in Table 9.2 on 3 consecutive occasions, the environmental authority holder must compare the downstream results to the upstream results and:

a) where the downstream result is the same or a lower value than the upstream value for the quality characteristic and the trigger values are not exceeded, then no action is to be taken; or

b) where the downstream result exceeds the values specified in Table 9.2:

    1. if the result is less than the upstream monitoring site data, then no action is to be taken, or

    2. if the result is greater than the upstream monitoring site data, complete an investigation and provide a written report to the administering authority via WaTERS within 90 days of receiving the result, outlining:

        i. details of the investigations carried out;

        ii. determine if the exceedance is a result of:

            a. activities authorised under the Project EA;

            b. natural variation; or

            c. neighbouring land uses;

    3. if exceedances are a result of activities authorised under the Project EA, detail:

        i. level of environmental harm; and

        ii. actions taken to prevent environmental harm.

Where an exceedance of a trigger level has occurred and is being investigated, in accordance with a) and b) (1) above, no further reporting is required for subsequent trigger events for that quality characteristic.

In accordance with condition F9 of the Project EA, if an investigation occurs in accordance with condition b) (3) above, Vitrinite will determine whether environmental harm has or may occur, and detail:

a) strategies to implement immediate measures to reduce the potential for environmental harm; and

b) develop long-term mitigation measures to address any surface water contamination and prevent recurrence of surface water contamination.

Vitrinite must provide details of the measures implemented or to be implemented to reduce the potential for environmental harm as well as the long-term mitigation measures to the administering authority within 28 days after completing the investigation.

9.6 RECEIVING ENVIRONMENT MONITORING PROGRAM (REMP)

Further details regarding the monitoring program, including the sampling methodology and analysis process of the monitoring program, is described in the REMP (Vitrinite, 2021). The REMP will incorporate the historical and proposed monitoring as described in Section 4.5.2 and in the sections above.

The main objective of the REMP will be to report against WQOs for local waterways potentially affected by discharge from the Project and will assist in assessing general aquatic ecosystem health.

10 Cumulative impacts

10.1 OVERVIEW

The objective of this assessment is to identify the potential for impacts from the Project to have compounding interactions with similar impacts from other projects, including activities proposed, under development or already in operation within a suitable region of influence of the Project.

There are two levels at which cumulative impacts have been assessed:

- Localised cumulative impacts – These are the impacts that may result from multiple existing or proposed mining operations in the immediate vicinity of the Project. Localised cumulative impacts include the effect from concurrent operations that are close enough to potentially cause additive effect on the receiving environment. For the purposes of this assessment, all existing and proposed projects located within the Isaac River catchment have been included; and
- Regional cumulative impacts – These include the Project's contribution to impacts that are caused by mining operations throughout the Bowen Basin region or at a catchment level. Each coal mining operations in itself may not represent a substantial impact at a regional level; however, the cumulative effect on the receiving environment may warrant consideration.

10.2 EXISTING PROJECTS

Projects which are currently operating within the Isaac River catchment upstream of the Deverill gauging station and have been included in the cumulative impacts assessment for the project are listed in Table 10.1.

10.3 NEW OR DEVELOPING PROJECTS

Relevant projects that have been considered include:

- Projects within the predicted sphere of influence of the Project, as listed on the Department of State Development, Manufacturing, Infrastructure and Planning (DSDMIP) website that are undergoing assessment under the State Development and Public Works Organisation Act 1971 (SDPWO Act) for which an Initial Advice Statement (IAS) or an EIS are available;
- Projects within the predicted sphere of influence of the Project, which are listed on the website of the Department of Environment and Science (DES) that are undergoing assessment under the Environmental Protection Act 1994 (EP Act) for which an IAS or an EIS are available; and
- Projects within the predicted sphere of influence of the Project, which are listed on the website of the Department of Infrastructure, Local Government and Planning (DILGP) that are undergoing assessment under the Regional Planning Interests Act 2014 (RPI Act) for which an Assessment Application is available.

Projects currently undergoing assessment or having recently completed assessment under these processes and included in the cumulative impact assessment for the Project are listed in Table 10.2.

10.4 CUMULATIVE IMPACTS – SURFACE WATER RESOURCES

10.4.1 Water quality

The Project is located in the Isaac River catchment, which is a major tributary within the Fitzroy basin. The Fitzroy basin is the largest catchment in Queensland draining into the Pacific Ocean and also the largest catchment that drains to the Great Barrier Reef, although it does not contribute significant freshwater flows to the coastal environment when compared to river systems further north.

In 2008, the Queensland Government undertook an investigation into the cumulative effects of coal mining in the Fitzroy River basin on water quality (EPA, 2009). The investigation found that:

- There were inconsistencies in discharge quality limits and operating requirements for coal mine water discharges as imposed through environmental authorities; and
- In some cases, discharge limits and operating conditions of coal mines were not adequately protecting downstream environmental values.

These conclusions led to a number of inter-related actions by Queensland Government and other stakeholders:

- Water quality objectives were developed for the Fitzroy Basin and added to Schedule 1 of the Environmental Protection (Water and Wetland Biodiversity) Policy 2019 (EPP (WWB)) in October 2011;
- Model water conditions were developed for coal mines in the Fitzroy basin (DERM February 2012). These model water conditions are designed to manage water discharges to meet the water quality objectives set out in the EPP (WWB) and to provide consistency between mining operations in the Fitzroy basin;
- Environmental authorities for a number of mining operations were amended to introduce conditions consistent with the model water conditions; and
- A number of mining operations entered into Transitional Environmental Programs (TEP) under the EP Act. These TEPs were focussed on actions that would allow mines to achieve compliance with new environmental authority conditions and upgrade operating conditions.

With these measures in place, a strong strategic and policy framework is now in place for management of cumulative water quality impacts from mining activities. This framework allows for management of individual mining activities in such a way that overarching water quality objectives can be achieved.

Mine affected water from the proposed Project will be managed through a mine water management system which is designed to operate in accordance with proposed EA conditions that are based on Model Mining Conditions, and incorporated into the release criteria used in modelling the mine water management system in this report.

It is noted that the Project is located within the Boomerang Creek catchment, which has already been significantly disturbed by existing mining operations in the Project vicinity.

In addition, given that the Project water releases will be managed within an existing overarching strategic framework for management of cumulative impacts of mining activities, the proposed management approach for mine water from the project is expected to have negligible cumulative impact on surface water quality and associated environmental values.

Table 10.1 – Existing projects considered in the cumulative impact assessment

Project - Proponent	Description	Operational status	Relationship to the Project Mining Lease	
			Timing	Location
Burton Mine – Peabody Energy Australia	Open cut coal mine	Ceased production indefinitely	May have overlapping operational phases with the construction and operations of the project, although unlikely given the current operational status.	Located 75 km to the north of the Project area. Located within the Isaac River catchment (upstream).
North Goonyella Mine - Peabody Energy Australia	Open cut coal mine	Operating	May have overlapping operational phases with the construction and operations of the project.	Located 75 km to the northwest of the Project area. Located within the Isaac River catchment (upstream).
Goonyella Riverside Mine - BMA	Open cut coal mine	Operating	May have overlapping operational phases with the construction and operations of the project.	Located 60 km to the northwest of the Project area. Located within the Isaac River catchment (upstream).
Moranbah North Mine – Anglo American	Underground coal mine	Operating	May have overlapping operational phases with the construction and operations of the project.	Located 50 km to the northwest of the Project area. Located within the Isaac River catchment (upstream).
Grosvenor Mine – Anglo American	Underground coal mine	Operating	May have overlapping operational phases with the construction and operations of the project.	Located 40 km to the north of the Project area. Located within the Isaac River catchment (upstream).
Broadlea Mine – Fitzroy Australia Resources	Open cut coal mine	Care and maintenance	May have overlapping operational phases with the construction and operations of the project.	Located 40 km to the north of the Project area. Located within the headwaters of Smoky Creek, within the Isaac River catchment.
Carborough Downs Mine – Fitzroy Australia Resources	Underground coal mine	Operating	May have overlapping operational phases with the construction and operations of the project.	Located 35 km to the northeast of the Project area. Located within the headwaters of Billy's Gully, within the Isaac River catchment.
Isaac Plains Mine - Stanmore Coal	Open cut coal mine	Operating	May have overlapping operational phases with the construction and operations of the project.	Located 35 km to the north of the Project area. Located within the headwaters of Billy's Gully, within the Isaac River catchment.
Millennium Mine – Peabody Energy Australia	Open cut coal mine	Operating	May have overlapping operational phases with the construction and operations of the project.	Located 30 km to the northeast of the Project area. Located within the headwaters of Southern Gully, within the Isaac River catchment.
Daunia Mine - BMA	Open cut coal mine	Operating	May have overlapping operational phases with the construction and operations of the project.	Located 25 km to the northeast of the Project area. Located within the Isaac River catchment (upstream).

Poitrel Mine - BMA	Open cut coal mine	Operating	May have overlapping operational phases with the construction and operations of the project.	Located 20 km to the northeast of the Project area. Located within the Isaac River catchment (upstream).
Caval Ridge Mine - BMA	Open cut coal mine	Operating	May have overlapping operational phases with the construction and operations of the project.	Located 10 km to the north of the Project area. Located within the Isaac River catchment (upstream).
Peak Downs Mine - BMA	Open cut coal mine	Operating	May have overlapping operational phases with the construction and operations of the project.	Located directly adjacent (i.e. less than 1 km to the north and east of the Project area. Located within the Isaac River catchment.
Moorvale Mine – Peabody Energy Australia	Open cut coal mine	Operating	May have overlapping operational phases with the construction and operations of the project.	Located 35 km to the northeast of the Project area. Located within the headwaters of North Creek, within the Isaac River catchment.
Saraji Mine – BMA	Open cut coal mine	Operating	May have overlapping operational phases with the construction and operations of the project.	Located 10 km to the southeast of the Project area. Located within the Isaac River catchment.
Norwich Park Mine – BMA	Open cut coal mine	Ceased production indefinitely	May have overlapping operational phases with the construction and operations of the project, although unlikely given the current operational status.	Located 45 km to the southeast of the Project area. Located within the Isaac River catchment (downstream).
Lake Vermont Mine – Jellinbah Group	Open cut coal mine	Operating	May have overlapping operational phases with the construction and operations of the project.	Located 30 km to the southeast of the Project area. Located within the Isaac River catchment (downstream).

Table 10.2 – Proposed projects considered in the cumulative impact assessment

Project - Proponent	Description	Project status	Relationship to the Project Mining Lease	
			Timing	Location
Moranbah South Project – Anglo American	Underground coal mine	Approved project	May have overlapping operational phases with the construction and operations of the project.	Located 30 km to the northwest of the Project area. Located within the Isaac River catchment (upstream).
Moorvale South Project – Peabody Energy Australia	Open cut coal mine	Approved project	May have overlapping operational phases with the construction and operations of the project.	Located 25 km to the northeast of the Project area. Located within the Isaac River catchment (upstream).
Eagle Downs Mine – Bowen Central Coal Joint Venture	Underground coal mine	Construction on hold – site on care and maintenance	May have overlapping operational phases with the construction and operations of the project.	Located 10 km to the north of the Project area. Located within the Isaac River catchment upstream).
Winchester South Project – Whitehaven Coal	Open cut coal mine	EIS active	May have overlapping operational phases with the construction and operations of the project.	Located 15 km to the northwest of the Project area. Located within the Isaac River catchment (upstream).
Olive Downs Coking Coal Project – Pembroke Olive Downs Pty Ltd	Open cut coal mine	Approved with conditions	May have overlapping operational phases with the construction and operations of the project.	Located 10 km to the west of the Project area. Located within the Isaac River catchment (downstream).
Saraji East Mine - BMA	Open cut coal mine	EIS active	May have overlapping operational phases with the construction and operations of the project.	Located 15 km to the southwest of the Project area. Located within the Isaac River catchment (downstream).
Dysart East Coal Mine – Bengal Coal	Underground coal mine	ML granted	May have overlapping operational phases with the construction and operations of the project.	Located 35 km to the southwest of the Project area. Located within the Isaac River catchment (downstream).
Red Hill - BMA	Underground coal mine	Approved with conditions	May have overlapping operational phases with the construction and operations of the project.	Located 60 km to the northeast of the Project area. Located within the Isaac River catchment (upstream).
Isaac Downs Project	Open cut coal mine	EIS active	May have overlapping operational phases with the construction and operations of the project.	Located 30 km to the north of the Project area. Located within the Isaac River catchment (upstream).

10.4.2 Loss of catchment and stream flows in the Isaac River

The Project will result in a loss of catchment to the Isaac River during operations, which will be reinstated after closure. The surface runoff volume lost from the catchment will generally be in proportion to the loss of catchment area. The Project area is less than 0.03% of the catchment area of the Isaac River to the confluence of Phillips Creek. Of this, around 60% of this area is managed through the ESCP and then released to the downstream environment.

There are approximately 18 existing coal mines in the vicinity of the Project that also capture runoff from the Isaac River catchment, as shown in Figure 10.1. The total estimated captured area of all these projects (including the Project) combined represents around 7.1% of the Isaac River catchment to the Phillips Creek confluence.

A comparison of the captured catchment areas of the existing mining projects considered in the cumulative impact assessment with the Isaac River catchment to the Phillips Creek confluence is provided in Table 10.3, which indicates the following:

- The combined total catchment area of the existing mines (including the Project) represents around 7.1% of the total catchment area of the Isaac River to the Phillips Creek confluence; and
- The combined mine affected catchment area (estimated) represents less than 2.4% of the total Isaac River catchment area to the Philips Creek confluence.

When taking into account potential discharges from the operating mines in accordance with their current approved release rules, the overall loss of catchment area and associated stream flow is relatively small. In practical terms, impacts on the volume of water flow in the Isaac River would be negligible.

Table 10.3 - Catchment area of existing projects considered in the cumulative impact assessment

Catchment	Total catchment area (km^2)	Estimated mine affected catchment area (km^2)
Vulcan Coal Mine (the Project)	2.64	1.1
Other mines	551	182
Combined	554	183
Isaac River (to the Phillips Creek confluence)	7,731	-

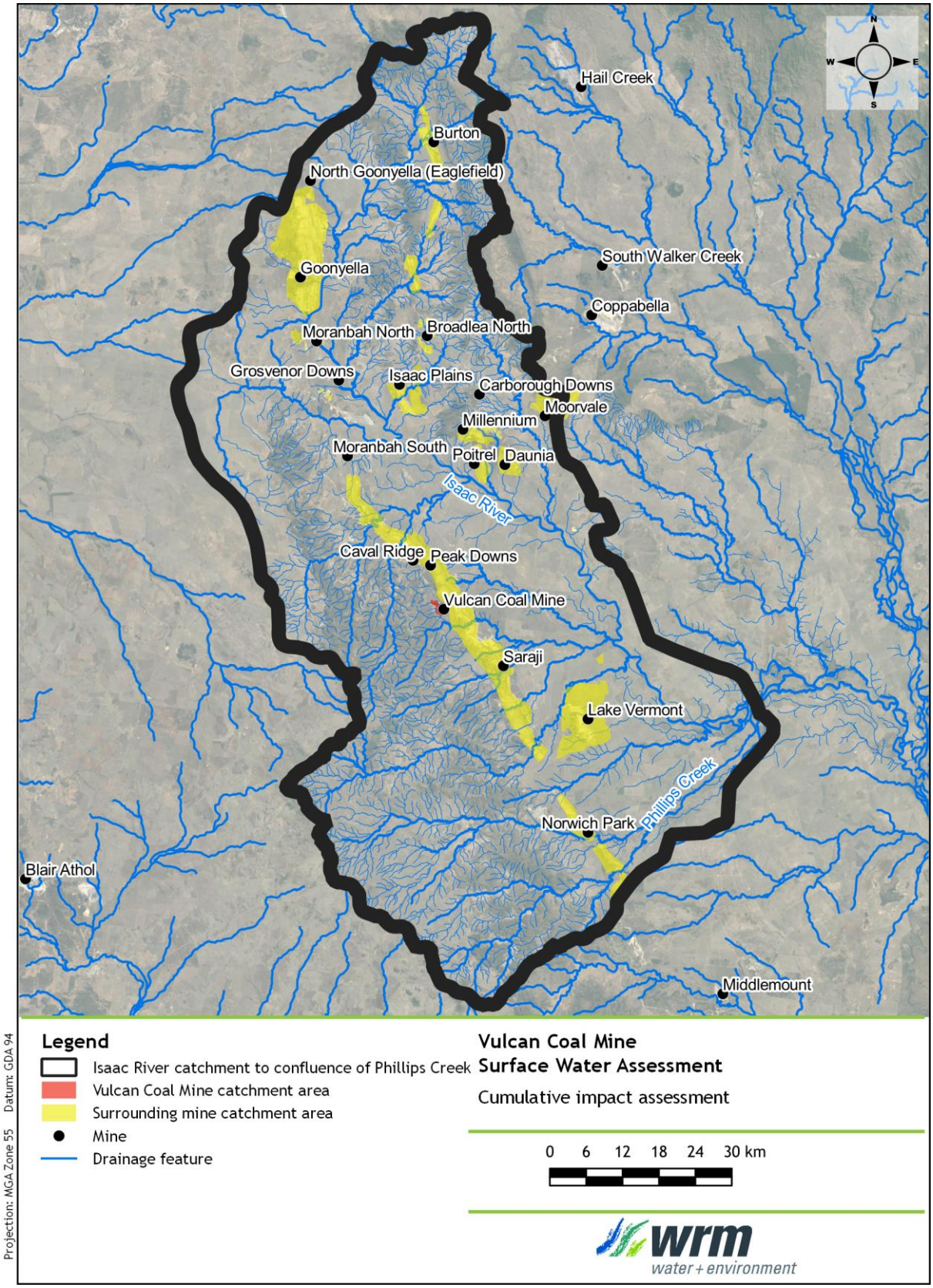


Figure 10.1 – Cumulative impact assessment

11 Summary of findings

11.1 OVERVIEW

The potential impacts of the Project on surface water resources will be mitigated through the implementation of a mine site water management system to control the flow and storage of water of different qualities across the site. A surface water monitoring program will be implemented to monitor potential environmental impacts and ensure that the site water management system is meeting its objectives.

11.2 WATER MANAGEMENT SYSTEM PERFORMANCE

The performance of the mine water management system has been investigated using a detailed site water balance model. The model simulated water inflows and outflows through the various stages of mine development, based on 125 realisations with different climatic sequences.

Water collected on the site will be used as first priority to satisfy site demands. Mine affected water from the infrastructure areas and open cut pit will be collected in MWD1 and reused to meet operational needs.

External water will be supplied to MWD1 when the site water inventory is at a low level, in order to meet site water demands.

The water balance results show that although water collected on site will be used as a first priority to meet mine demands, the Project will frequently require external water to operate. Under 50%ile conditions, the Project is predicted to require up to 302 ML/annum in external water under 50%ile conditions.

The water balance model was used to assess the risk of uncontrolled offsite spills from the mine affected water dams that can potentially overflow directly to the receiving environment (MWD1, MWD2, MWD3, MWD4, MWD5 and MWD6). There were no modelled overflows from the mine affected water dams to the receiving environment during any of the model realisations over the life of the Project.

11.3 FLOODING

The flood impact assessment undertaken for the Project showed that Operational and Post-closure conditions compared with Pre-mining Conditions results in changes to flood levels and velocities, however, impacts are generally confined within the Project ML.

The operational conditions infrastructure creates impacts (temporarily for the life of the Project) that are generally confined within the Project ML, and does not impact on flood levels upstream or downstream of the Project area. Impacts in waterways within the Project ML occur upstream of proposed embankments (rail and road crossing) of the waterways and it is recommended that erosion and scour protection options are implemented to key in these embankments.

For the modelled scenario with the existing drainage diversion and levee, the changes in peak water levels and peak velocities were relatively small under the 10% and 1% AEP events. The modelled scenario with no existing drainage diversion and levee resulted in increased flows draining east through the site and showed that the potential impacts under the 10% and 1% AEP events are slightly higher than the scenario with the levee.

For rare events (0.1% AEP), the predicted change in flood level and velocity in the vicinity of the Project ML extends downstream of the Saraji Road realignment and the Norwich Park Branch Railway corridor. The predicted increase in water level and velocity is less than 0.35 m and 0.4 m/s respectively for both levee scenarios. It is recommended that erosion and scour protection options are considered along the proposed drainage corridor

and existing channels where these increases occur as required to mitigate the risk of rapid geomorphic change.

Overall, the impact of the Project on the hydraulic characteristics of Boomerang Creek and its tributaries do not affect the Pre-mining Conditions significantly. It is expected that the channel and floodplain will undergo little, if any, adjustment to the altered hydraulic conditions upstream or downstream of the Project as a result of the Project. It is critical that suitable erosion protection and revegetation is implemented along permanent drainage structures as soon as possible to mitigate the risk of any rapid geomorphic change.

11.4 WATER QUALITY OBJECTIVES

Water quality objectives were set based on an assessment of baseline sample data collected at selected monitoring point locations, Schedule 1 of EPP (WWB) and the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018) and MMC (DES, 2017) default trigger values.

As per ANZG (2018), reference data can be used to derive SSGVs for water quality when natural background concentrations of a toxicant exceed the Project WQO default trigger value. Samples were collected over seven (7) flow events and twenty-four (24) upstream monitoring point samples were analysed. The 80th percentile values of the baseline sample data which were adopted (i.e. parameters which exceeded default trigger values) as the locally derived WQOs include:

- Filtered Iron - 0.72 mg/L;
- Filtered Aluminium – 0.72 mg/L;
- Filtered Selenium – 0.01 mg/L;
- Iron – 10.44 mg/L;
- Aluminium – 8.13 mg/L;
- Bicarbonate as CaCO3 - 97 mg/L;
- Sodium – 19.40 mg/L;
- Carbonate as CaCO3 – 8.00 mg/L;
- Calcium – 5.80 mg/L;
- Chloride – 31.00 mg/L;
- Potassium – 7.00 mg/L; and
- Magnesium – 5.40 mg/L.

11.5 IMPACTS ON DOWNSTREAM WATER QUALITY

The baseline monitoring and WQO assessment indicates that water quality in the surrounding environment is of poor quality. Notwithstanding, the water balance modelling indicates that no mine affected spills are predicted from mine operations. In addition, modelling predicts that spills from the sediment dams will be below the 720 µS/cm WQO for low flows. Baseline salinity exceeds the WQO for high flows.

In consideration of the already heavily disturbed nature of the surrounding catchment, it is unlikely that Project releases will have a measurable impact on receiving water quality or environmental values.

11.6 CUMULATIVE IMPACTS

The Project will reduce the catchment area draining to receiving waters due to capture of runoff from disturbed catchment areas within the water management system. The Project catchment area represents approximately 0.03% of the total catchment area of the Isaac River to its confluence with Phillips Creek. Of this, approximately 60% will be managed through the Project ESC and released back to receiving waters. The combined total

catchment area of the existing mines (including the Project) represents around 7.1% of the total catchment area of the Isaac River to the Phillips Creek confluence.

The site water management system has been designed such that the risk of offsite release of mine affected water is very low (with no modelled mine affected dam uncontrolled releases under any climatic conditions).

11.7 OPERATIONAL CONDITIONS

A conceptual operational conditions water management plan for the Project over the life-of-mine plan has been developed. The key features of the operational conditions are:

- Proposed life-of-mine landforms and open cut pits;
- Proposed haul road, haul road crossing and haul road culverts;
- Proposed modifications to BMA's existing drainage diversion and levee;
- Proposed rail loop and associated rail loop drainage infrastructure;
- Proposed Matilda Pit drainage diversion and levees;
- Proposed CHPP infrastructure area;
- Proposed DD1 dam and diversion drains/bunds;
- Realignment of Saraji Road; and
- Saraji Road culverts.

In summary, the proposed infrastructure over the life of the Project will create temporary impacts within the Project ML, however, is not considered likely to have a long-term significant impact on the receiving waters.

11.8 FINAL LANDFORM

A conceptual final landform water management plan for the Project under post-closure conditions has been developed. The key features of the final landforms are:

- No final voids are proposed. All open cut pits will be backfilled with overburden material.
- Drainage structures will be implemented on and around the final landforms to ensure that the landforms are free draining.
- When sediment dam catchments are completely rehabilitated, and water quality monitoring of the runoff has established that it is consistent with natural background conditions, the sediment dam and associated drainage infrastructure will be decommissioned.

In summary, the conceptual final landforms are not considered likely to have a long-term significant impact on the receiving waters.

12 References

AARC, 2019	*Vulcan Project Soil and Land Suitability Assessment*. October 2019
ANZECC & ARMCANZ, 2000	Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality.
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 ACT, Australia. Available at www.waterquality.gov.au/anz-guidelines
Ball et al, 2019	*'Australian Rainfall and Runoff: A Guide to Flood Estimation'*, Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), © Commonwealth of Australia (Geoscience Australia), 2019.
BMT, 2018a	TUFLOW (software), BMT, version 2018-03-AD, 2018.
BMT, 2018b	*'TUFLOW Classic/HPC User Manual – Build 2018-03-AD'*, BMT WBM, 2018a.
BOM, 2003	*'The Estimation of Probable Maximum Precipitation in Australia, Generalised Short Duration Method'*, Hydrometeorological Advisory Service, Commonwealth Bureau of Meteorology, June 2003.
Boughton, 2003	Cooperative Research Centre for Catchment Hydrology (2003). Technical Report 03/15, Calibrations of the AWBM for the use on ungauged catchments.
Chow, 1959	*Open-Channel Hydraulics*, McGraw-Hill Inc., Singapore, 1959.
CSIRO and Bureau of Meteorology, 2015	*Climate change in Australia Information for Australia's Natural resource Management Regions: Technical Report*, CSIRO and Bureau of Meteorology, Australia.
DEHP, 2011	*Isaac River Sub-basin Environmental Values and Water Quality Objectives Basin No. 130 (part)*
DES, 2013	*WQ1301 – Isaac River Sub-basin Environmental Protection (Water) Policy 2009 – Central Queensland Map Series*, Department of Environment and Science, published July 2013, < https://environment.des.qld.gov.au/__ data/assets/pdf_file/0023/86900/isaac_plan_300811.pdf>
DES, 2016	*Manual for assessing consequence categories and hydraulic performance of structures*. Version 5.02.
DES, 2017	*Guideline Model Mining Conditions*. ESR/2016/1936. Version 6.02. Effective 07 March 2017.
RDMW, 2017	Department of Regional Development, Manufacturing and Water (RDMW) (2017). Water Information Portal (https://water-monitoring.information.qld.gov.au/).
Geoscience Australia, 2019	AR&R Data Hub (software), Geoscience Australia, Version 2019_v1, April 2019, <http://data.arr-software.org/>.

Hydrogeologist.com.au, 2020	*Vulcan Mining Complex Groundwater Assessment*
IECA, 2008	International Erosion Control Association (IECA) (2008). *Best Practice Erosion and Sediment Control Guideline*.
Innovyze, 2019	XP-RAFTS (software), Innoyvze, Version 2018.1.2, 2019
McKenzie NJ, Grundy MJ, Webster R and Ringrose-Voase, 2008	*Guidelines for Surveying Soil and Land Resources*. Australian Soil and Land Survey Handbook Series. CSIRO Publishing, Melbourne
Queensland Government, 2019	*Queensland Globe service*. Accessed February 2020
RGS Environmental Pty Ltd, 2022	*Preliminary Geochemistry Results – Jupiter and Vulcan Target Prospects. Vulcan Complex.*
WRM, 2012	*Lake Vermont Coal Mine Site Water Balance Model Report*. Lake Vermont Resources

Appendix A – Pre-mining Conditions flood maps and results

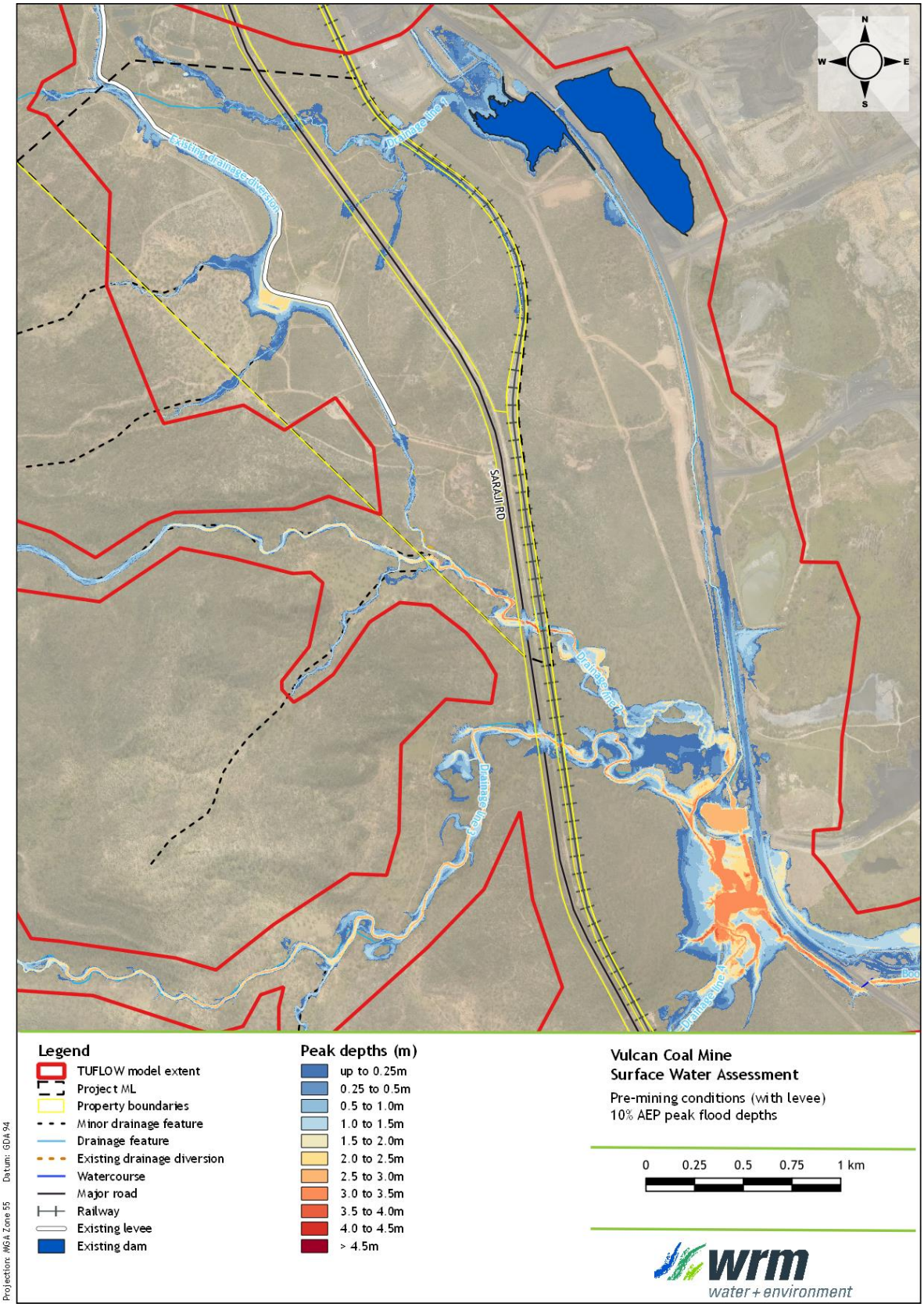


Figure A.1 – 10% AEP peak flood depths – Pre-mining Conditions (with levee)

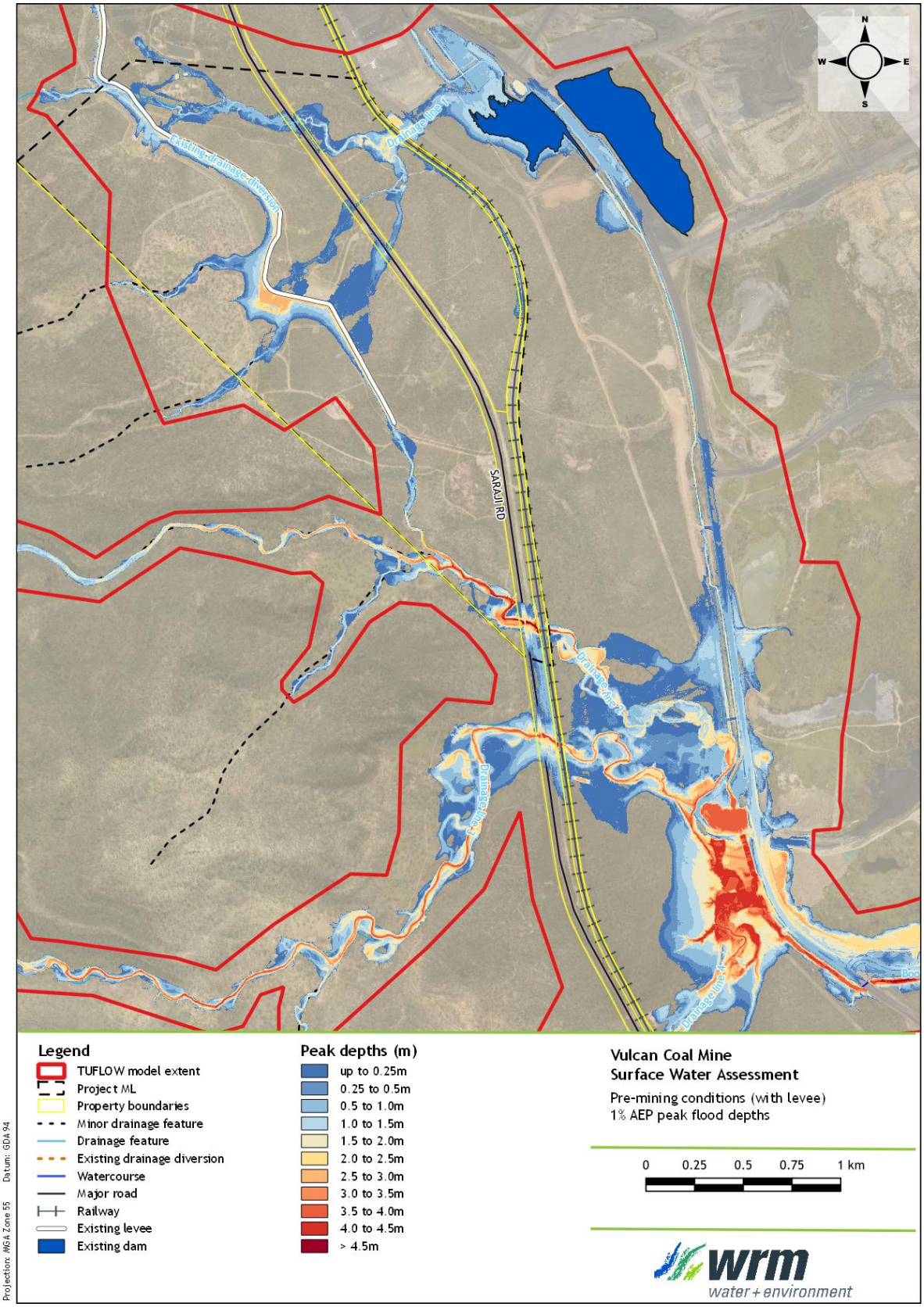


Figure A.2 – 1% AEP peak flood depths – Pre-mining Conditions (with levee)

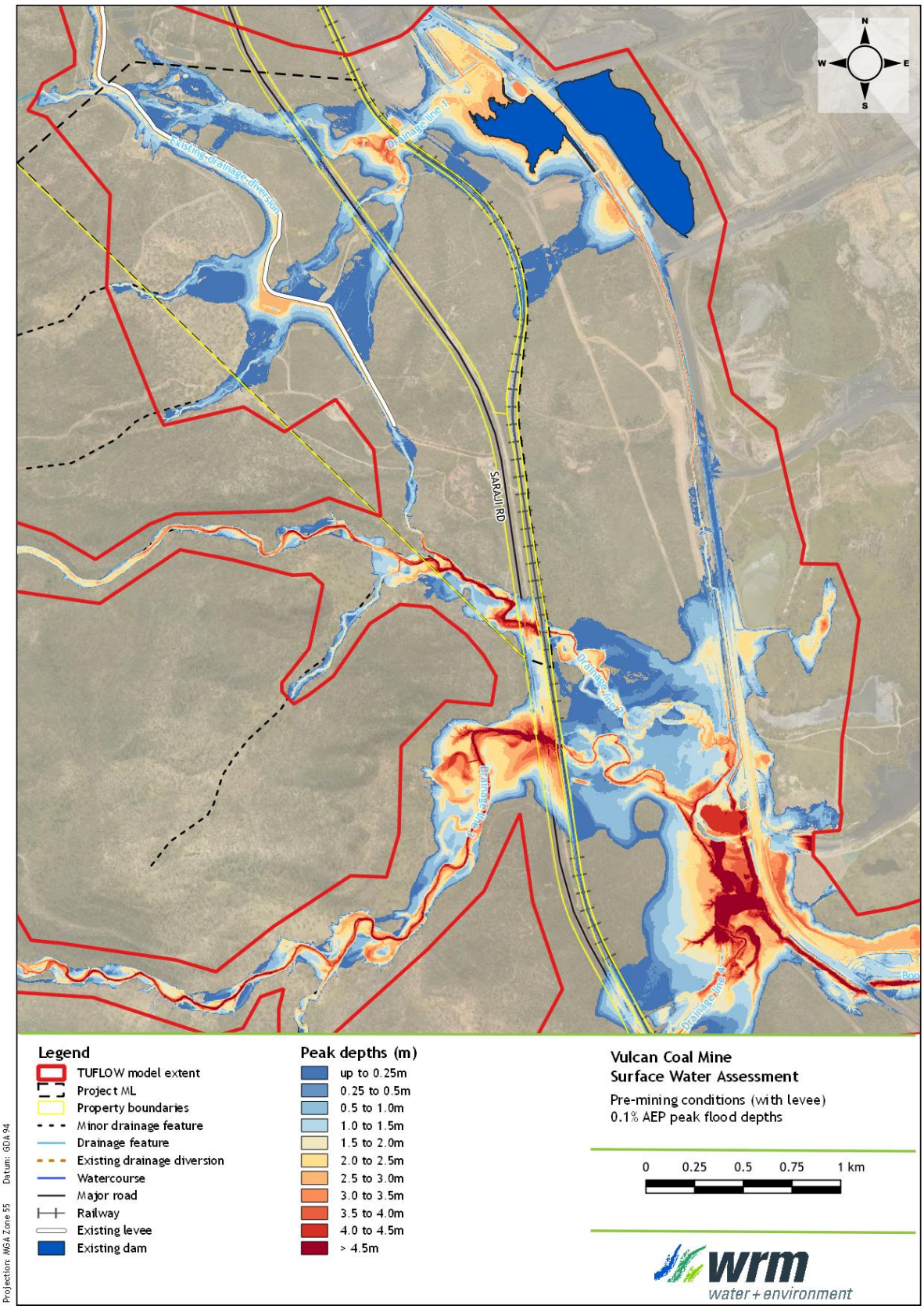


Figure A.3 - 0.1% AEP peak flood depths - Pre-mining Conditions (with levee)

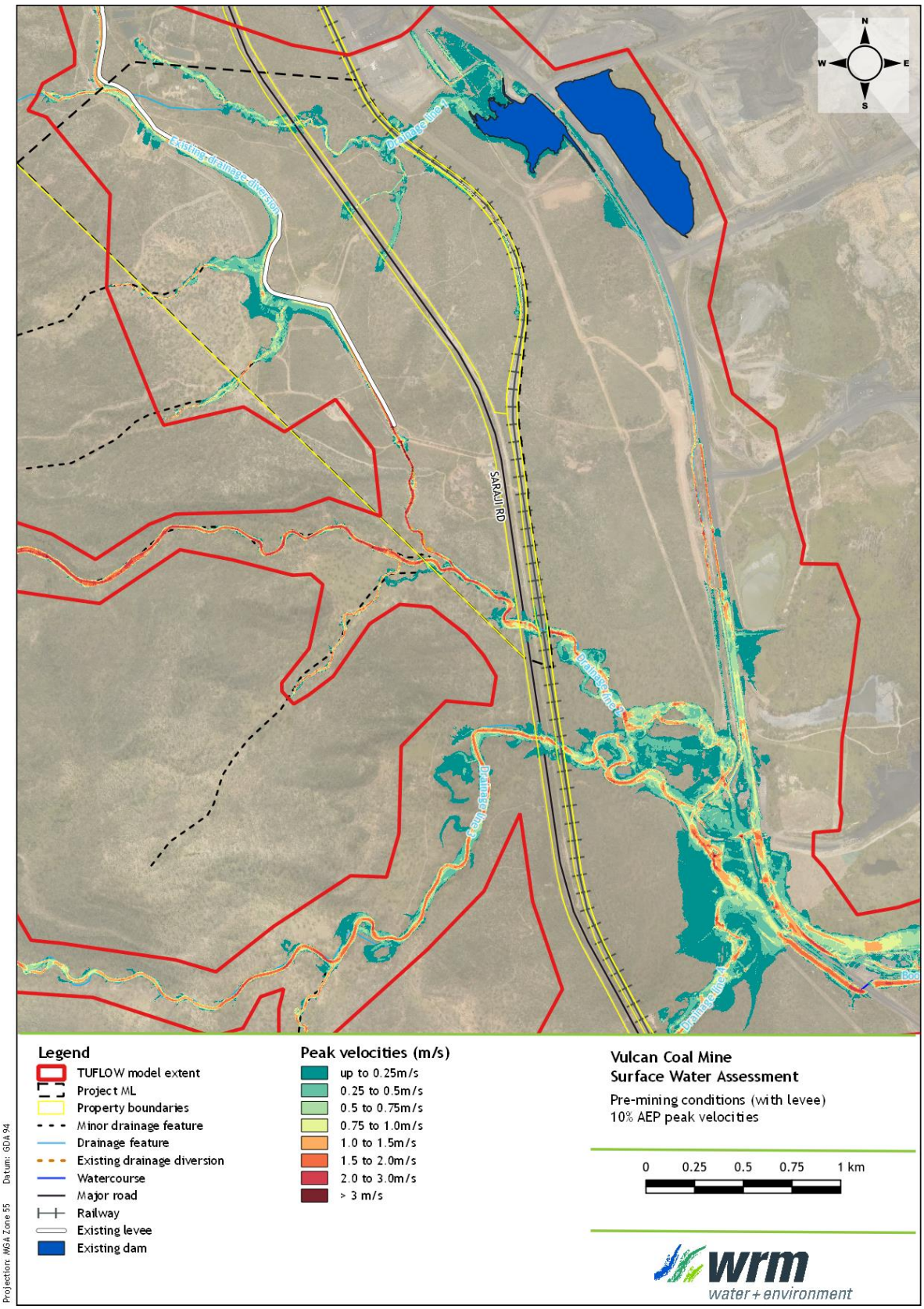


Figure A.4 - 10% AEP peak velocities - Pre-mining Conditions (with levee)

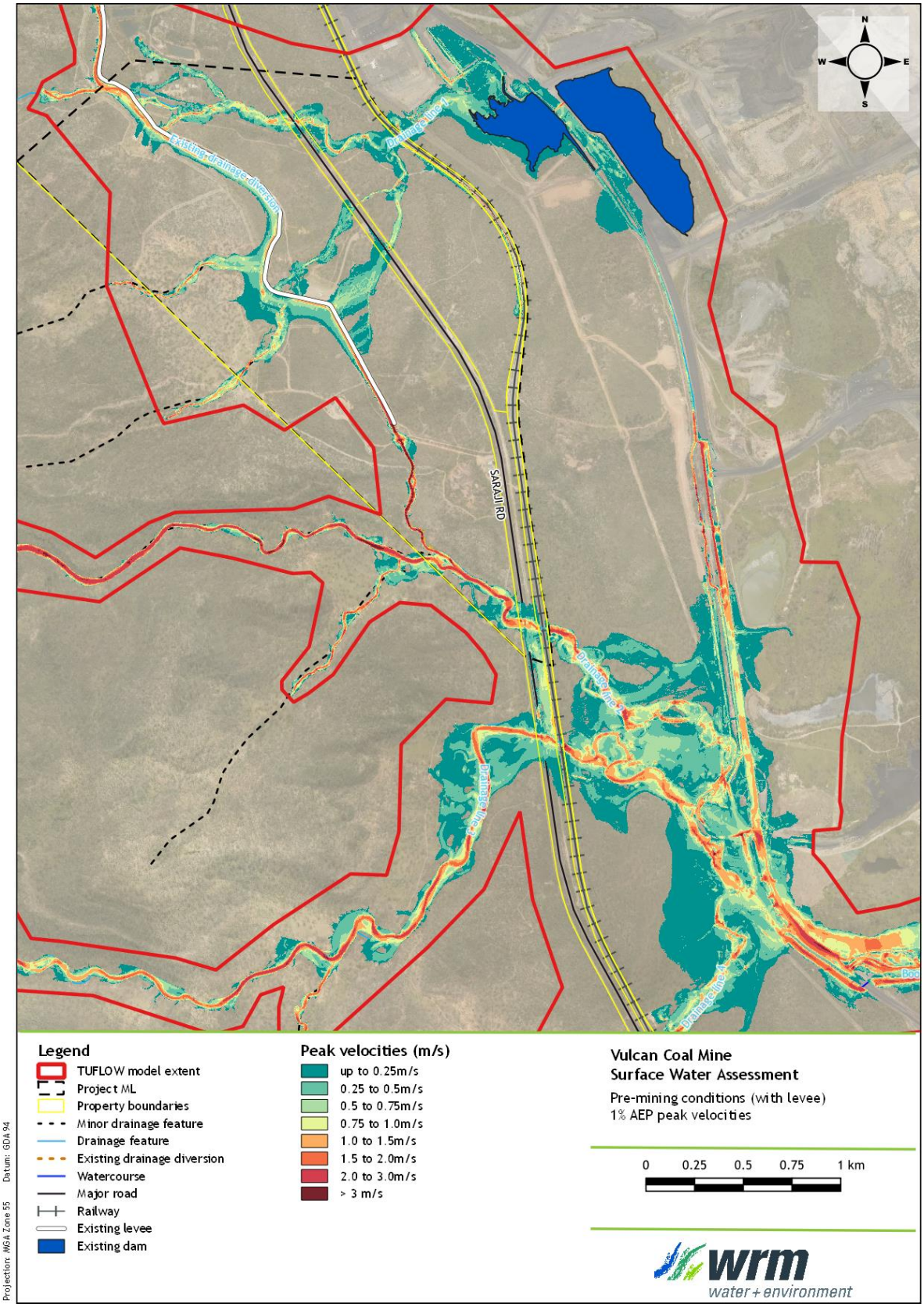


Figure A.5 – 1% AEP peak velocities – Pre-mining Conditions (with levee)

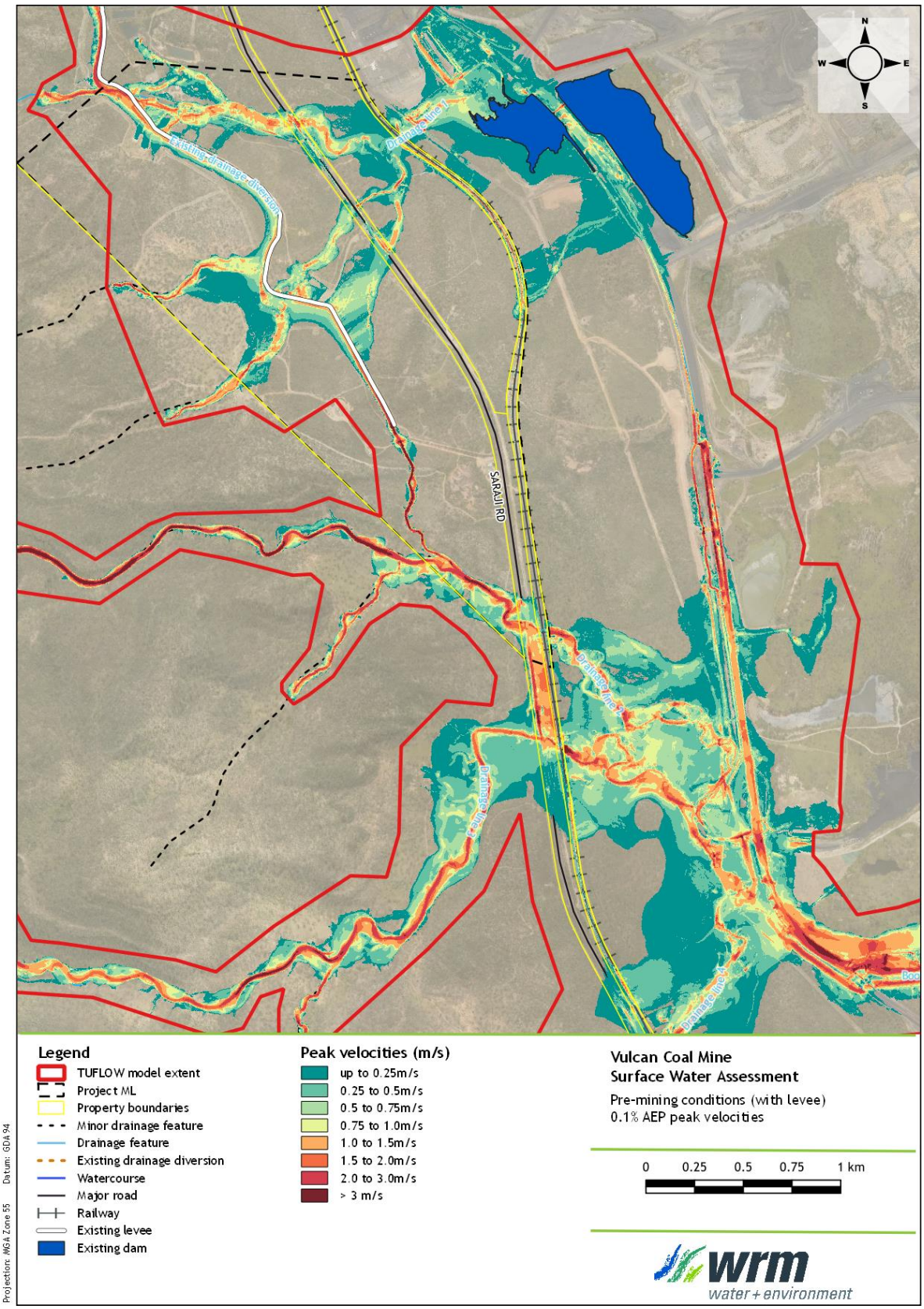


Figure A.6 - 0.1% AEP peak velocities - Pre-mining Conditions (with levee)

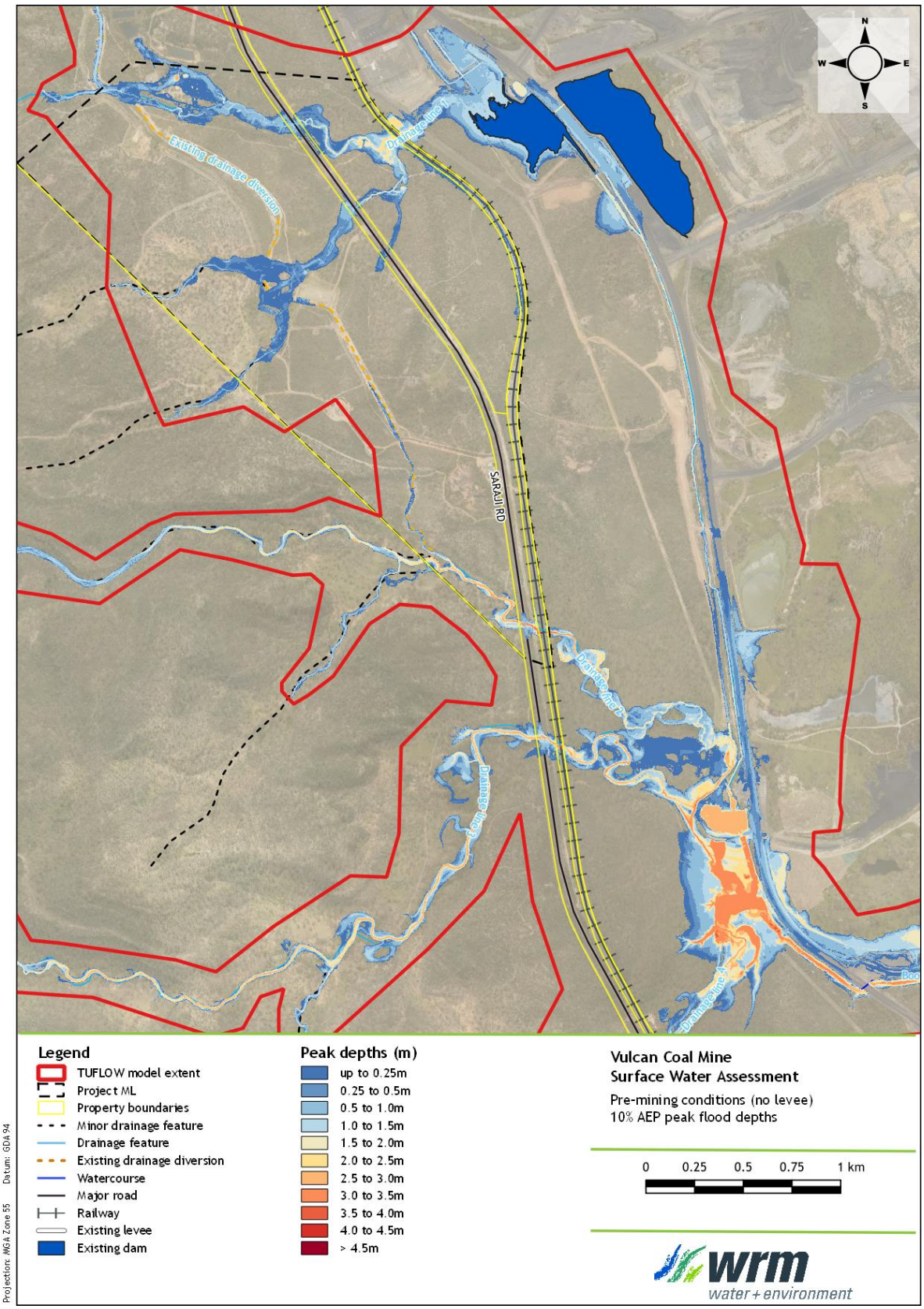


Figure A.7 – 10% AEP peak flood depths – Pre-mining Conditions (no levee)

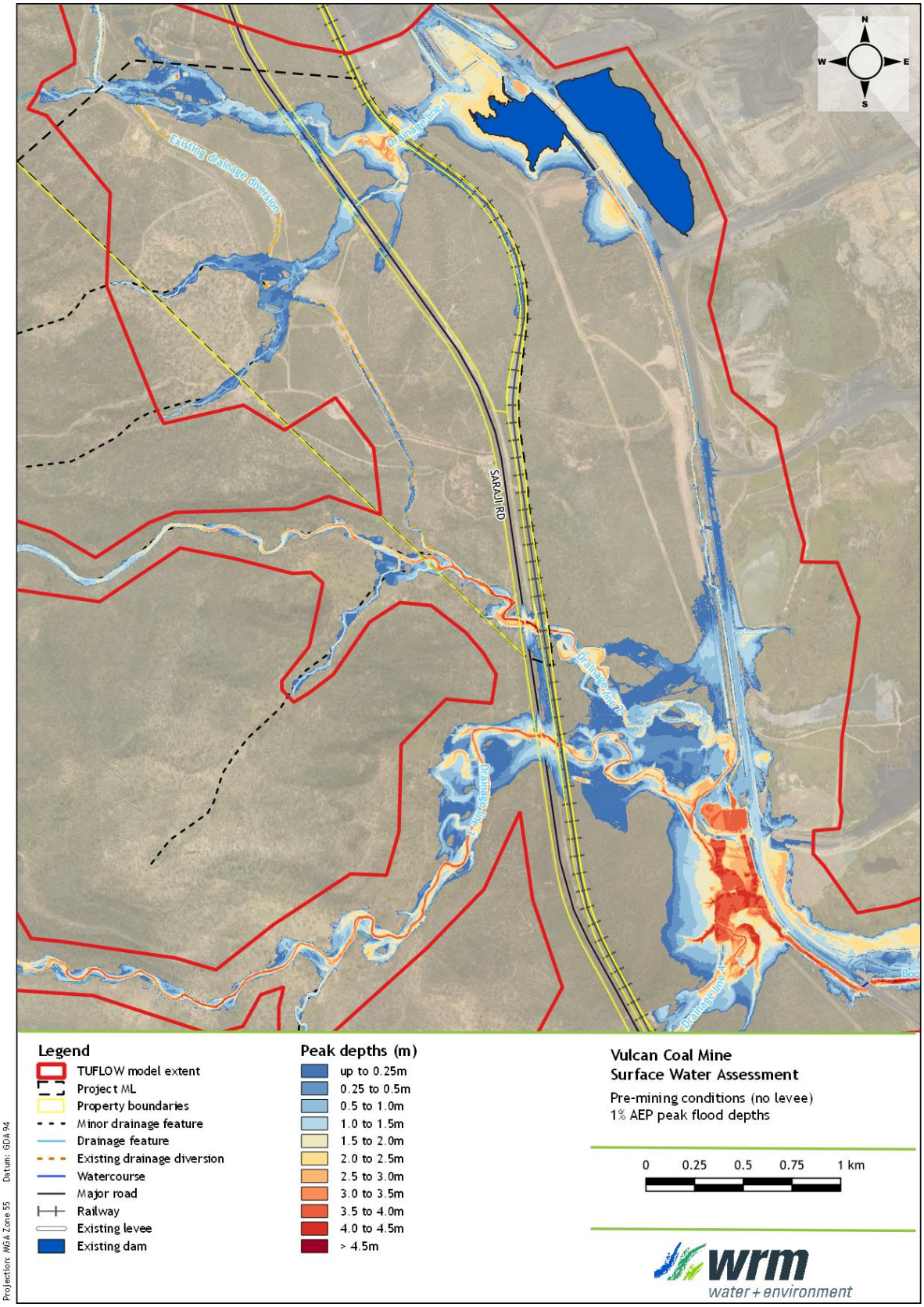


Figure A.8 - 1% AEP peak flood depths - Pre-mining Conditions (no levee)

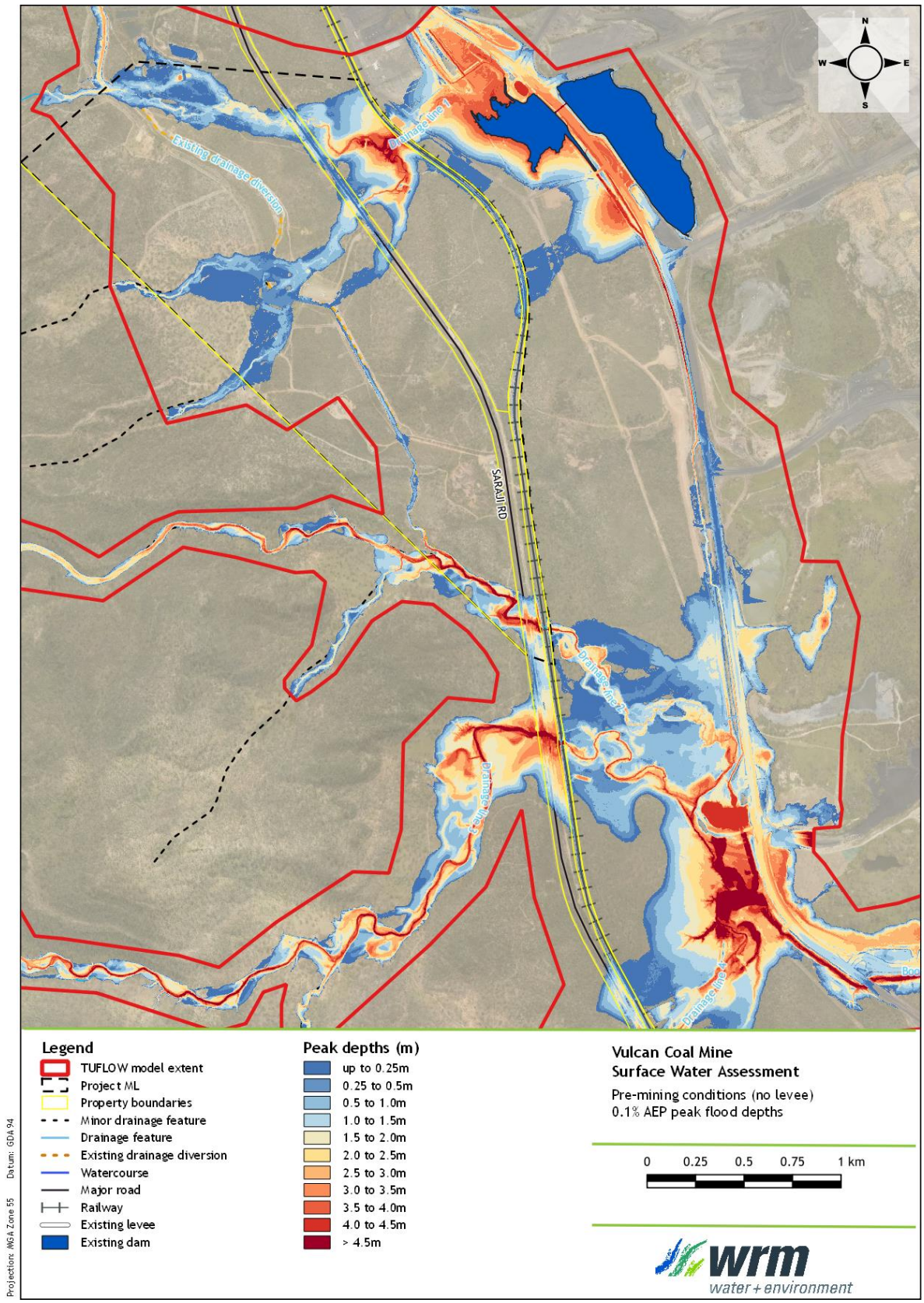


Figure A.9 - 0.1% AEP peak flood depths - Pre-mining Conditions (no levee)

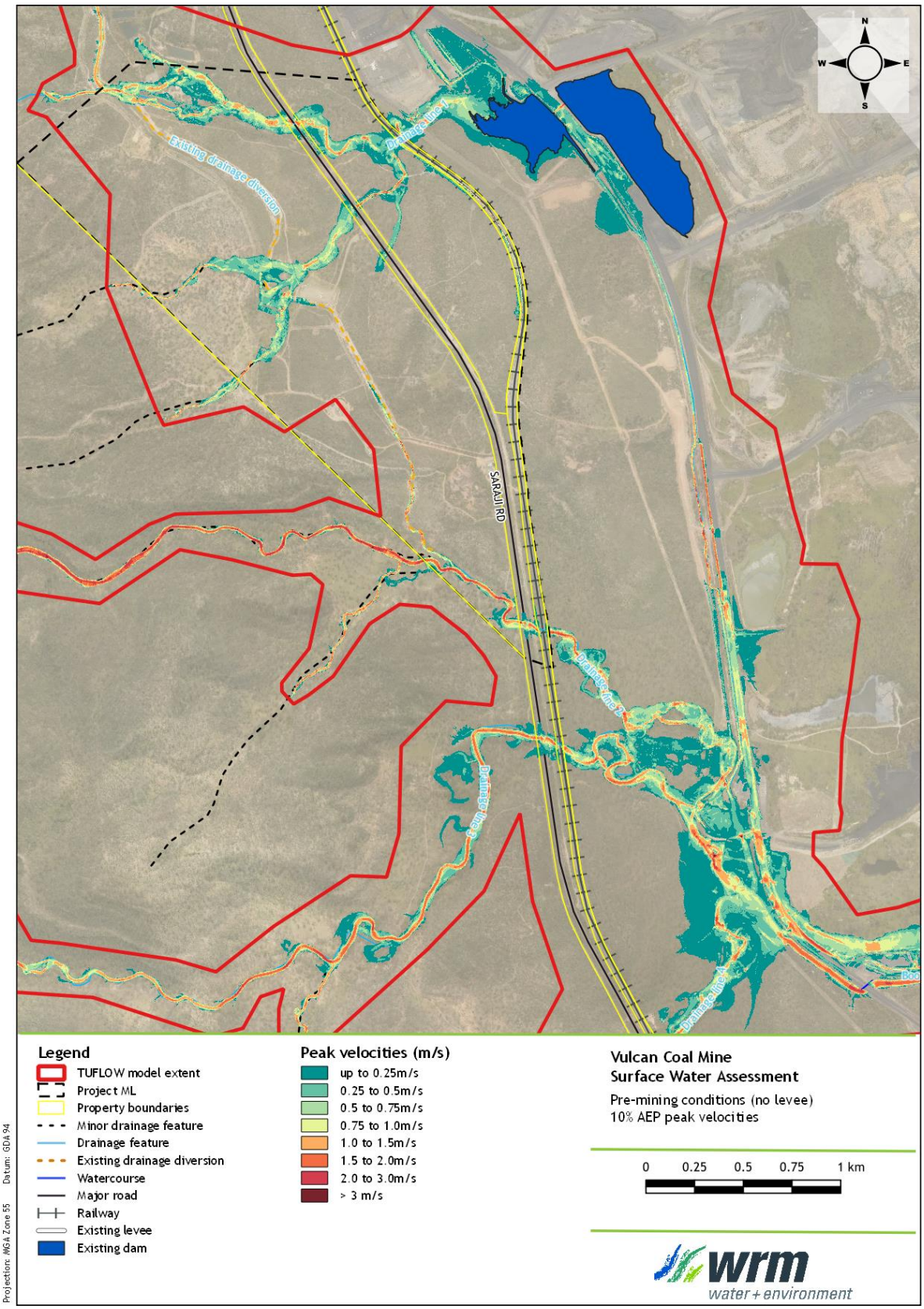


Figure A.10 – 10% AEP peak velocities – Pre-mining Conditions (no levee)

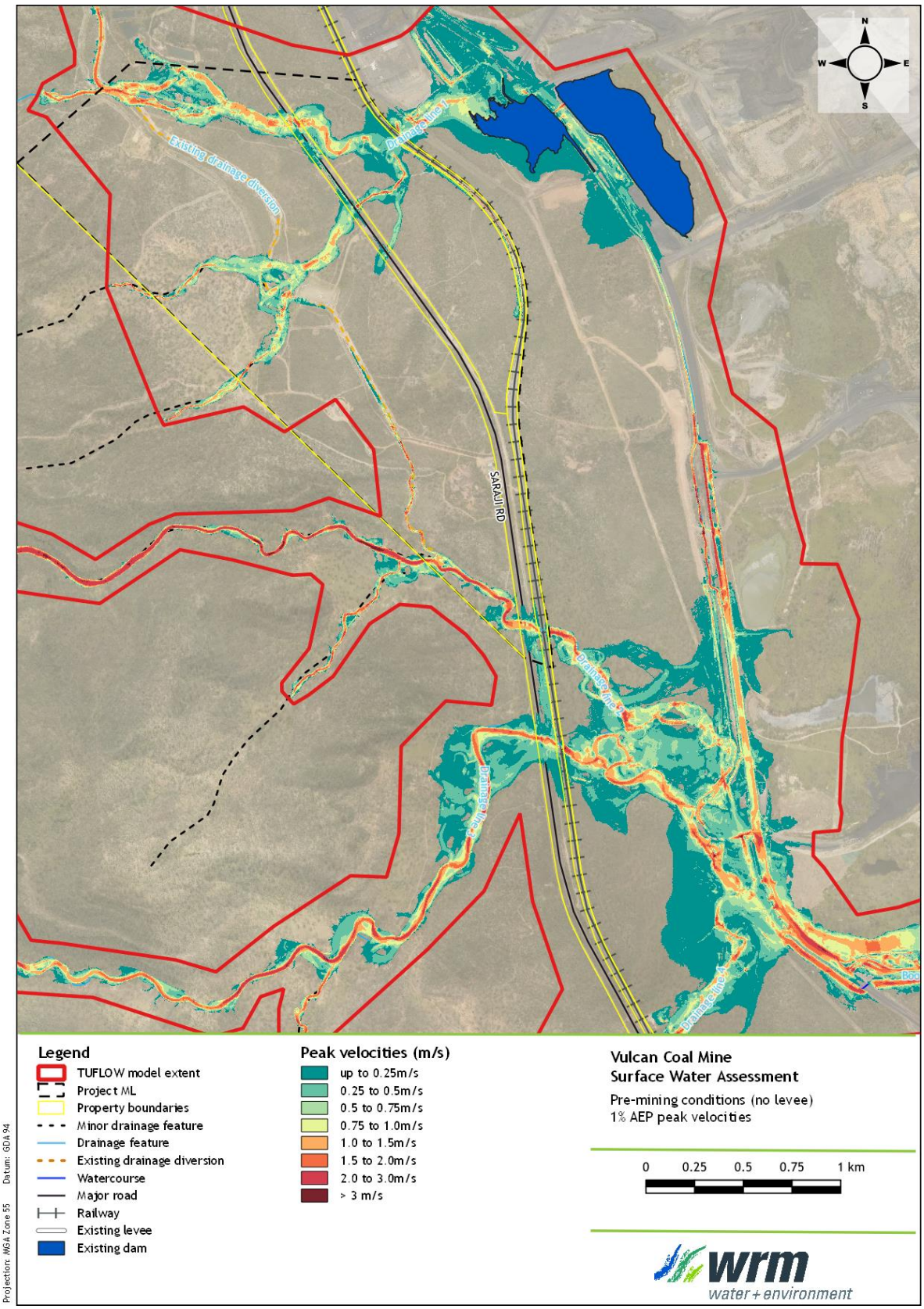


Figure A.11 – 1% AEP peak velocities – Pre-mining Conditions (no levee)

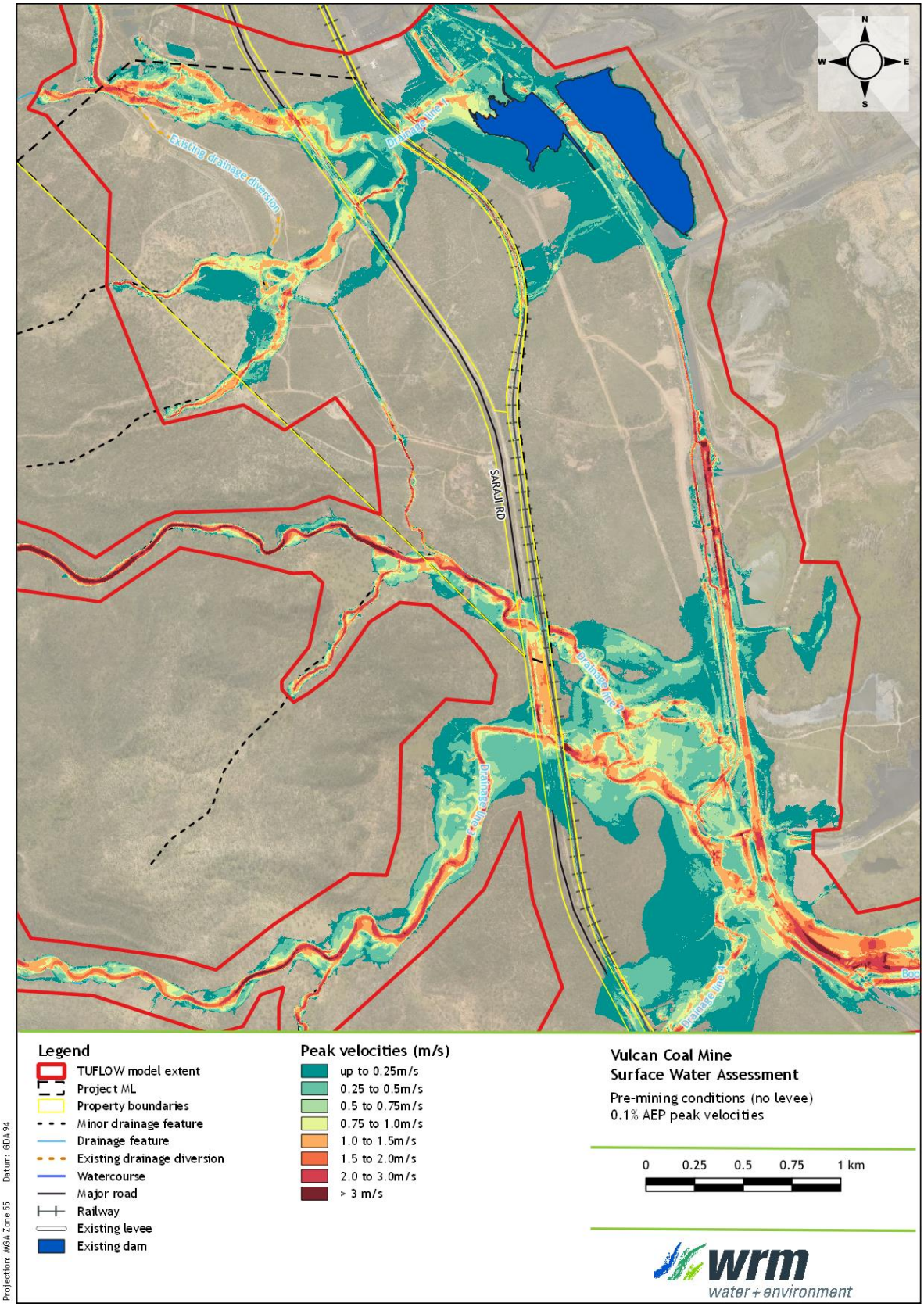


Figure A.12 – 0.1% AEP peak velocities – Pre-mining Conditions (no levee)

Appendix B – Operational Conditions flood maps and results

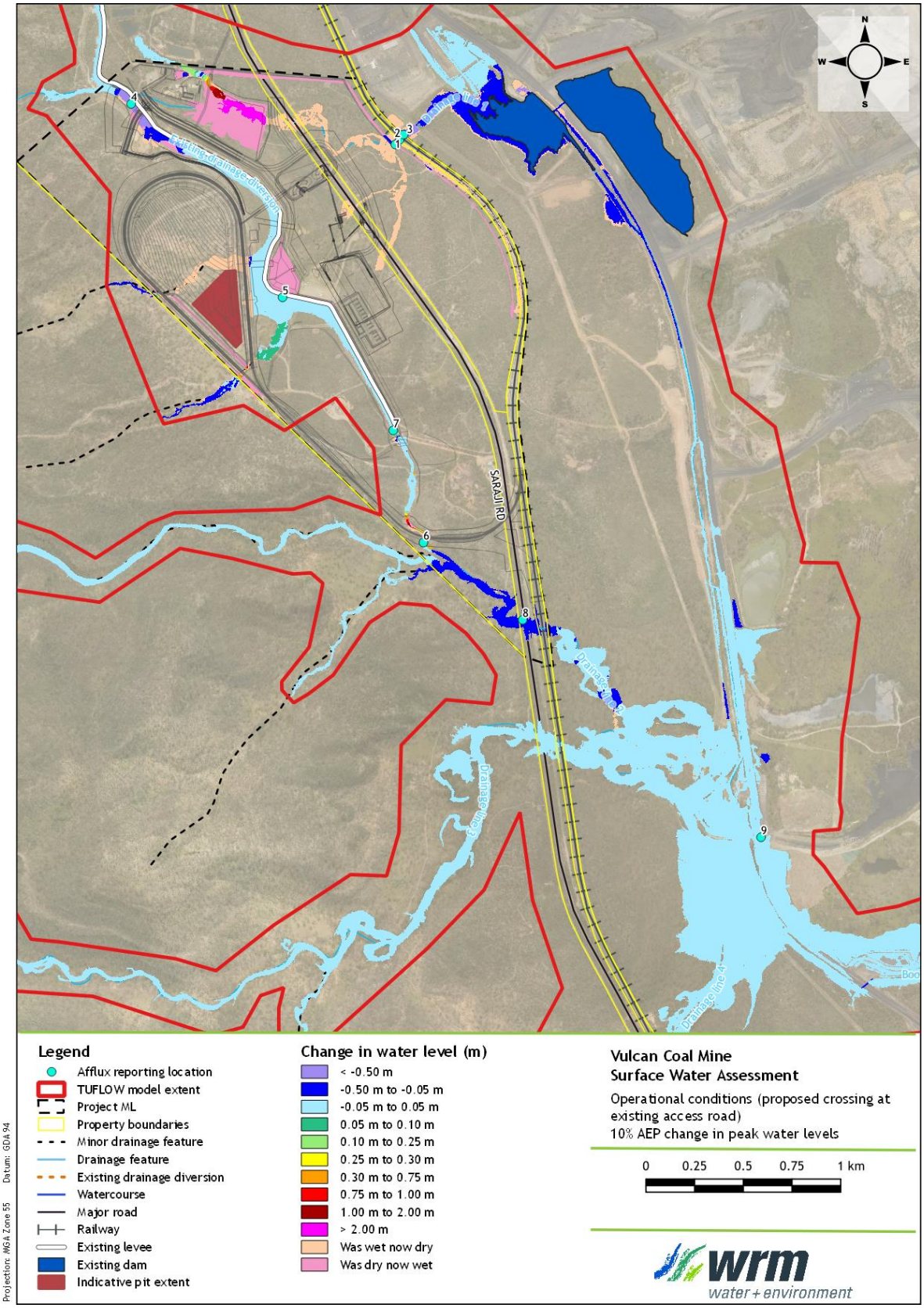


Figure B.1 – 10% AEP change in peak water levels – Operational Conditions (proposed crossing at existing access road) impacts

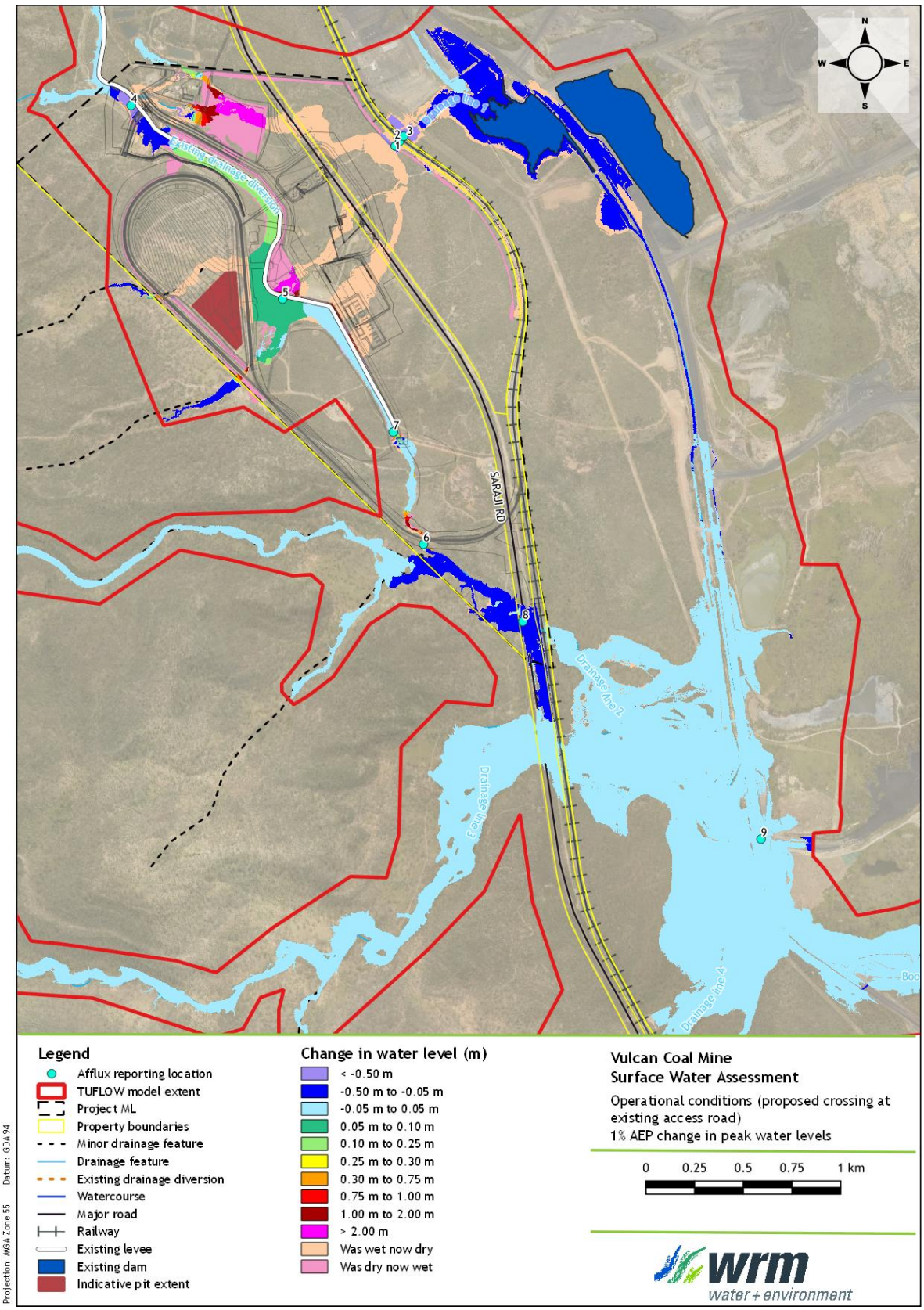


Figure B.2 - 1% AEP change in peak water levels - Operational Conditions (proposed crossing at existing access road) impacts

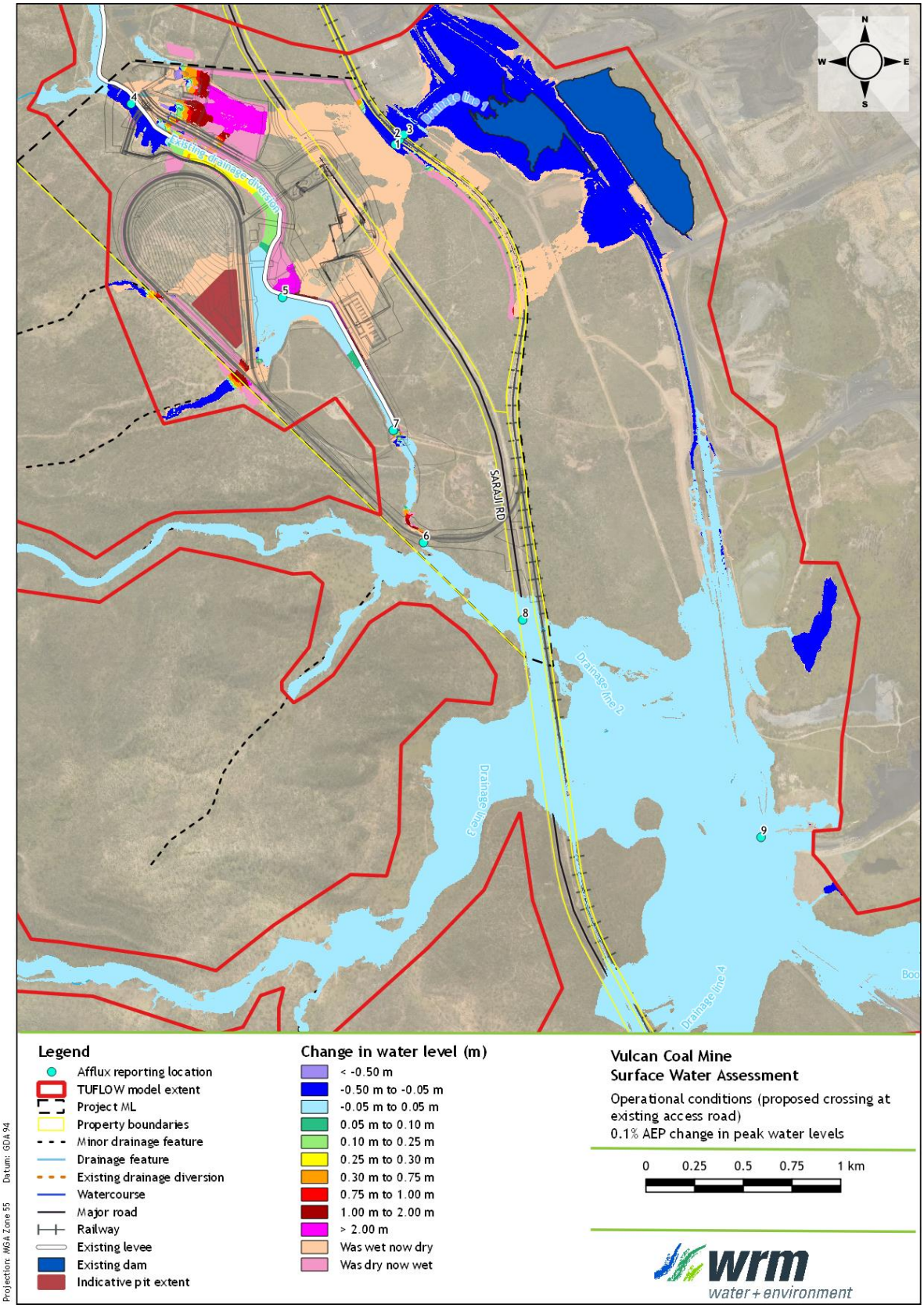


Figure B.3 - 0.1% AEP change in peak water levels - Operational Conditions (proposed crossing at existing access road) impacts

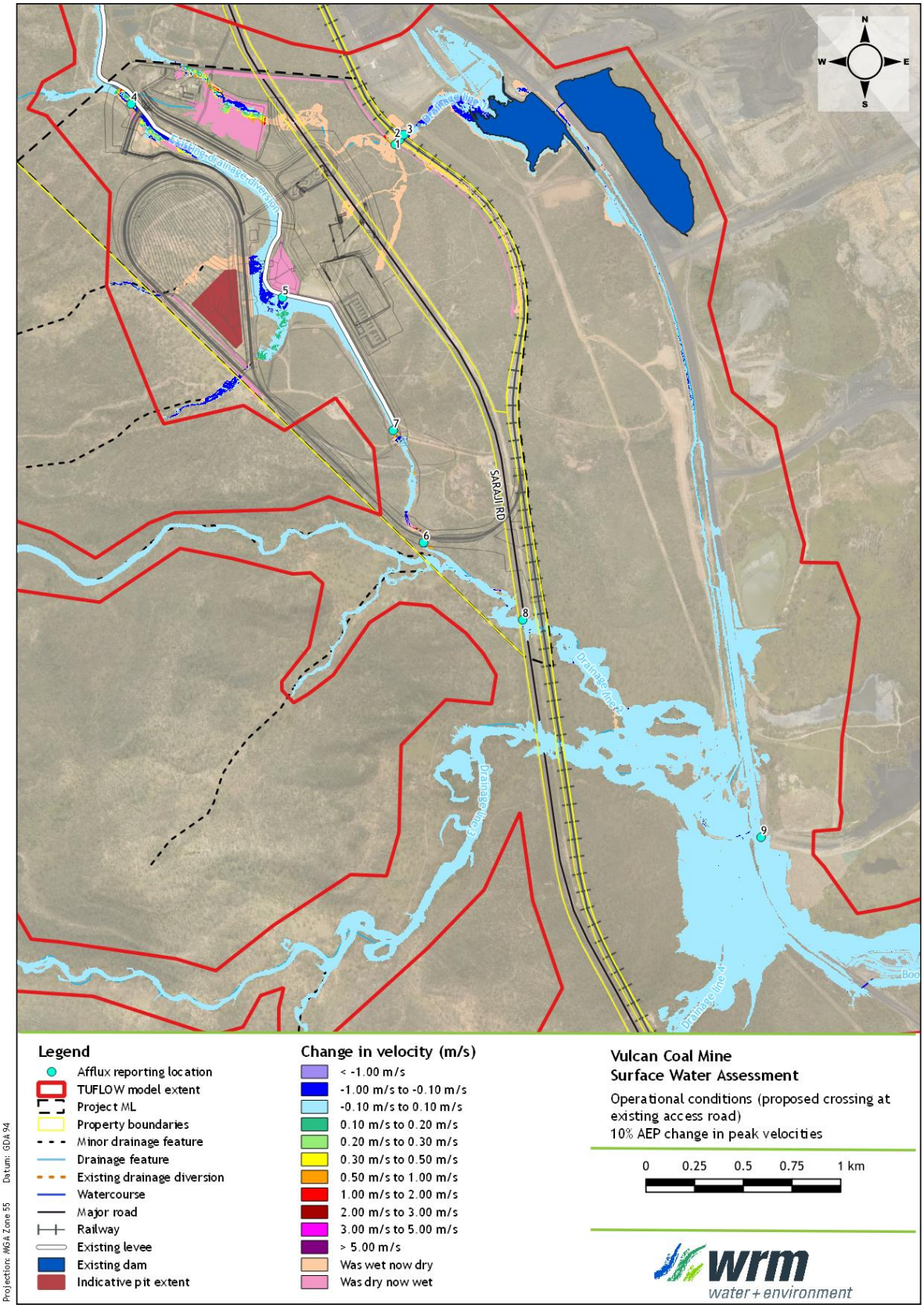


Figure B.4 - 10% AEP change in peak velocities - Operational Conditions (proposed crossing at existing access road) impacts

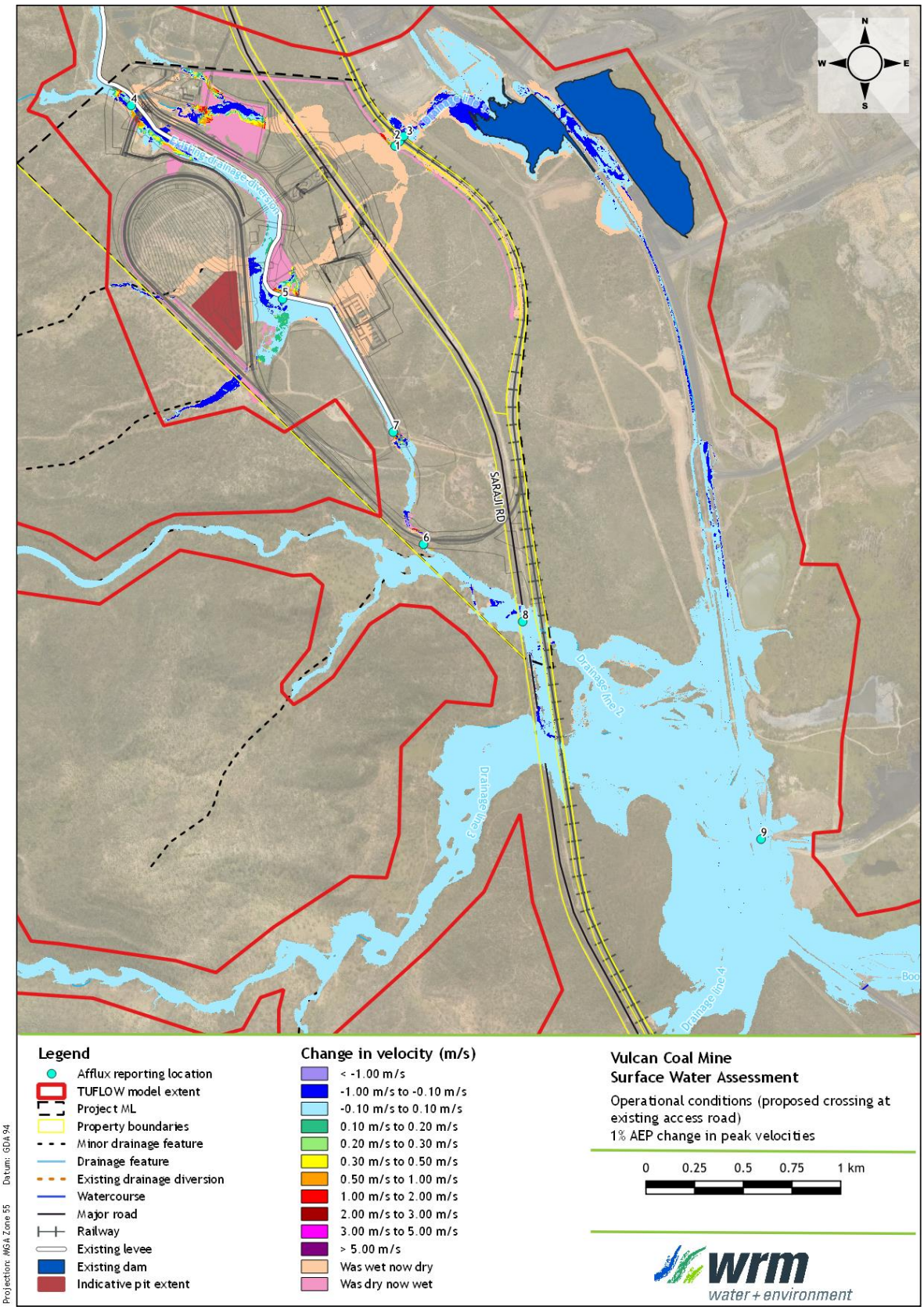


Figure B.5 - 1% AEP change in peak velocities - Operational Conditions (proposed crossing at existing access road) impacts

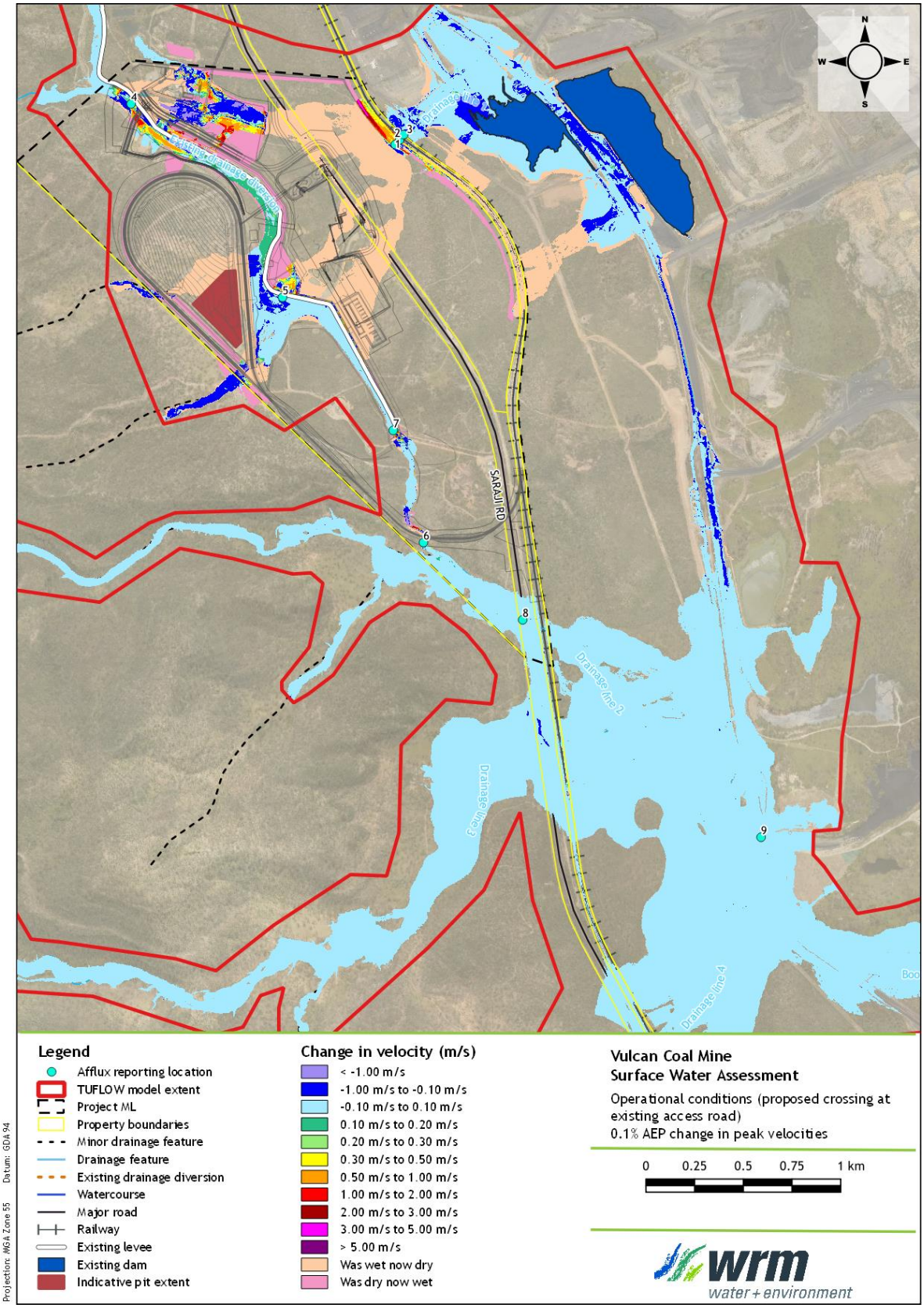


Figure B.6 - 0.1% AEP change in peak velocities - Operational Conditions (proposed crossing at existing access road) impacts

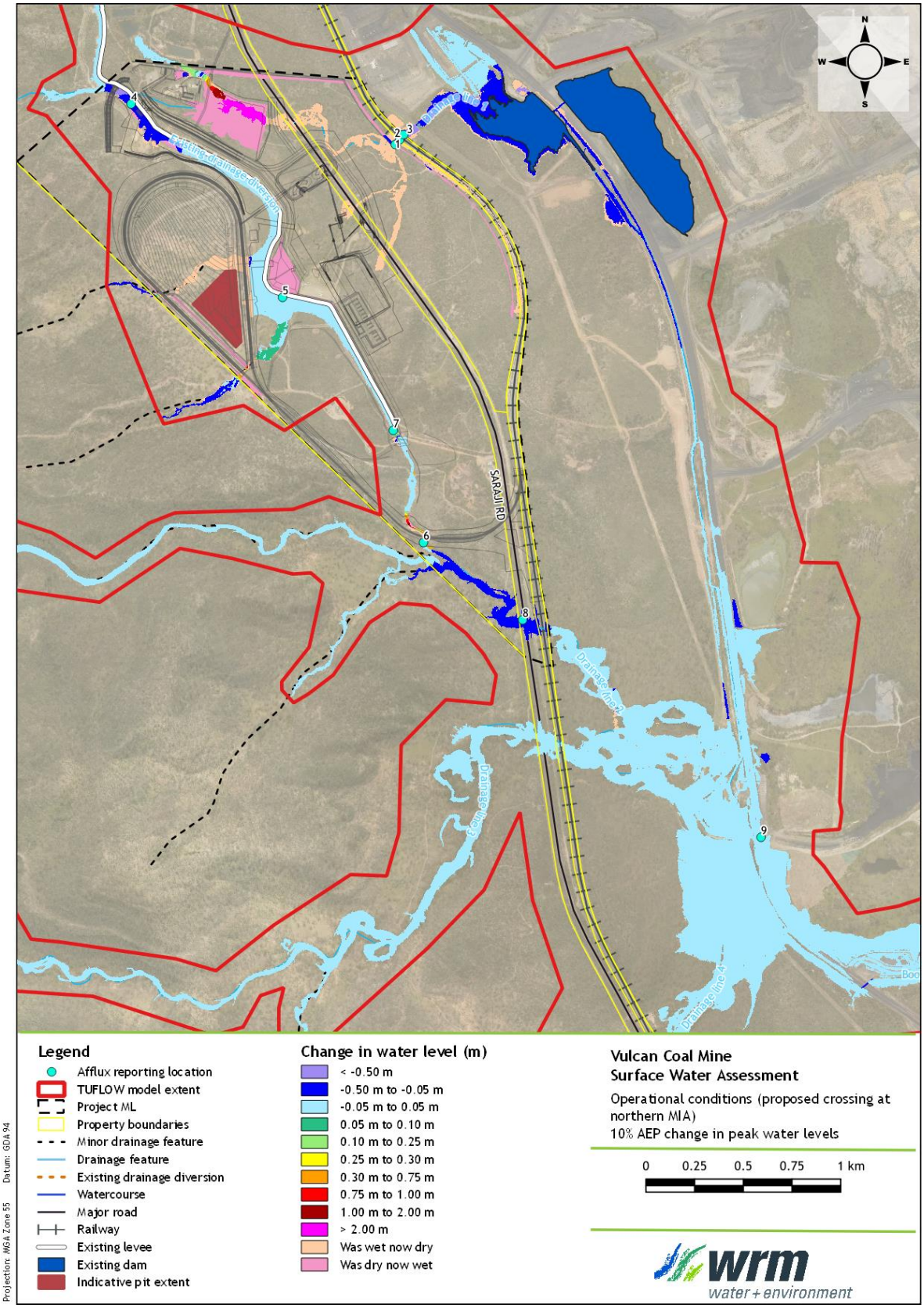


Figure B.7 - 10% AEP change in peak water levels - Operational Conditions (proposed crossing at northern MIA) impacts

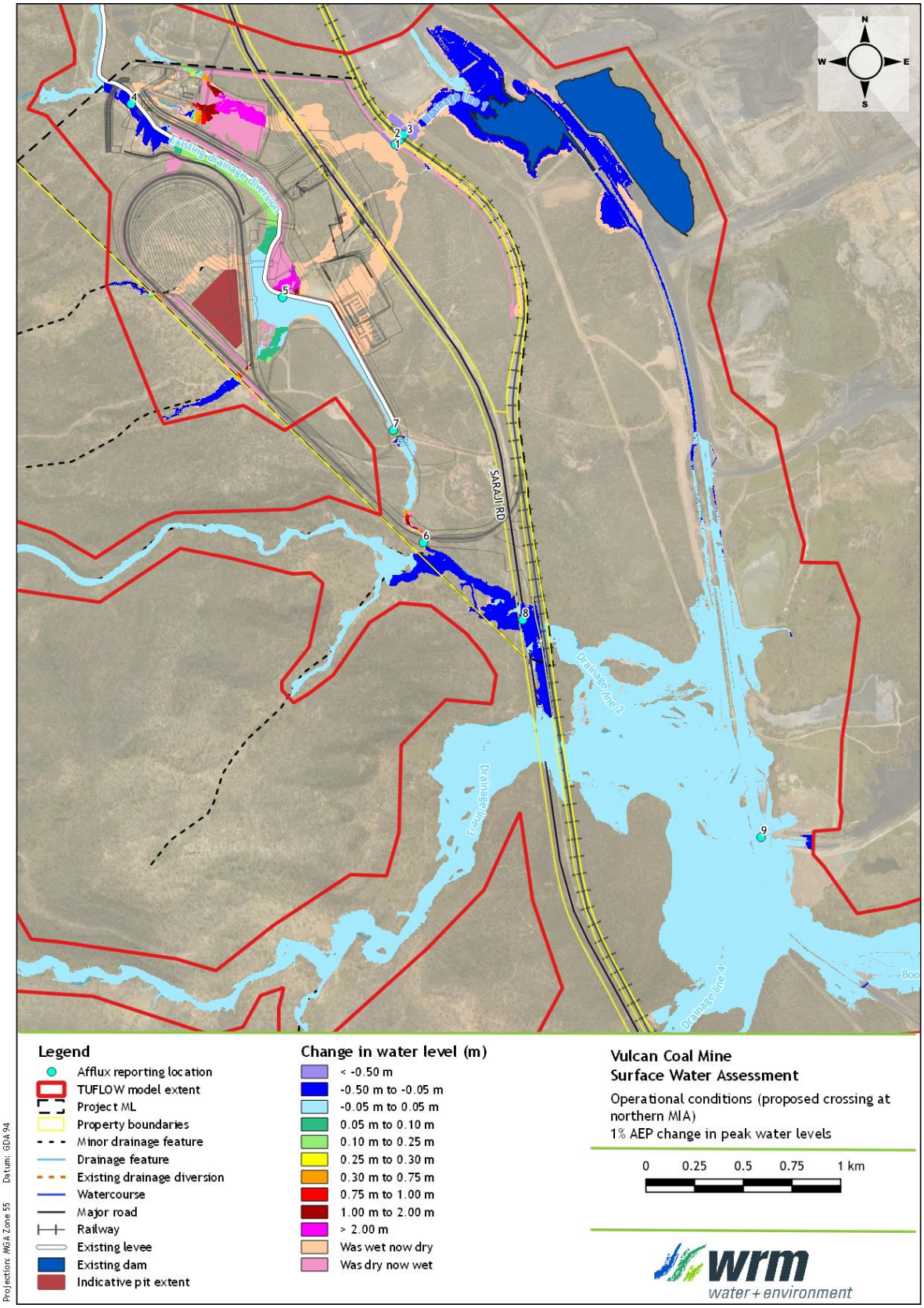


Figure B.8 - 1% AEP change in peak water levels - Operational Conditions (proposed crossing at northern MIA) impact

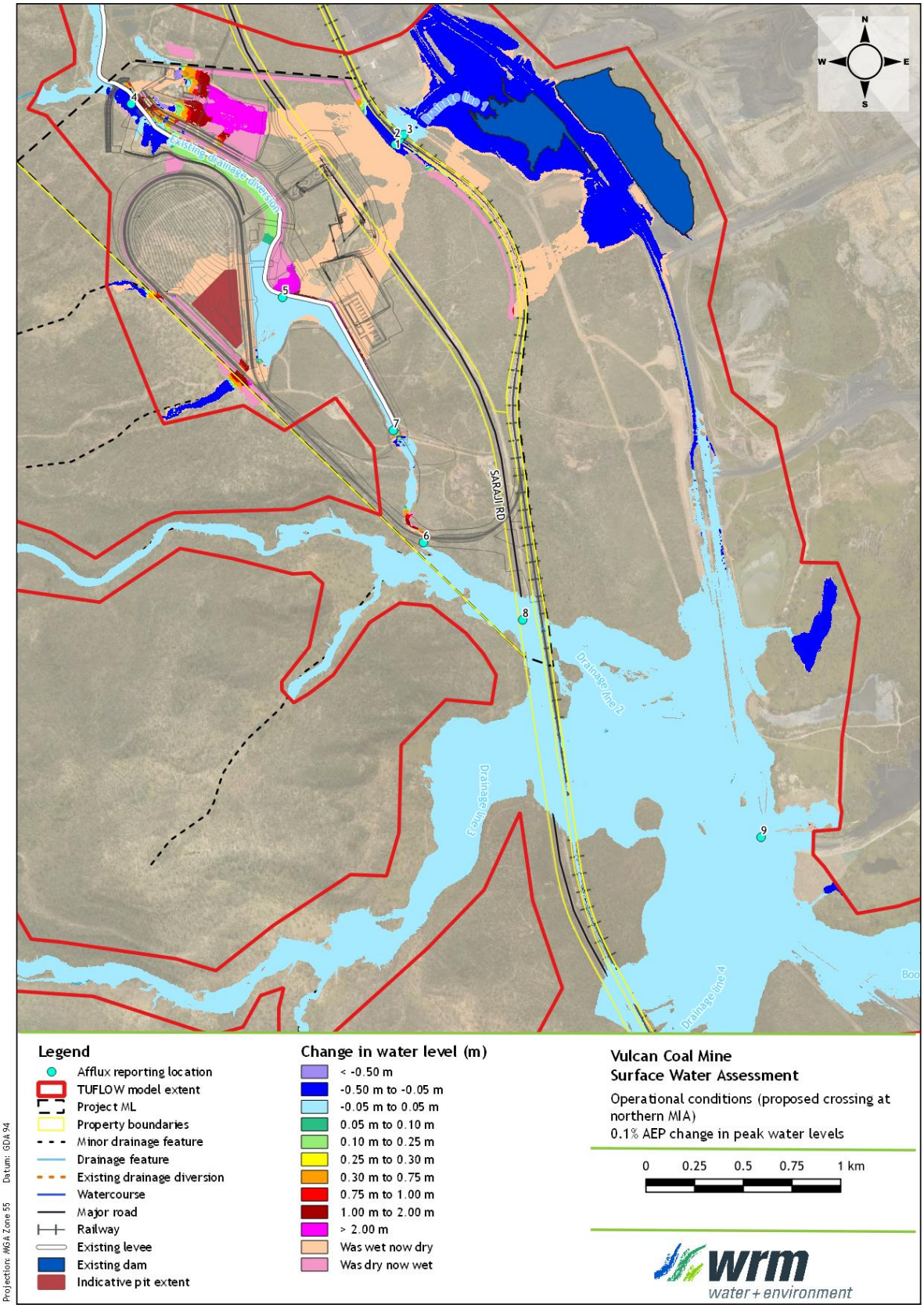


Figure B.9 - 0.1% AEP change in peak water levels - Operational Conditions (proposed crossing at northern MIA) impacts

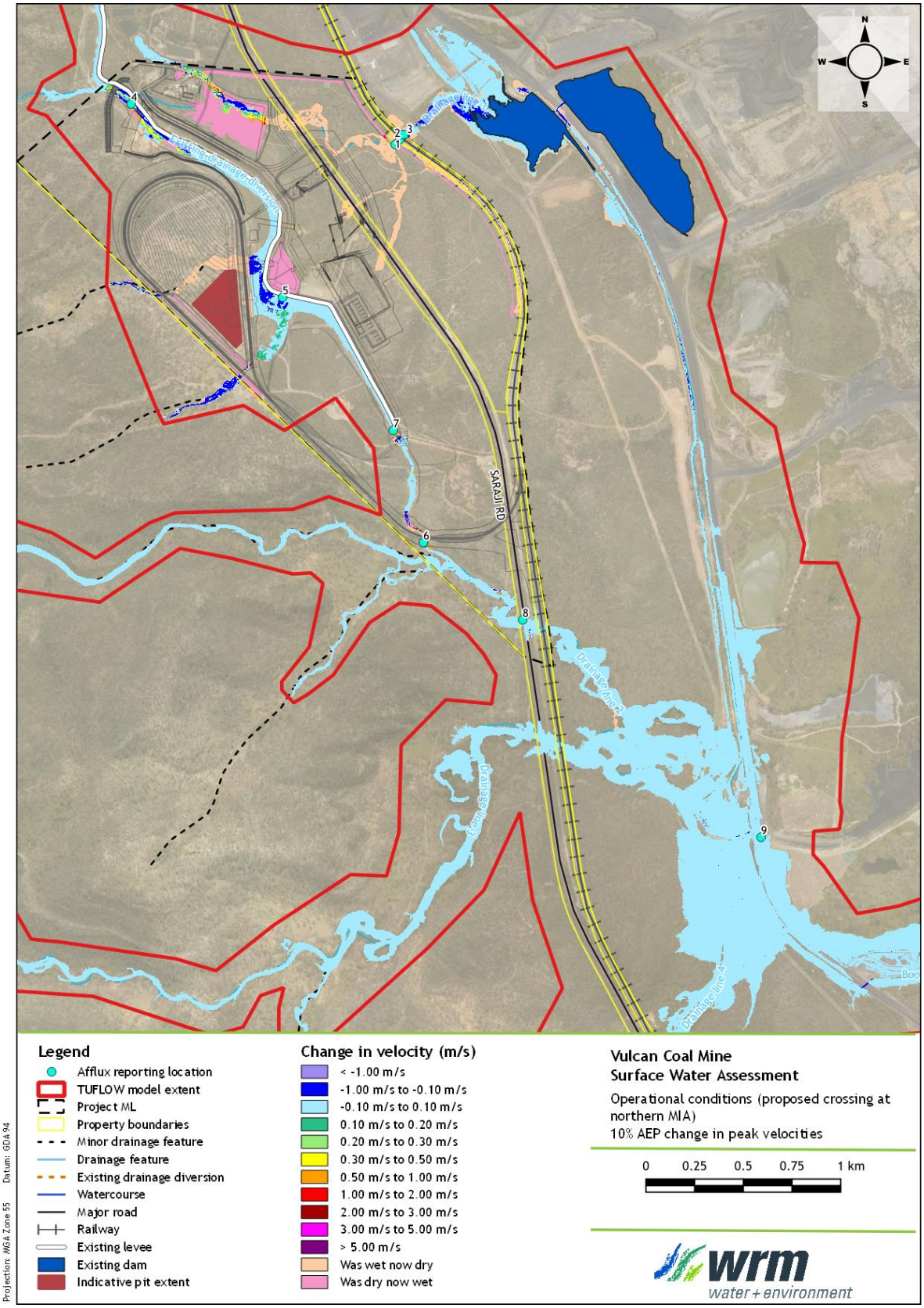


Figure B.10 - 10% AEP change in peak velocities - Operational Conditions (proposed crossing at northern MIA) impacts

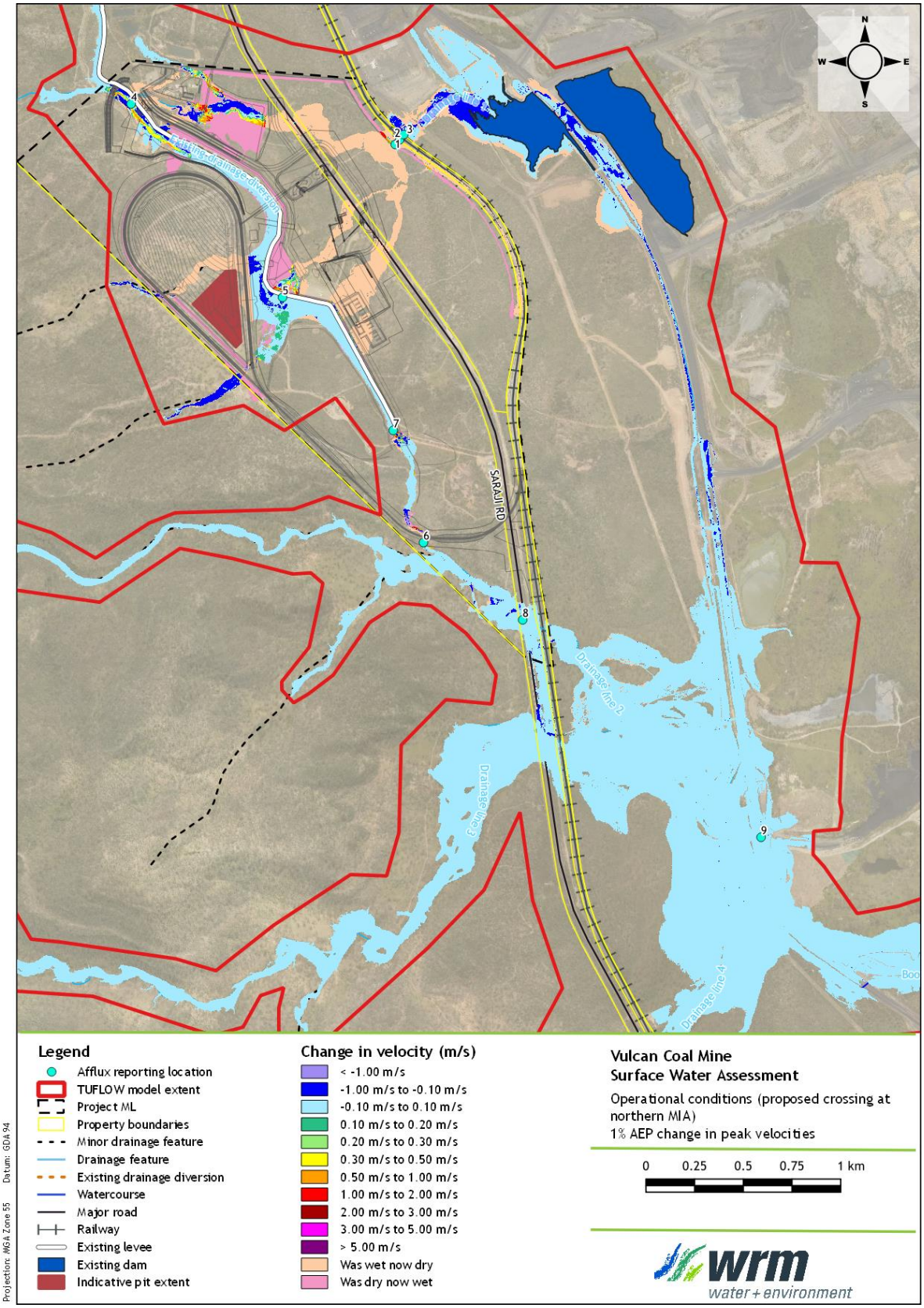


Figure B.11 - 1% AEP change in peak velocities - Operational Conditions (proposed crossing at northern MIA) impacts

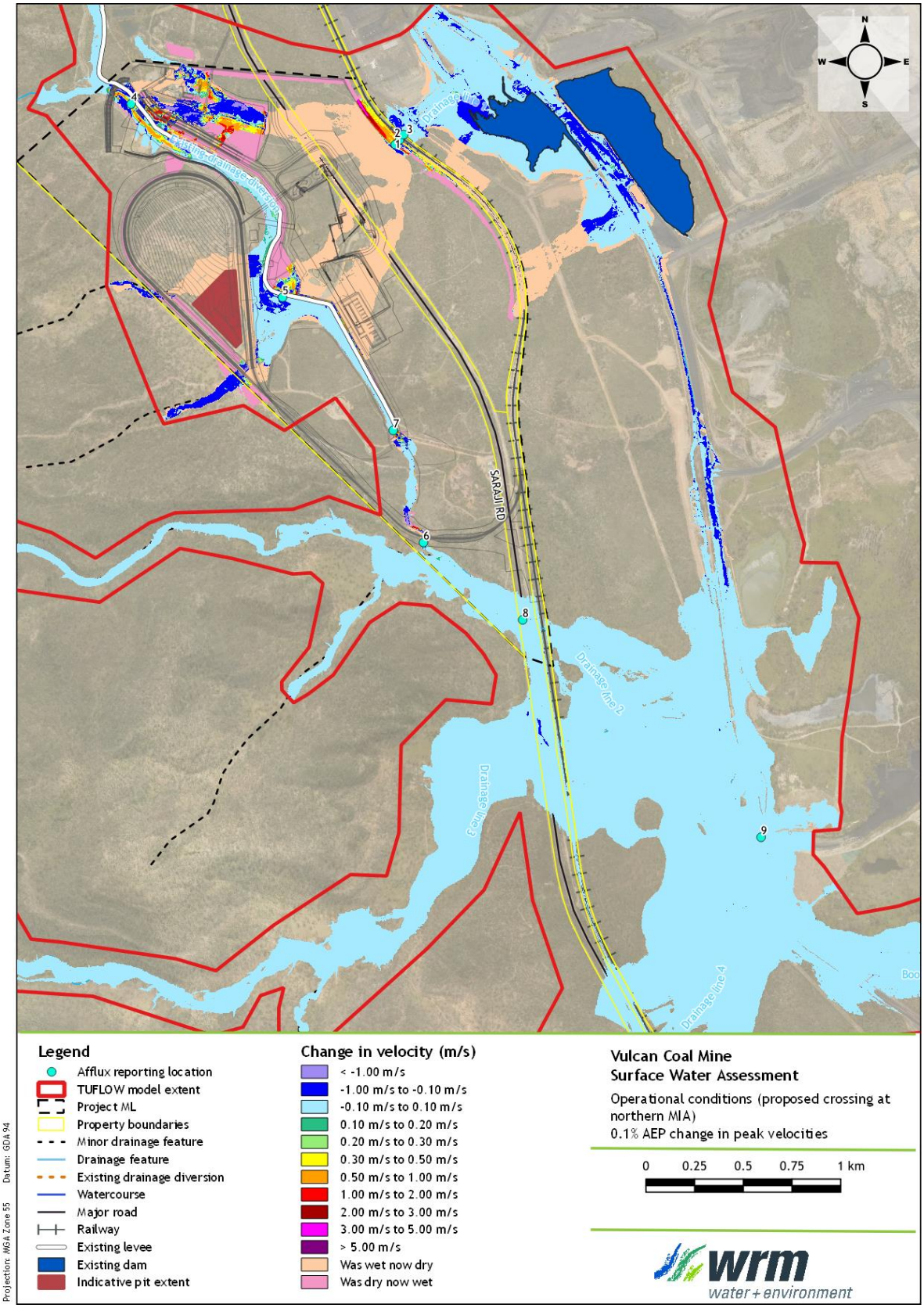


Figure B.12 - 0.1% AEP change in peak velocities - Operational Conditions (proposed crossing at northern MIA) impacts

Appendix C – Post-closure Conditions flood impact maps

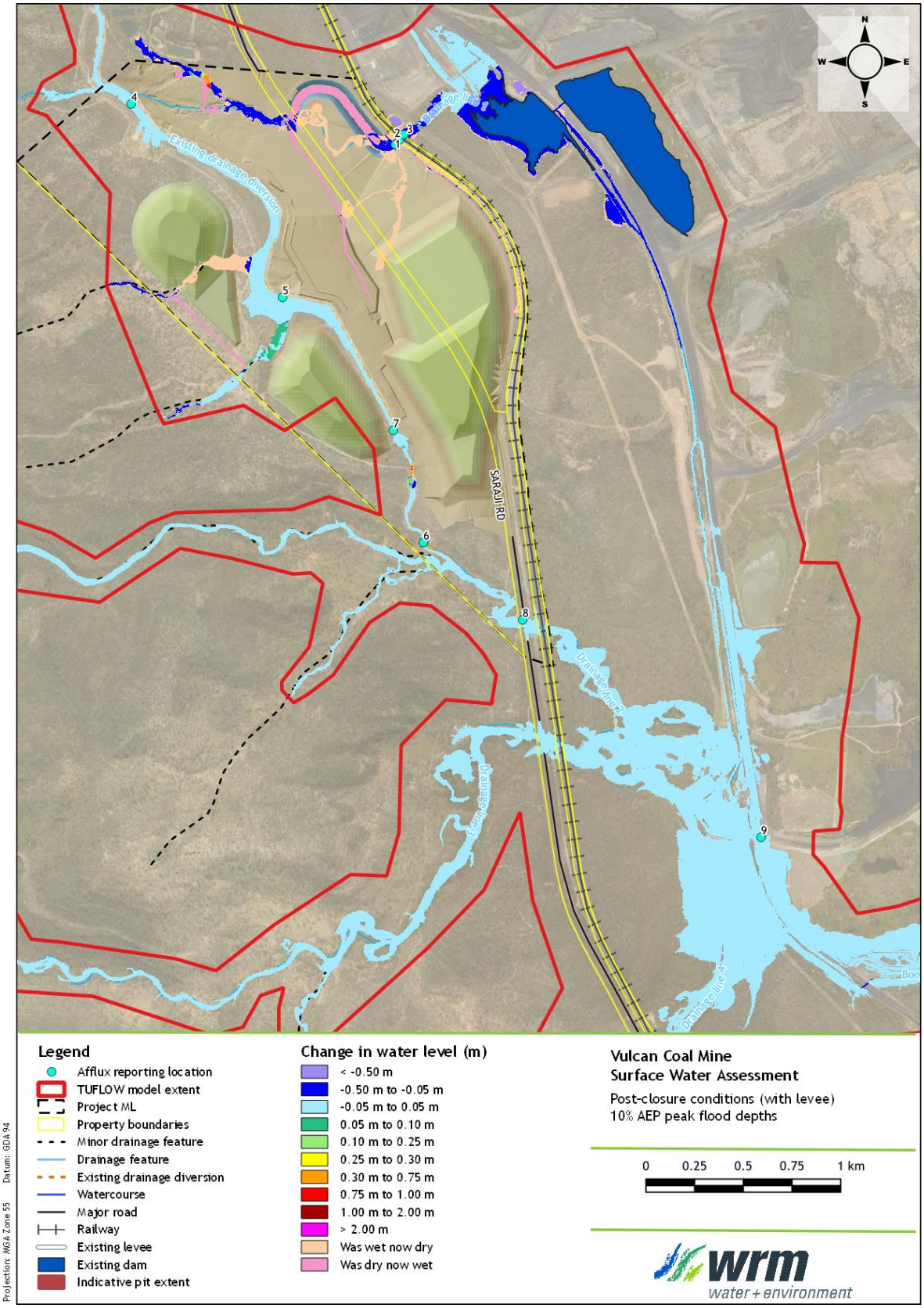


Figure C.1 – 10% AEP change in peak water levels – Post-closure Conditions (with levee) impacts

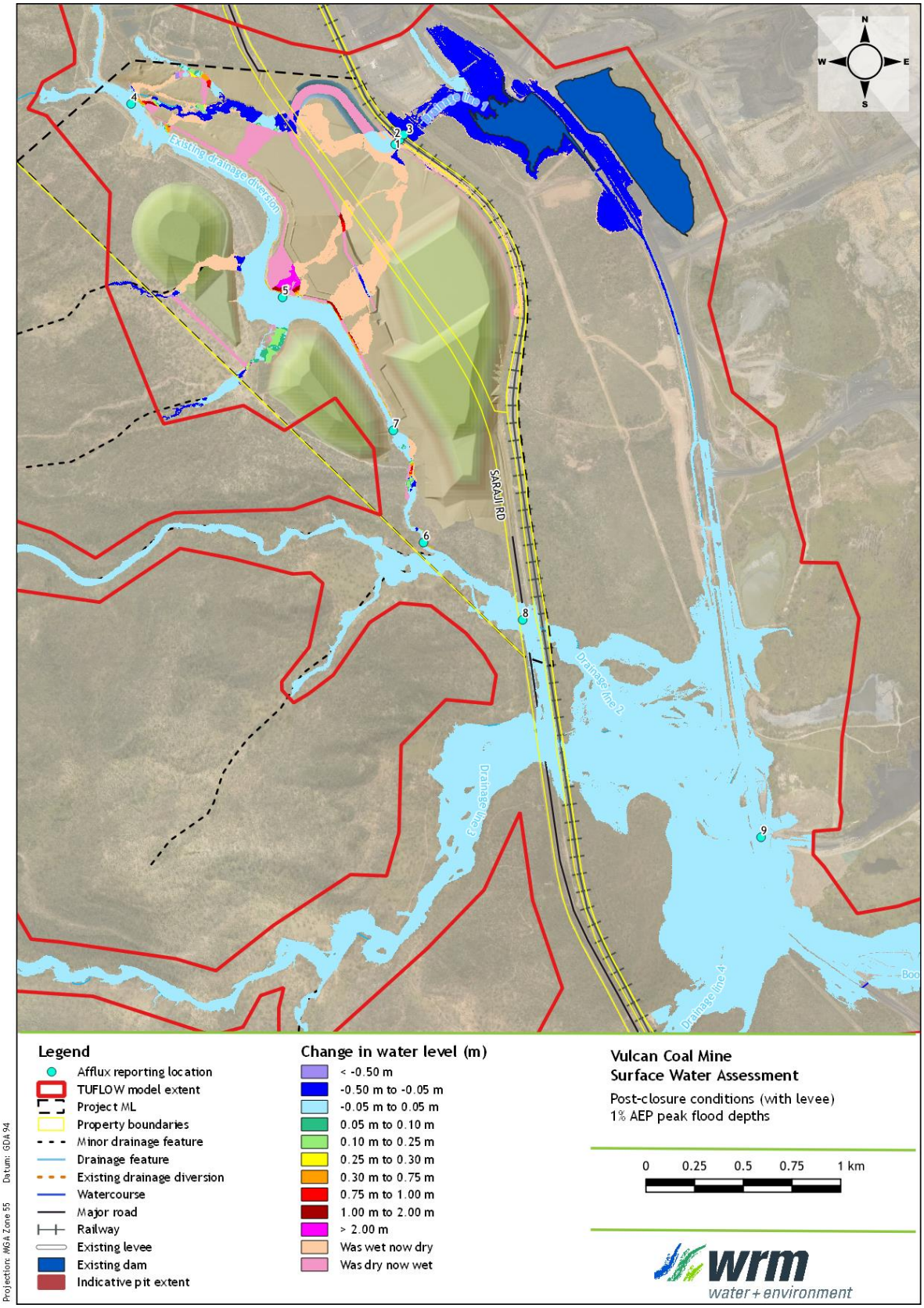


Figure C.2 - 1% AEP change in peak water levels - Post-closure Conditions (with levee) impacts

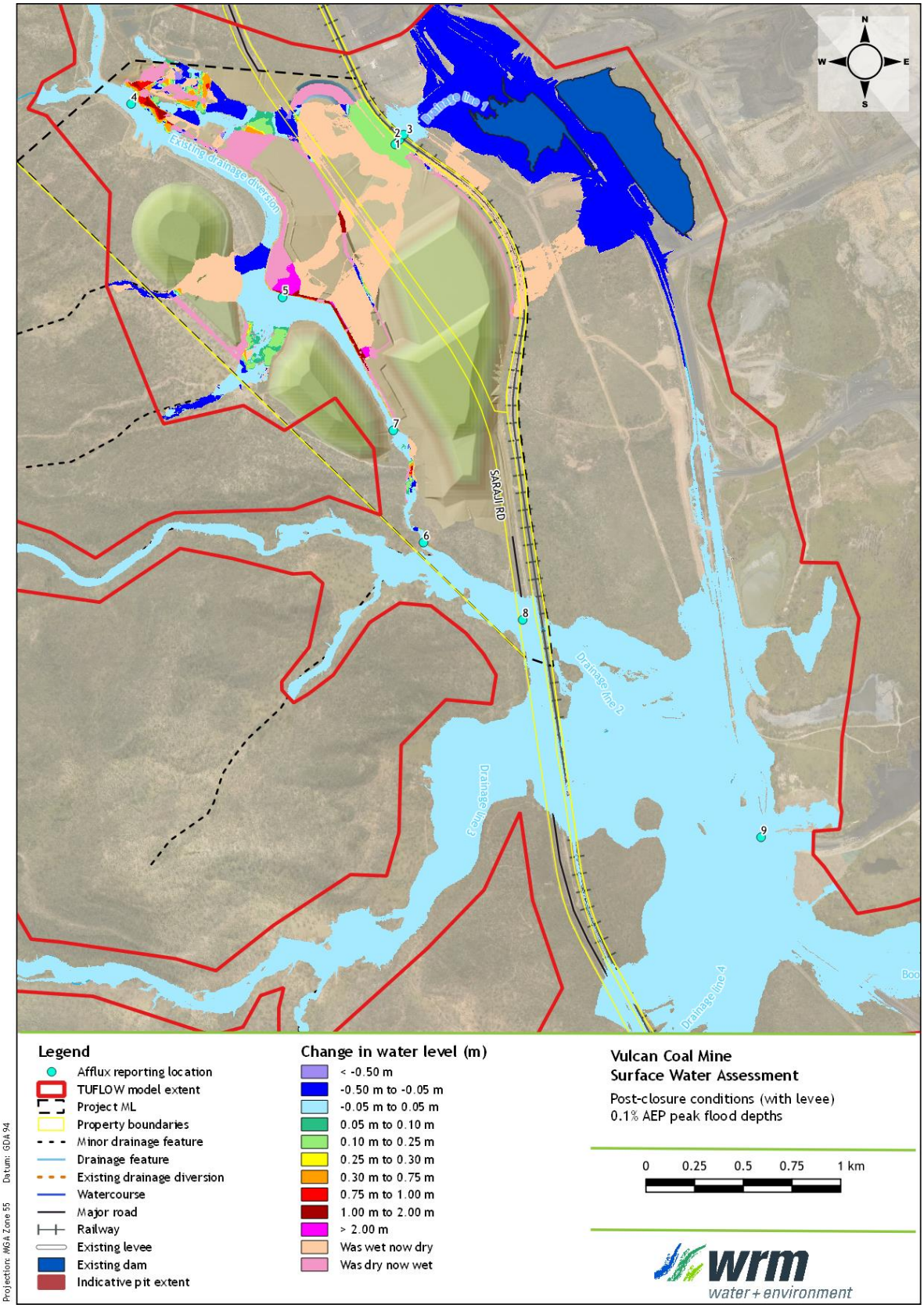


Figure C.3 - 0.1% AEP change in peak water levels - Post-closure Conditions (with levee) impacts

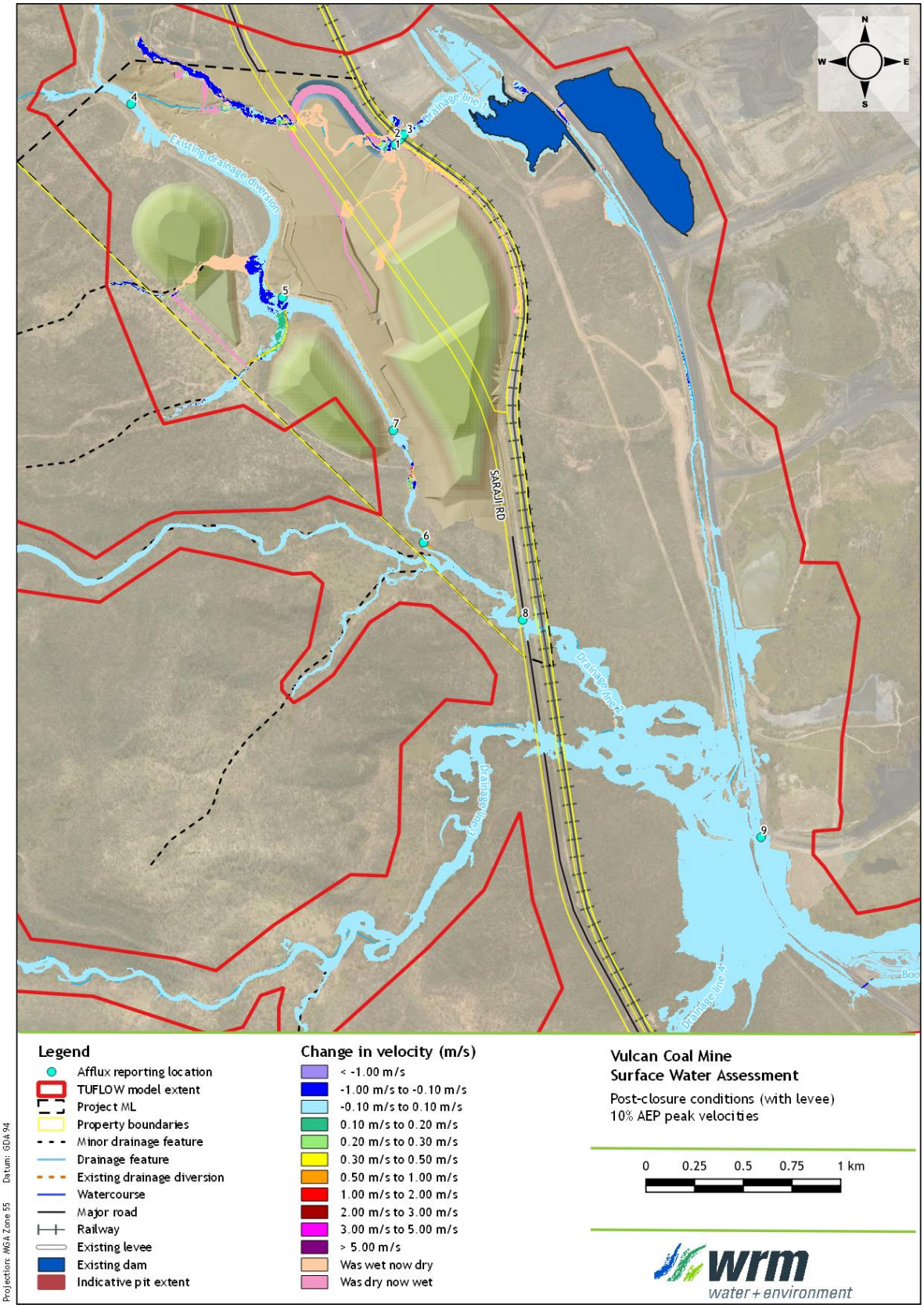


Figure C.4 - 10% AEP change in peak velocities - Post-closure Conditions (with levee) impacts

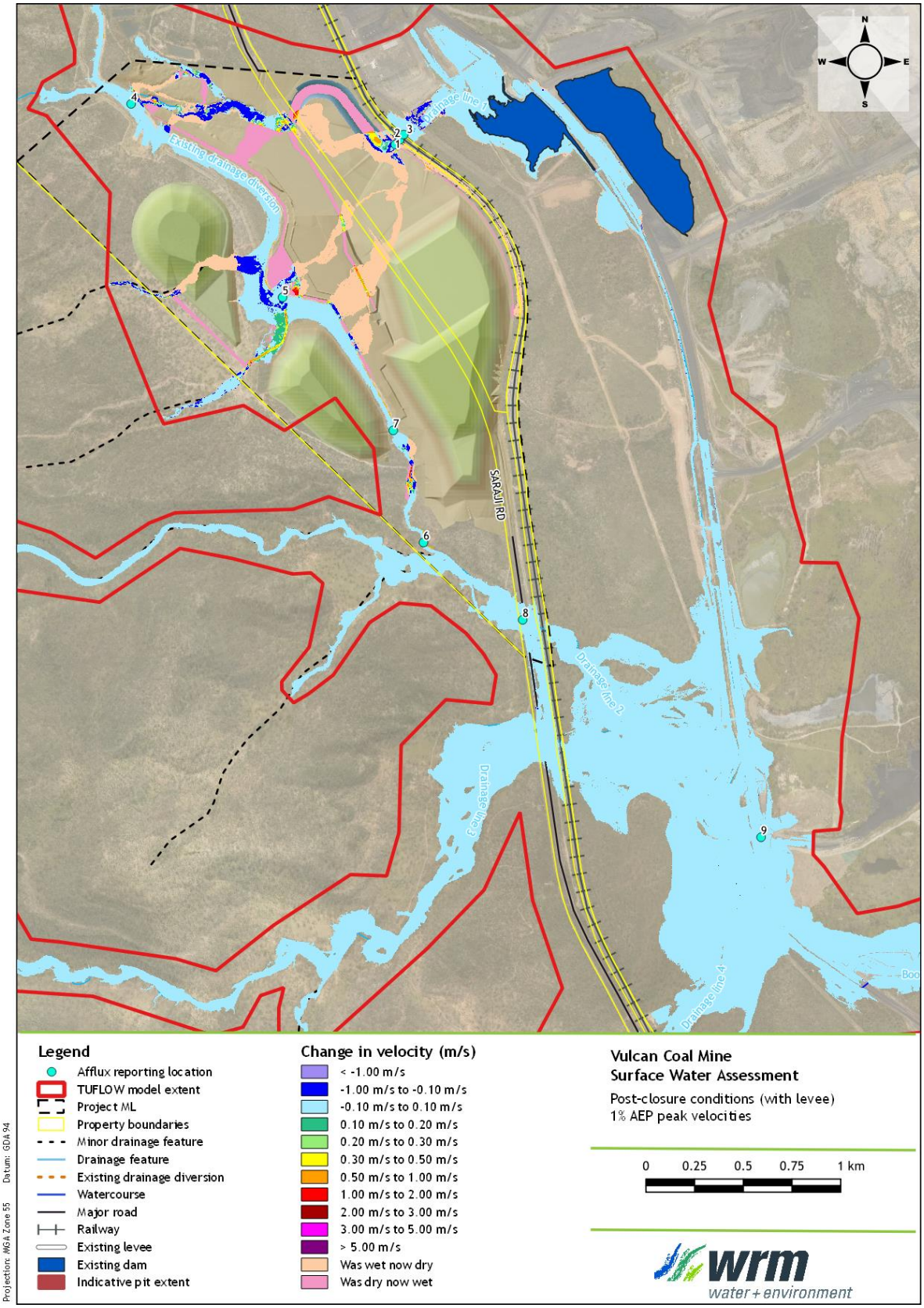


Figure C.5 - 1% AEP change in peak velocities - Post-closure Conditions (with levee) impacts

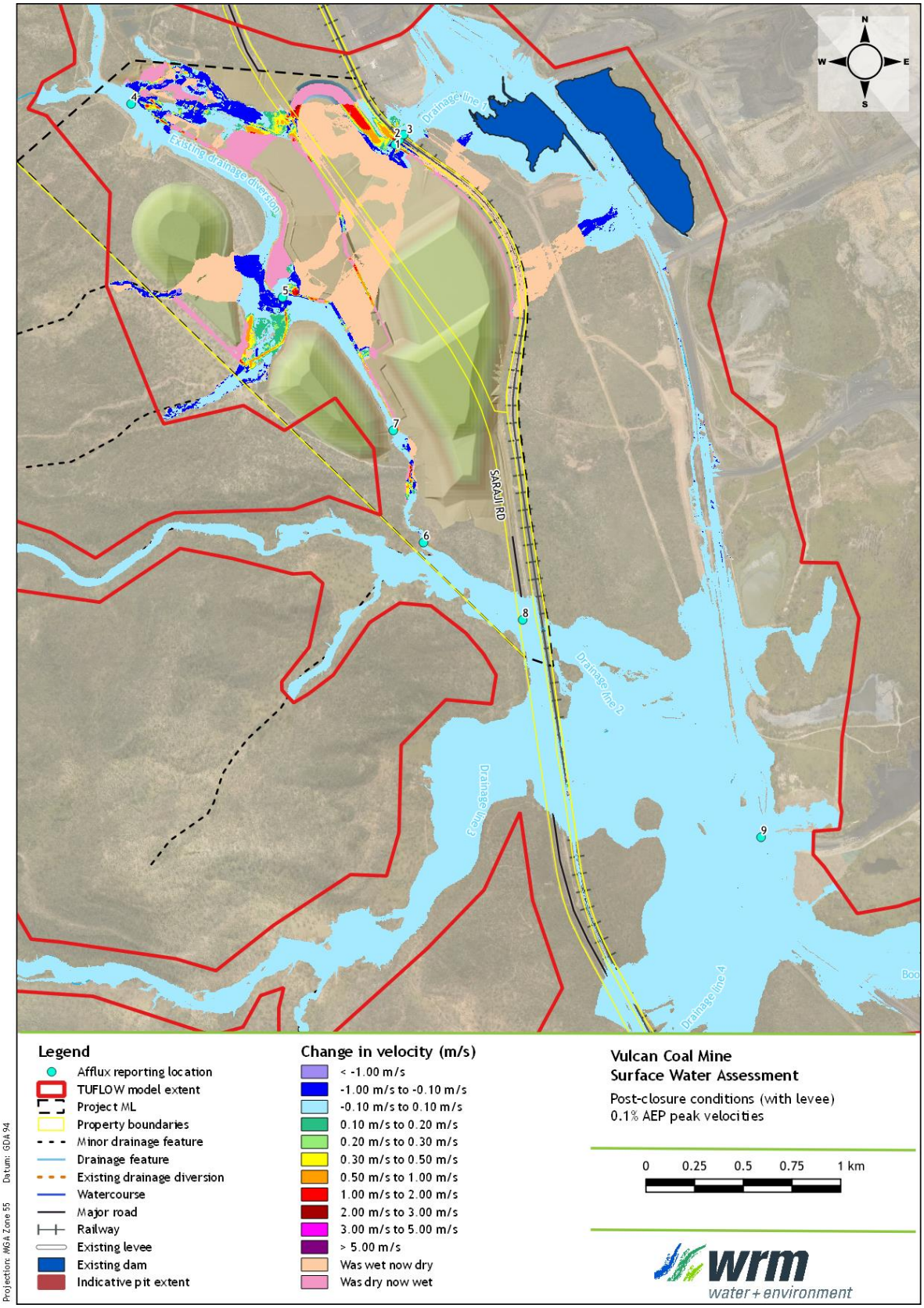


Figure C.6 - 0.1% AEP change in peak velocities - Post-closure Conditions (with levee) impacts

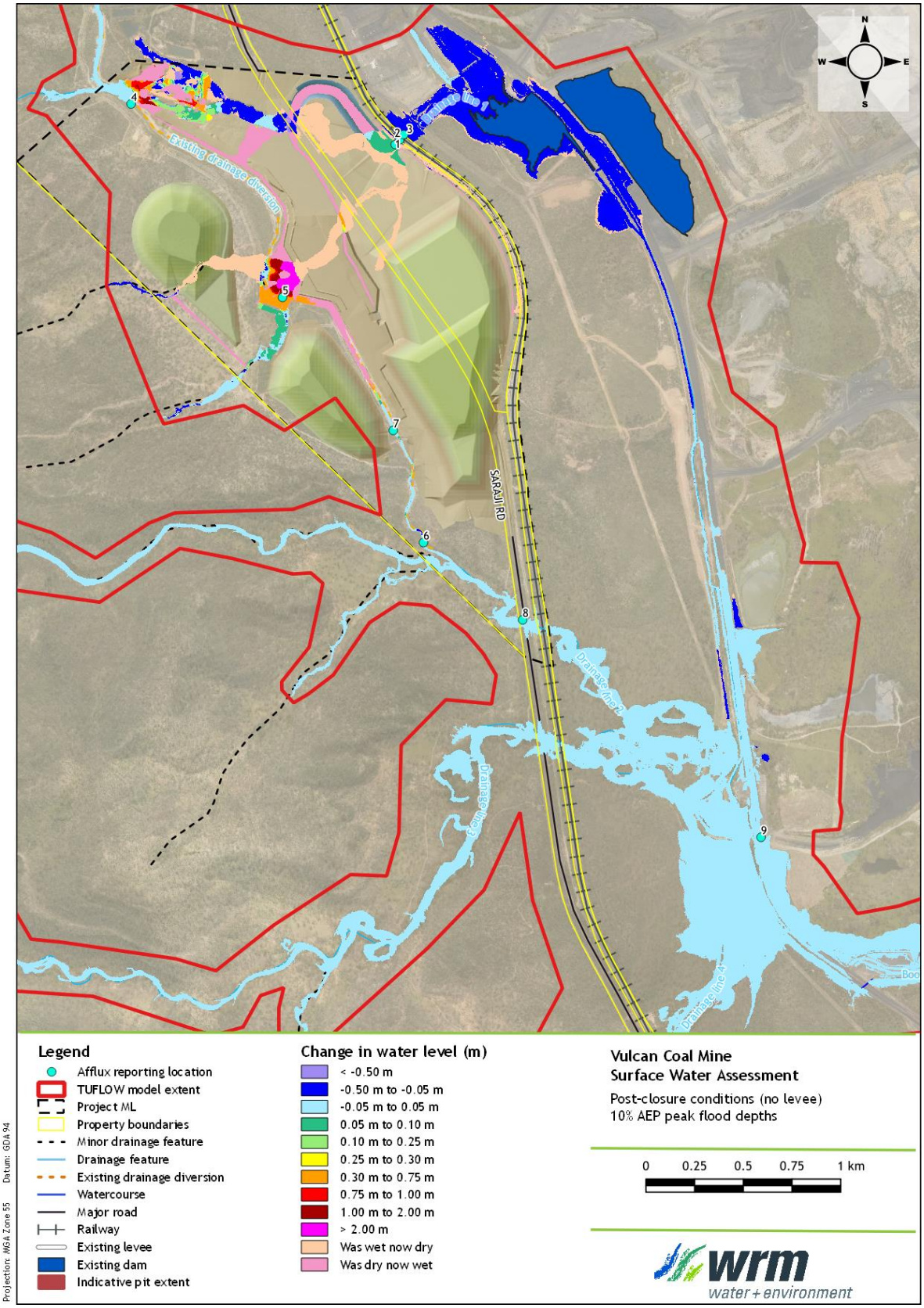


Figure C.7 - 10% AEP change in peak water levels - Post-closure Conditions (no levee) impacts

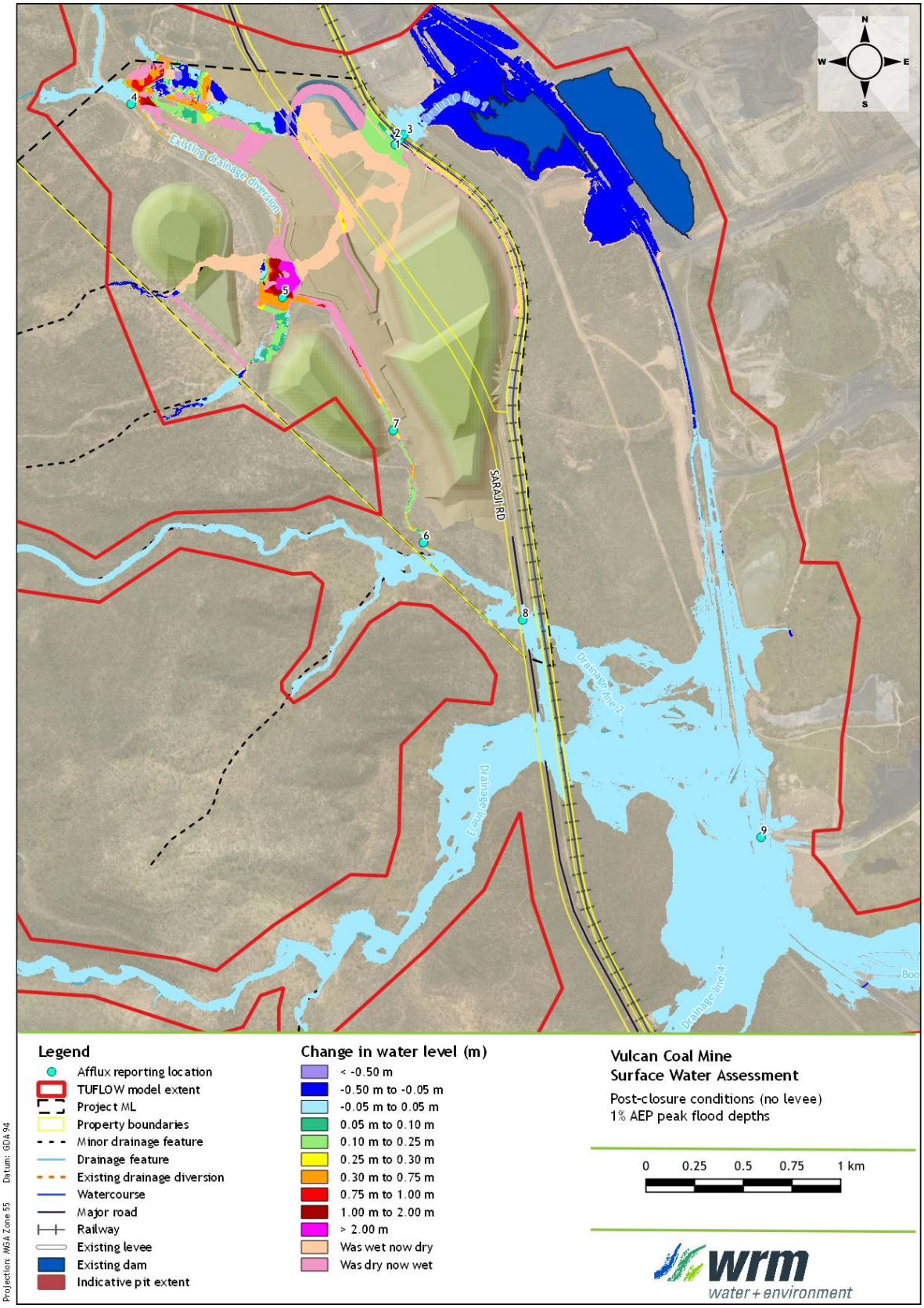


Figure C.8 - 1% AEP change in peak water levels - Post-closure Conditions (no levee) impacts

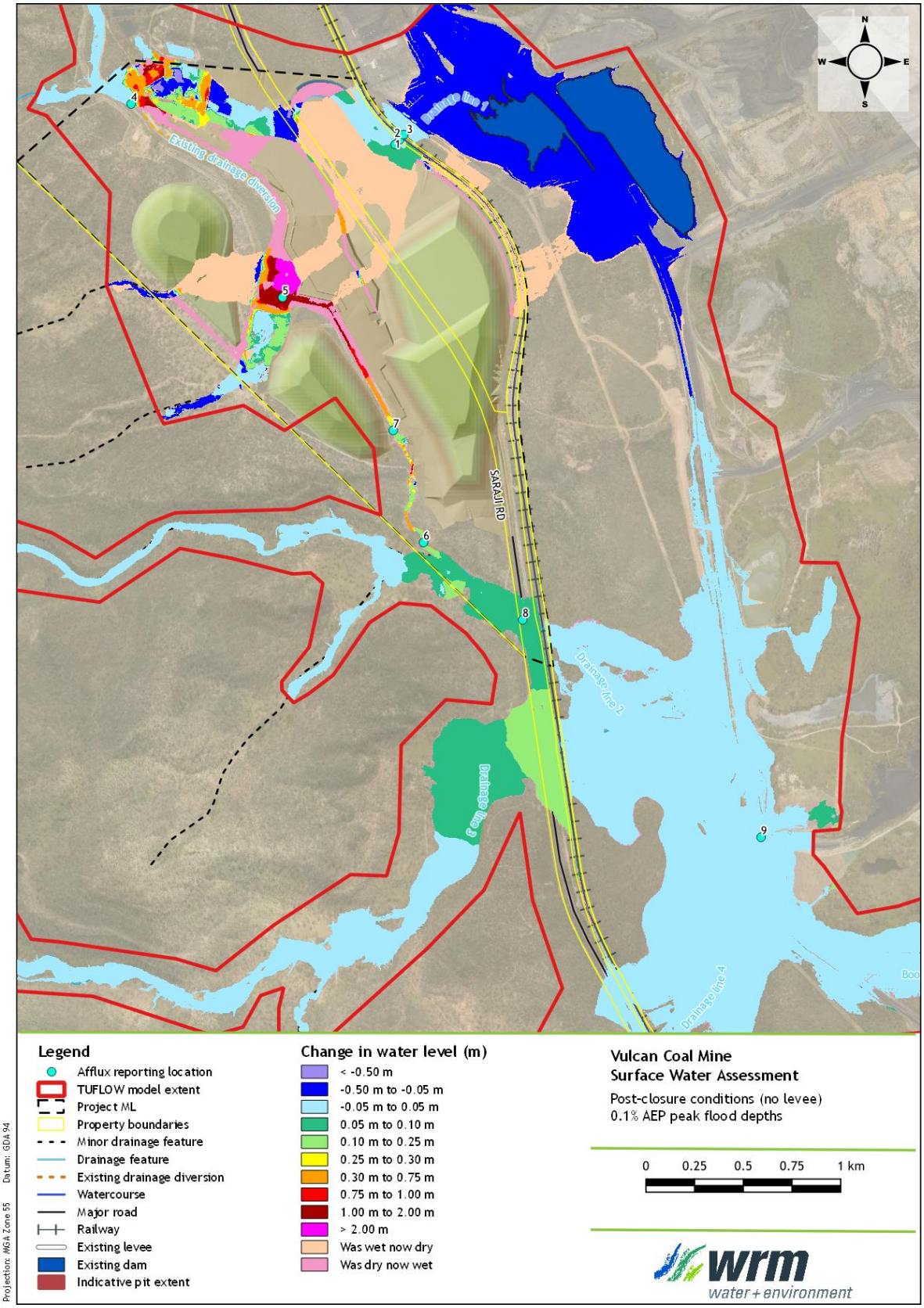


Figure C.9 - 0.1% AEP change in peak water levels - Post-closure Conditions (no levee) impacts

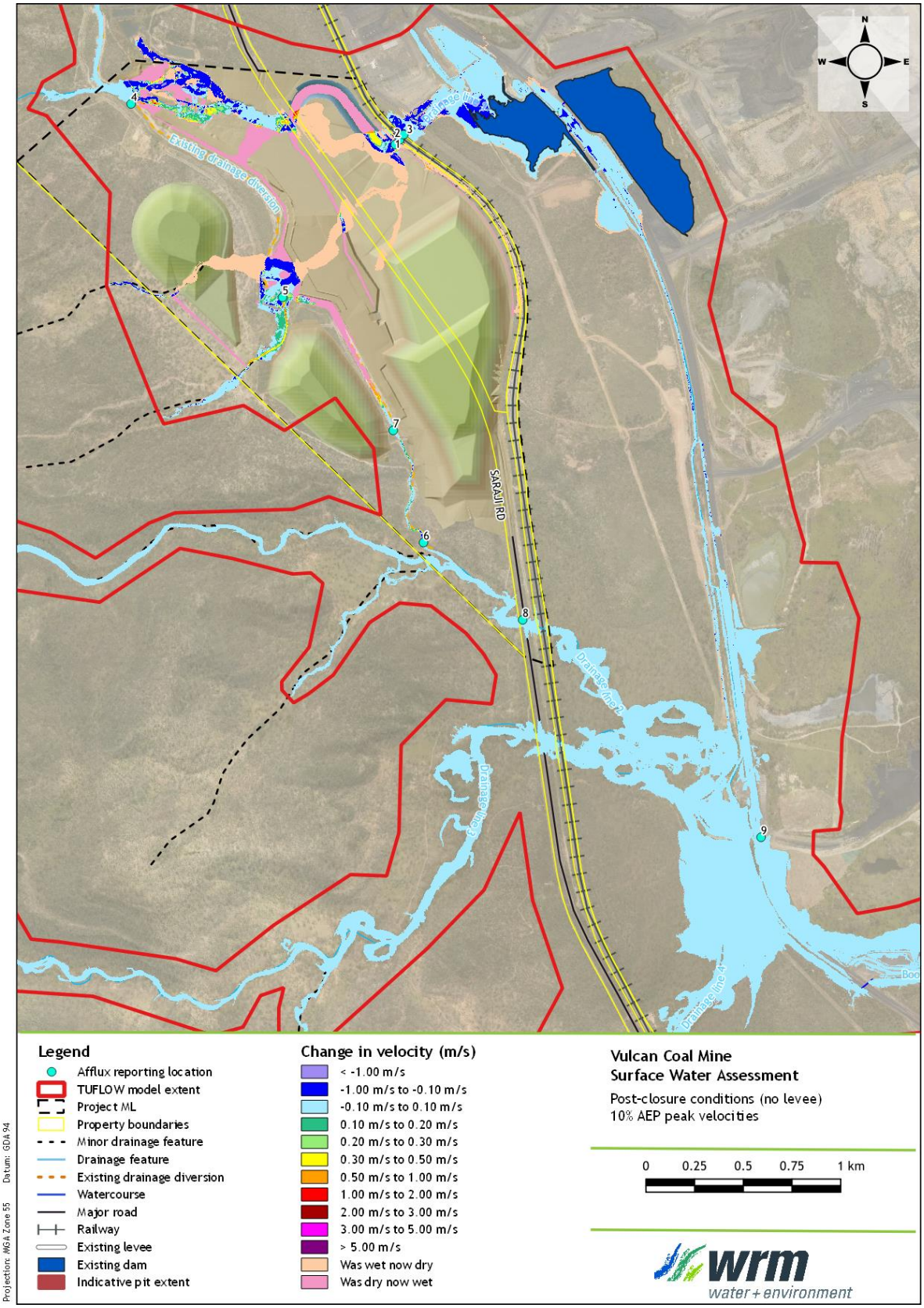


Figure C.10 - 10% AEP change in peak velocities - Post-closure Conditions (no levee) impacts

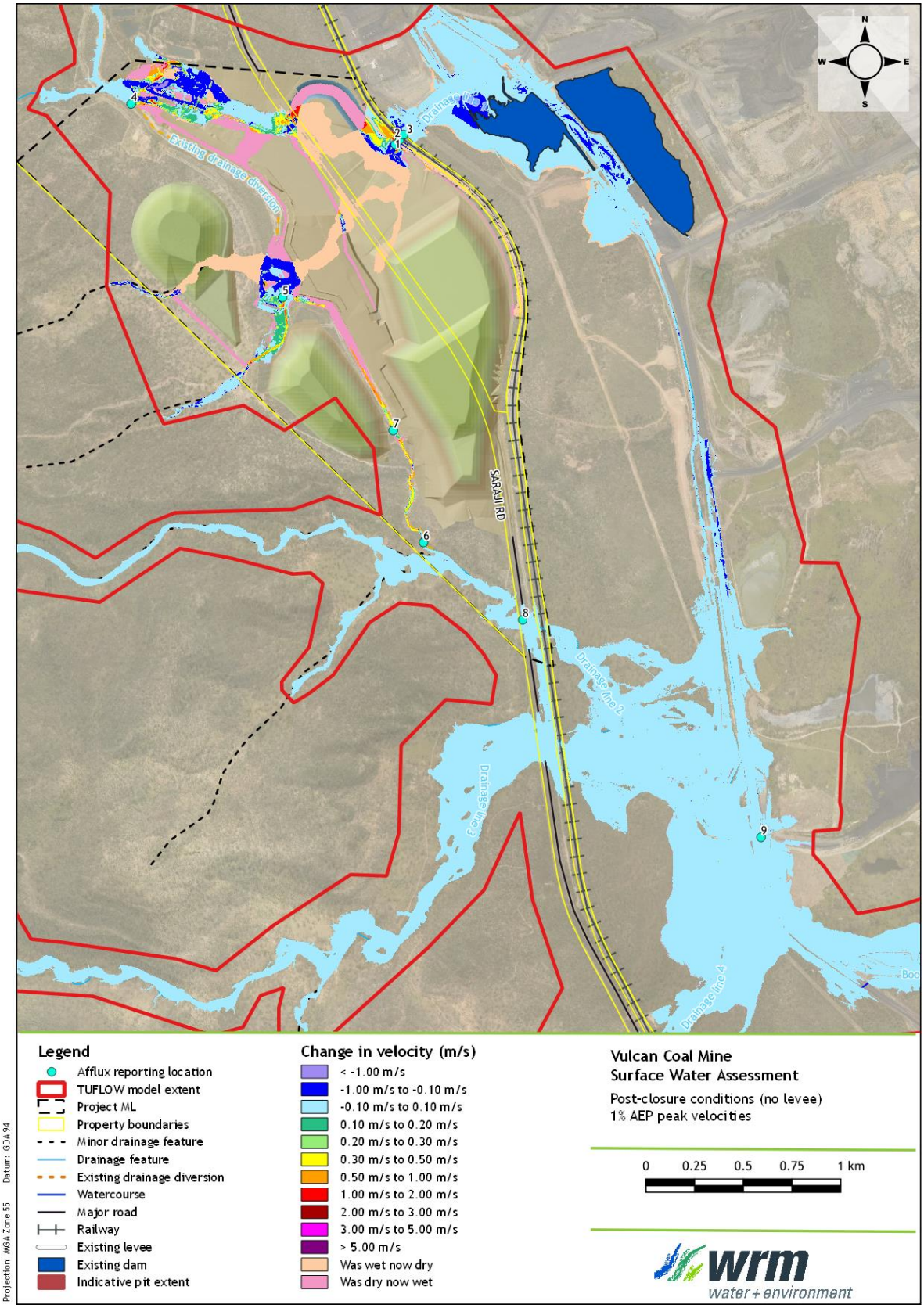


Figure C.11 - 1% AEP change in peak velocities - Post-closure Conditions (no levee) impacts

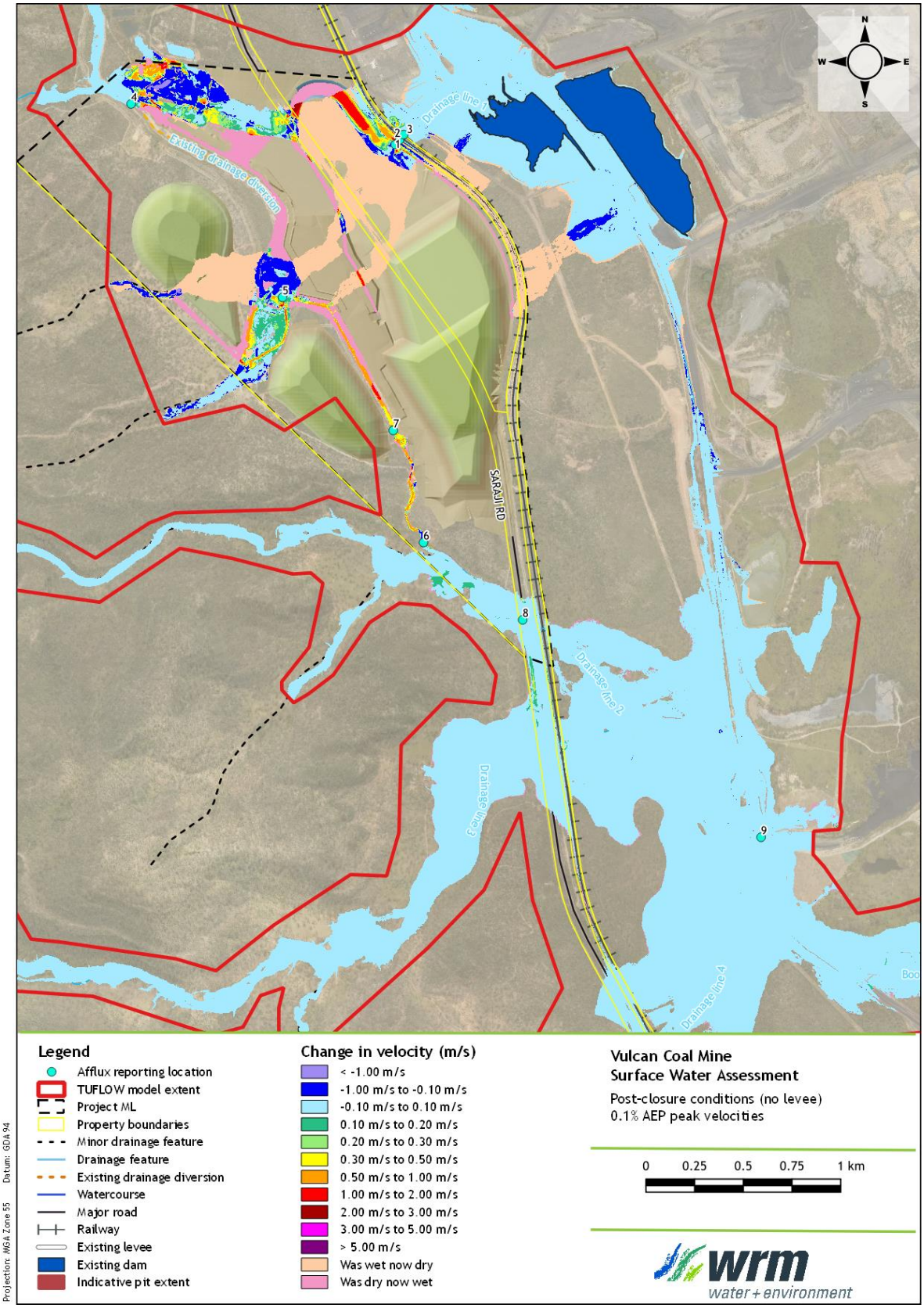


Figure C.12 - 0.1% AEP change in peak velocities - Post-closure Conditions (no levee) impacts

Appendix B- Groundwater Assessment Report

REPORT ON

VULCAN COAL MINE EA AMENDMENT

GROUNDWATER IMPACT ASSESSMENT

Project number: 4124

Date: 08/08/2022

ABN: 50 627 068 866 www.hydrogeologist.com.au info@hydrogeologist.com.au

1/149 Boundary Road, Bardon. QLD. 4065 P.O. Box 108, The Gap. QLD. 4061

Table of contents

1. Introduction 1
   1.1. Background 3
   1.2. Objectives and scope 5
   1.3. Data and information sources 6
2. Regulatory framework 7
   2.1. Queensland 7
      2.1.1. Water Act 2000 7
      2.1.2. Environmental Protection Act 1994 9
      2.1.3. Environmental authority 10
   2.2. Commonwealth 10
3. Baseline conditions 15
   3.1. Climate 15
   3.2. Topography and drainage 17
   3.3. Land use 20
4. Geology 22
   4.1. Quaternary sediments 24
   4.2. Tertiary sediments 24
   4.3. Permian coal measures 24
      4.3.1. Blackwater Group 24
      4.3.2. Back Creek Group 25
5. Hydrogeology 26
   5.1. Hydrostratigraphy 26
      5.1.1. Tertiary sediments 26
      5.1.2. Moranbah Coal Measures 27
      5.1.3. Back Creek Group 27
   5.2. Groundwater monitoring network 27
      5.2.1. Rationale 30
      5.2.2. Current monitoring plan 30
   5.3. Hydraulic properties 35
   5.4. Groundwater flow, recharge and discharge 37
      5.4.1. Tertiary sediments 37
      5.4.2. Permian coal measures 38
      5.4.3. Recharge and discharge rates 39
      5.4.4. Groundwater flow 40
   5.5. Surface-groundwater interaction 45

Table of contents (continued)

5.6. Groundwater use 45
5.6.1. Third party users 45
5.6.2. Groundwater dependent ecosystems 47
5.7. Groundwater quality 52
5.7.1. Site specific data 52
5.7.2. Environmental values 57
5.7.3. Water quality objectives 59
5.8. Conceptual model 60

6. Impact assessment 62
6.1. Summary of numerical modelling 62
6.1.1. Objectives 62
6.1.2. Design 62
6.1.3. Transient calibration 66
6.2. Predictions 67
6.2.1. Mine inflows 67
6.2.2. Drawdown 68
6.2.3. Sensitivity analysis 70
6.3. Impacts on users 72
6.4. Impacts on surface drainage 72
6.5. Impacts on GDEs 72
6.6. Impacts on groundwater quality 76
6.7. Cumulative impacts 76

7. Management and mitigation 77
7.1. Licensing 77
7.2. Adaptive management strategy 77
7.2.1. Drawdown 77
7.2.2. Groundwater quality 78
7.3. Mitigation measures 78

8. Conclusions 79

9. References 80

Table of contents (continued)

Figure list

Figure 1-1 Project location and surrounding mines 2
Figure 1-2 Site layout (Matilda update) 4
Figure 2-1 Groundwater management areas and units 8
Figure 3-1 Average monthly precipitation and evaporation 16
Figure 3-2 Precipitation trend – cumulative rainfall departure (CRD) 16
Figure 3-3 Topography and drainage 18
Figure 3-4 Discharge and water level, Phillips Creek at Tayglen (from DRDMW Water Monitoring Information Portal) 19
Figure 3-5 Daily flow duration, Phillips Creek at Tayglen (from DRDMW Water Monitoring Information Portal) 20
Figure 3-6 Mining tenure 21
Figure 4-1 Cross-section D-D' from URS (2012) 22
Figure 4-2 Local surface geology 23
Figure 5-1 Groundwater monitoring bore network 29
Figure 5-2 Groundwater hydrographs for Vulcan Coal Mine monitoring bores 35
Figure 5-3 Schematic diagram of recharge processes 38
Figure 5-4 Hydrogeological cross section showing the saturation extent of the Permian coal measures in the Project area 39
Figure 5-5 Groundwater elevation contours 42
Figure 5-6 Faults with >1 m throw mapped in the Dysart seam of the Middle Tile, after CSIRO (2002) 44
Figure 5-7 Aquatic groundwater dependent ecosystems 49
Figure 5-8 Terrestrial groundwater dependent ecosystems 50
Figure 5-9 Depth to groundwater 51
Figure 5-10 Extended Durov diagram for site specific monitoring bores 55
Figure 5-11 Piper diagram for site specific monitoring bores 56
Figure 6-1 Model mesh and recharge zones 63
Figure 6-2 Boundaries of the model domain 64
Figure 6-3 Model calibration scatter diagrams – observed and modelled heads and head differences 67
Figure 6-4 Predicted mine inflow rates 67
Figure 6-5 Predicted drawdown in MAT coal seam (L11) 69
Figure 6-6 Sensitivity analysis – maximum drawdown (L11) 71
Figure 6-7 Sensitivity analyses - predicted mine inflow rates 72
Figure 6-8 Maximum drawdown and aquatic GDEs 74
Figure 6-9 Maximum drawdown and terrestrial GDEs 75
Figure 6-10 Predicted inflow rates – Saraji Mine, Peak Downs Mine and Matilda pit 76

Table of contents (continued)

Table list

Table 2-1 IESC information requirements checklist 11
Table 3.1 Average monthly precipitation and evaporation 15
Table 5-1 Local hydrostratigraphic units 26
Table 5-2 Vulcan Coal Mine monitoring bores 28
Table 5.3 Groundwater monitoring location and frequency (Table E1) 31
Table 5.4 Proposed groundwater quality triggers and limits (Table E2) 32
Table 5.5 Groundwater level monitoring (Table E3) 33
Table 5-6 Summary of manual groundwater level measurements 34
Table 5-7 Summary of hydraulic testing from the VCM monitoring bores 36
Table 5-8 Horizontal hydraulic conductivity estimates (m/d) from studies in the Moranbah-Dysart region 36
Table 5-9 Estimates of recharge rates (mm/yr) 40
Table 5-10 Groundwater salinity classification based on Mayer *et.al.* (2005) 52
Table 5-11 Historical summary of field electrical conductivity (µS/cm) 53
Table 5-12 Historical summary of field pH 54
Table 5-13 Zone 34 deep percentiles and medians of preliminary local monitoring data 60
Table 6-1 Temporal discretisation – calibration and predictive models 62
Table 6-2 Model layering 65
Table 6-3 Numerical model – zone budget – predicted inflow rates for the Project 68

Vulcan Coal Mine EA Amendment

Groundwater Impact Assessment

Prepared for

Vitrinite Pty Ltd

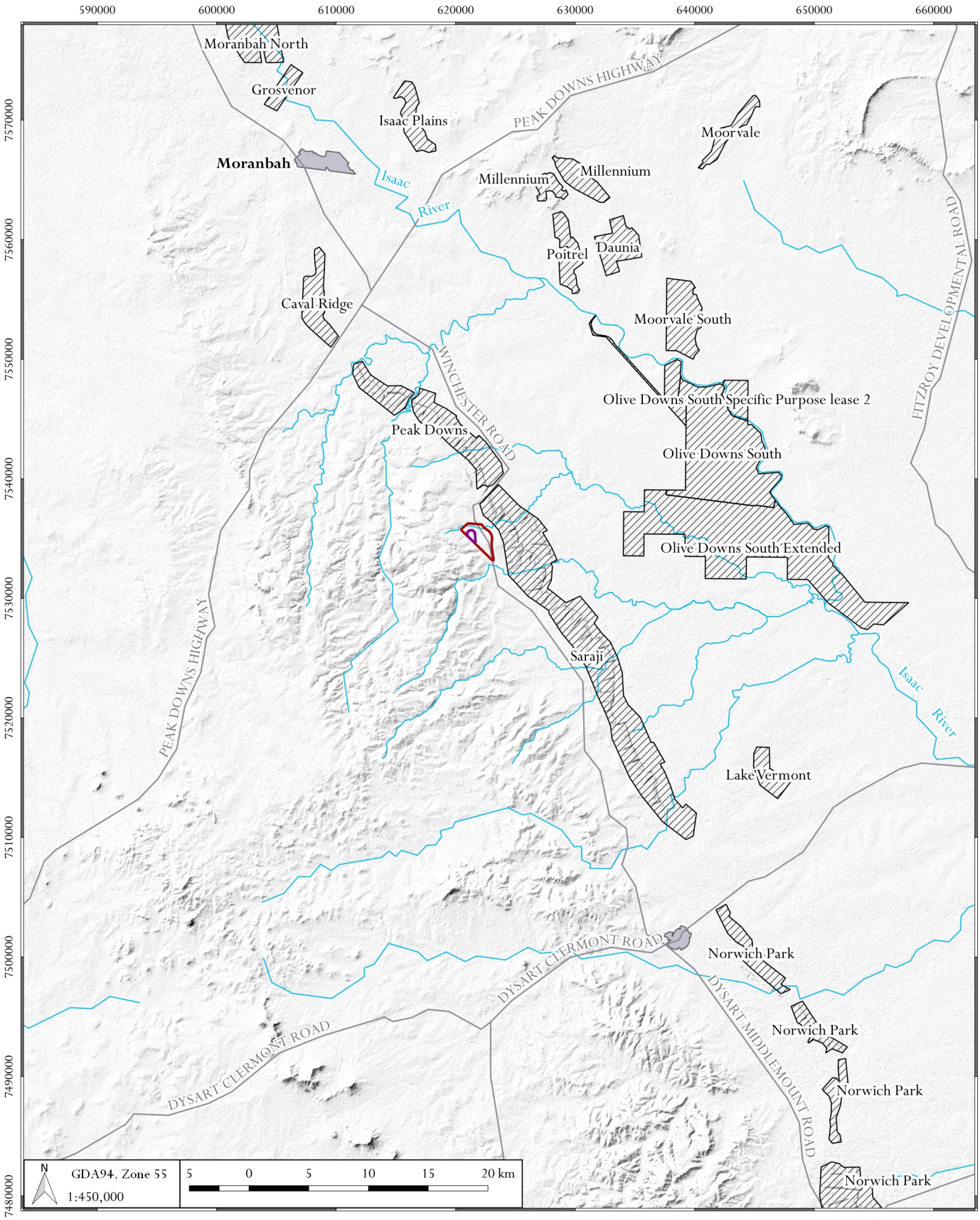
1. Introduction

hydrogeologist.com.au has been engaged by Mining & Energy Technical Services Pty Ltd (METServe) to prepare a groundwater impact assessment to support an Environmental Authority (EA) amendment for the Vulcan Coal Mine (VCM) (the Project). The Project, which is proposed to be developed by Vitrinite Pty. Ltd., owner of Qld Coal Aust No.1 Pty. Ltd. and Queensland Coking Coal Pty. Ltd. (Vitrinite) is located:

- approximately 35 km south of the township of Moranbah, within Mining Lease (ML) 700060; and
- to the immediate west of the BHP Saraji Mine and nearby to several other established BHP mining operations including Caval Ridge Mine, Peak Downs Mine and Norwich Park Mine.

The Project location is presented in Figure 1-1.

METServe has been engaged by Vitrinite to manage the environmental approval process for the Project. Vitrinite has commissioned environmental assessment work for the purposes of preparing an Environmental Authority (EA) amendment. The groundwater impact assessment will also support the referral of the Project to the Commonwealth Department of the Environment and Energy (DoEE) under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).



LEGEND

- Combined exploration permits coal
- Established mining operation
- ML700060
- Matilda pit
- Watercourse
- Major road

DATE
21/06/2022

hydrogeologist .com.au

Vulcan Coal Mine EA amendment - Groundwater Impact Assessment (4124)

Project location and surrounding mines

FIGURE No.
1.1

©2022 Oasis Hydrogeology Pty Ltd - trading as hydrogeologist.com.au

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.
Z:\4000_Projects\4124_Metserve_Matilda Pit\3_GIS\3_11_Workspaces_QGIS\01_01_4124_Matilda_Vulcan South_Project location.qgz

1.1. Background

Vitrinite holds an Environmental Authority (EA0002912) and Mining Lease (ML 700060) authorising the extraction of black coal, quarry material and crushing and screening activities. The VCM is approved to operate for approximately 4 years extracting approximately 6 million tonnes (Mt) of Run of Mine (ROM) hard coking coal at a rate of up to 1.95 Mt per annum (Mtpa). The VCM currently targets the Alex and multiple Dysart Lower coal seams.

The proposed amendment primarily includes the establishment of a Coal Handling and Preparation Plant (CHPP), Train Load-out facility (TLO), a dedicated rail loop and an additional open cut pit on ML700060. The open cut pit, referred to as the 'Matilda pit' is proposed to be located within the rail loop and will provide supplementary coal to the ROM stockpile. Development of the Matilda pit will not require an increase of the approved production rate, nor have a significant impact on the life of the project.

The Matilda pit will be a small, shallow (maximum depth of 40 m) open pit within the rail loop alignment. It will target the Matilda (MAT) coal seam which underlies the Alex and multiple Dysart Lower coal seams mined in the existing open pit to the east. The Matilda pit will be mined concurrently with the existing pit to the east. The extent of mining in the Matilda pit is shown in Figure 1-2.

There is no requirement to increase the production rate or significantly alter project timeframes. This is because further planning work has been completed on the main pit and the amount of coal to be extracted has reduced from what was originally proposed and approved.

hydrogeologist.com.au (2019) established a groundwater monitoring network for the Vulcan Coal Mine in June 2019 to support baseline characterisation and impact assessment. The groundwater monitoring network has been monitored in accordance with the EA and has been supplemented overtime with additional monitoring bores where required.

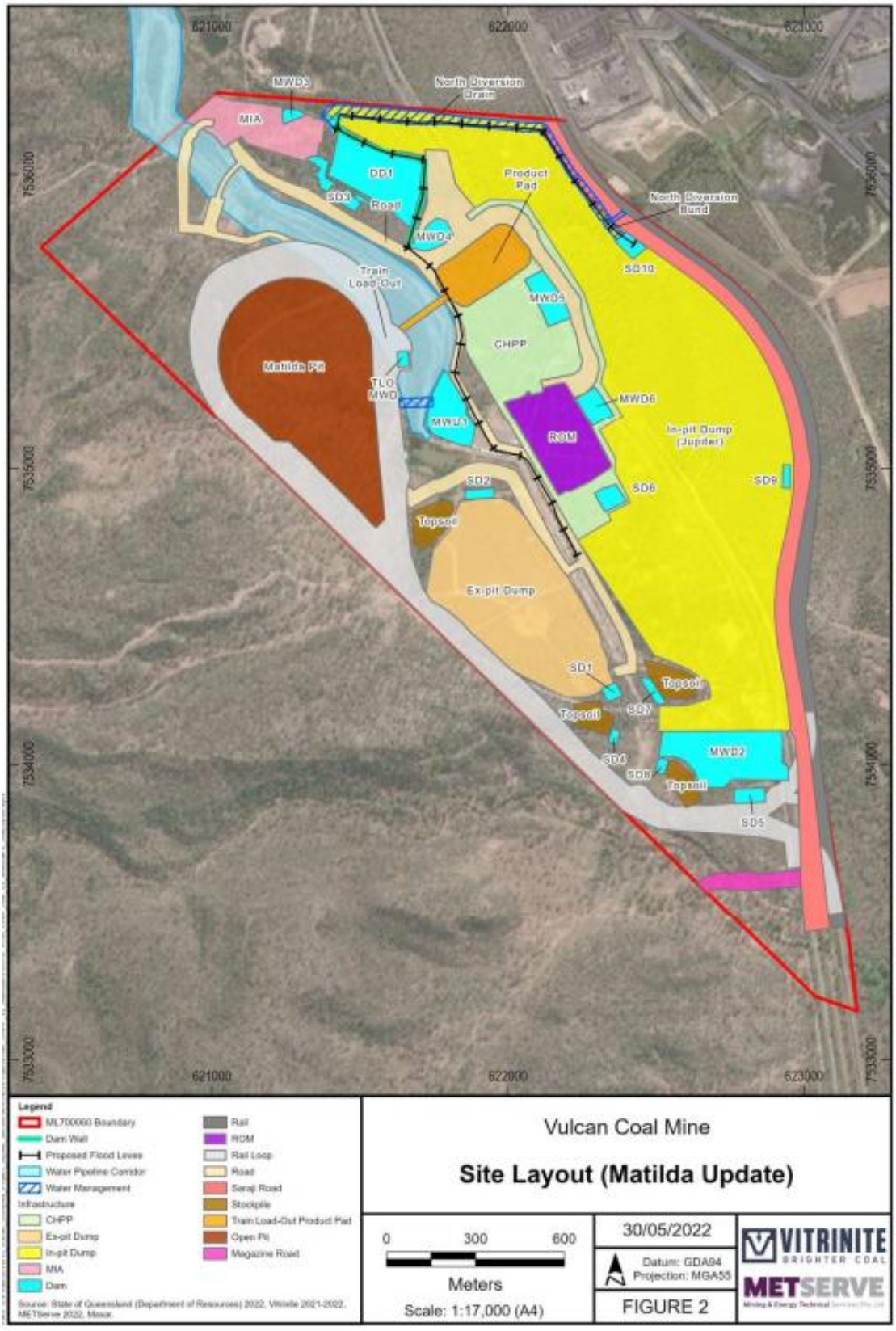


Figure 1-2 Site layout (Matilda update)

1.2. Objectives and scope

The objective of the assessment is to identify and assess the Project's groundwater impacts in a robust manner that meets the expectations of multiple stakeholders. These stakeholders include the Queensland Government, the Commonwealth Government, surrounding landholders and mining companies. The scope of work defines the following distinct activities which have been compiled into the groundwater impact assessment to support Project's approval:

- Review existing geological and hydrogeological information in the public domain and from private investigations.
- Describe the following components of the groundwater regime:
    - geology and stratigraphy, locally and regionally, including faulting;
    - depth to, and thickness of aquifers and their transmissivity;
    - relationship between local and regional groundwater flows;
    - groundwater flow directions and discharge;
    - groundwater quality and chemistry;
    - sources of recharge and recharge rates for each aquifer; and
    - surface water interactions and potential groundwater dependent ecosystems (GDEs).
- Determine the local environmental values and water quality objectives of the groundwater resource in accordance with the Environmental Protection (Water and Wetland Biodiversity) Policy 2019 (EPP Water and Wetland Biodiversity), the Queensland Water Quality Guidelines (Department of Environment and Heritage Protection, 2009), and the ANZECC Water Quality Guidelines (AWQG, 2018).
- Predict potential drawdown of all relevant aquifers using the existing site conceptual and numerical model. The groundwater impact assessment should:
    - simulate the Project and predict groundwater level drawdown or depressurisation in each hydrostratigraphic unit during the Project and post closure;
    - predict the volumes of groundwater reporting to the Matilda pit as seepage or inflow;
    - predict residual groundwater levels and recovery rates in each hydrostratigraphic unit during post closure; and
    - include a sensitivity analysis.
- Predict and present impacts on identified third party landholder bores and potential GDEs.
- Predict and present impacts on potential interactions and connectivity between surface waters and groundwaters.
- Predict and present drawdown impacts during operations and post mining resulting from the Project.
- Predict and present cumulative drawdown impacts with other existing, known or reasonably foreseeable projects in the region during and post mining.
- Propose an ongoing groundwater management strategy including monitoring of the established bore monitoring network, any measures to manage or mitigate potential impacts and a program for the review and update of the numerical model.
- Describe potential impacts on groundwater quality from the Project (e.g., spills, contaminants).

1.3. Data and information sources

Data and information used for the purposes of this assessment has been obtained from the following sources:

- proponent provided information from METServe and Vitrinite;
- reports and publications as listed in Section 9 of this report;
- groundwater assessments from nearby mines including:
  - Caval Ridge Mine (URS, 2009);
  - Saraji Mine (AECOM, 2016); and
  - Olive Downs Coal Project (HydroSimulations, 2018).
- relevant Bowen Basin publications including:
  - CSIRO (2002);
  - Arrow Energy (2012);
  - URS (2012); and
  - Arrow Energy (2016).
- publicly available datasets including:
  - Australian Bureau of Meteorology (BoM) weather and climate data (Bureau of Meteorology, 2016);
  - Scientific Information for Land Owners (SILO) rainfall and evaporation (https://www.longpaddock.qld.gov.au/silo/);
  - Groundwater Dependent Ecosystems Atlas (GDE Atlas, BOM, 2018) (http://www.bom.gov.au/water/groundwater/gde/);
  - QLD globe (https://qldglobe.information.qld.gov.au/); and
  - Queensland Springs Database (https://data.qld.gov.au/dataset/springs/resource/4cdc89ef-b583-446e-a5c7-0836a91a3767).
- spatial mapping data from the Queensland spatial catalogue (QSpatial) (http://qldspatial.information.qld.gov.au/catalogue/custom/index.page).

2. Regulatory framework

hydrogeologist.com.au have considered the Project description and activities proposed against the various legislation and guidelines produced by the Queensland and Commonwealth Governments. Relevant legislation is described below.

2.1. Queensland

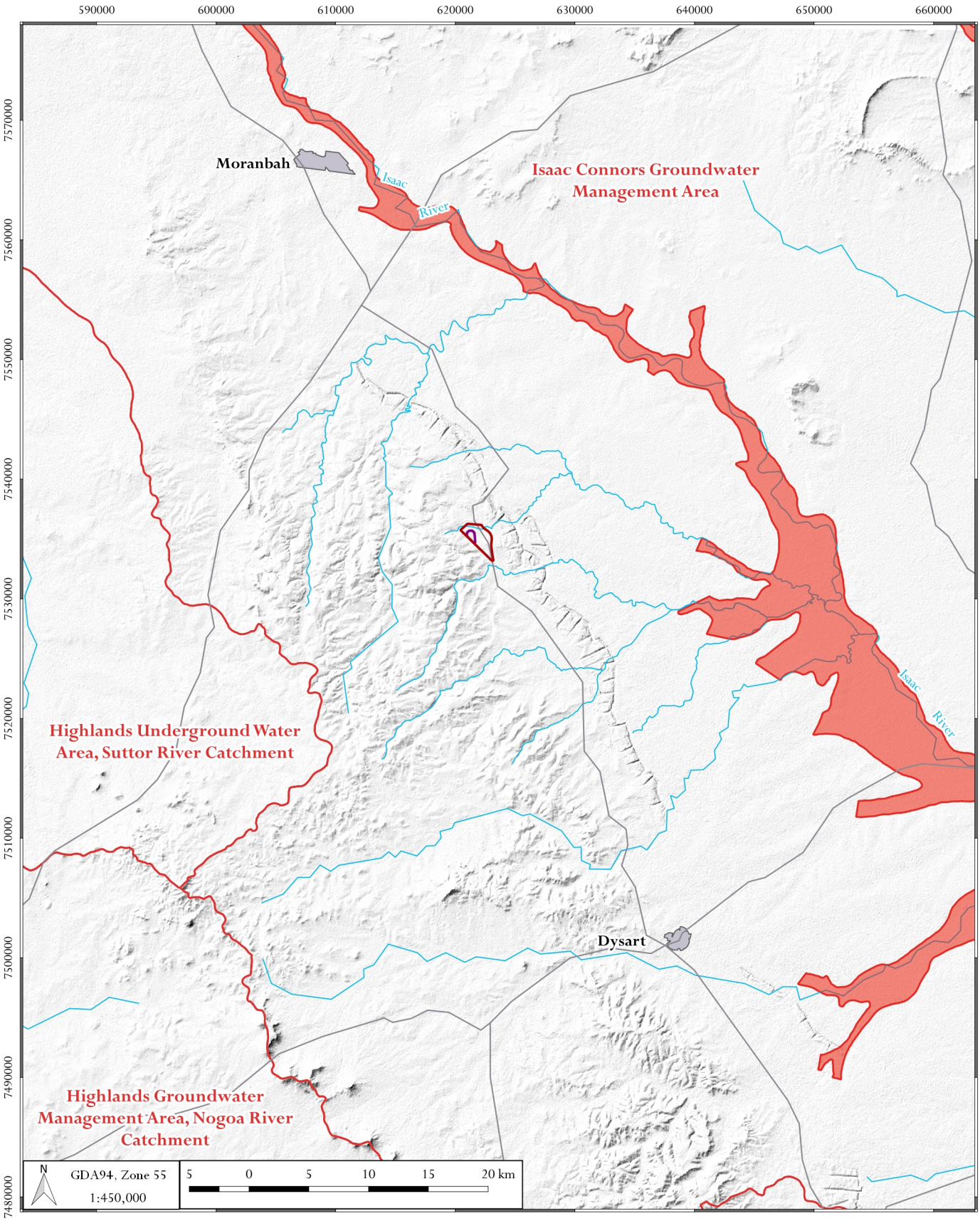
2.1.1. Water Act 2000

The *Water Act 2000* (Water Act), supported by the subordinate Water Regulation 2016, is the primary legislation regulating groundwater resources in Queensland. The purpose of the Water Act is to advance sustainable management and efficient use of water resources by establishing a system for planning, allocation and use of water. The Water Act is enacted under a framework of catchment specific Water Plans.

Water resources within the Project area are covered by the Water Plan (Fitzroy Basin) 2011 (Queensland Government, 2014) (Water Plan). The Water Plan covers surface waters (zone WQ1301) associated with the Isaac River, and groundwaters (zone WQ1310) of the Fitzroy Basin. Section 7 of the Water Plan defines the groundwater units and groundwater sub-areas, including the Isaac Connors groundwater management area, as follows:

> *(3) The Isaac Connors groundwater management area consists of the following (also each a groundwater unit)—*
>
> *(a) Isaac Connors Groundwater Unit 1, containing the aquifers of the Quaternary alluvium;*
>
> *(b) Isaac Connors Groundwater Unit 2, containing all subartesian aquifers within the Isaac Connors groundwater management area other than the aquifers included in Isaac Connors Groundwater Unit 1.*
>
> *(4) The area of Isaac Connors Groundwater Unit 1 shown on map E in schedule 4 is the Isaac Connors Alluvium groundwater sub-area for this plan.*

Map E, in Schedule 4, is reproduced as Figure 2-1 in this report. Figure 2-1 indicates that the Isaac Connors Alluvium groundwater sub-area is limited to the Isaac River and those parts of its tributaries that are adjacent to the confluence with the Isaac River. The Project area is approximately 15 km to the west of the Isaac River (Figure 2-1) and is well outside the Isaac Connors Groundwater Unit 1. It is assessed by **hydrogeologist.com.au** that the proposed open pit would take groundwater from the Isaac Connors Groundwater Unit 2, that is the sub-artesian aquifers within the Isaac Connors groundwater management area.



LEGEND

- ML700060
- Matilda pit
- Groundwater management area
- Isaac Connors Alluvium Groundwater Sub-Area
- Watercourse
- Major road

DATE
21/06/2022

hydrogeologist.com.au

Vulcan Coal Mine EA amendment - Groundwater Impact Assessment (4124)

Groundwater management areas and units

FIGURE No.
2.1

©2022 Oasis Hydrogeology Pty Ltd - trading as hydrogeologist.com.au

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.
Z:\4000_Projects\4124_Metserve_Matilda Pit\3_GIS\3_11_Workspaces_QGIS\02_01_4124_Matilda_Vulcan South_Groundwater management area.qgz

2.1.2. Environmental Protection Act 1994

The quality of Queensland waters is protected under the Environmental Protection (Water and Wetland Biodiversity) Policy 2019 (EPP Water and Wetland Biodiversity). The EPP Water and Wetland Biodiversity achieves the objective of the *Environmental Protection Act 1994* (EP Act) to protect Queensland waters whilst supporting ecologically sustainable development. Queensland waters include waters in rivers, streams, wetlands, lakes, aquifers, estuaries and coastal areas.

The Isaac River Sub-basin Environmental Values and Water Quality Objectives (2011) is made pursuant to the provisions of the EPP Water and Wetland Biodiversity, which is subordinate legislation under the EP Act. The EPP Water and Wetland Biodiversity provides a framework for identifying environmental values (EVs) for Queensland waters, and deciding the water quality objectives (WQOs) to protect or enhance the EV. The Isaac River Sub-basin Environmental Values and Water Quality Objectives (2011) contains EV (Section 2, Table 1) and WQO for waters (including groundwaters) in the Isaac River Sub-basin.

For Isaac River groundwaters, the EVs selected for protection are as follows:

- aquatic ecosystems;
- irrigation;
- farm supply/use;
- stock water;
- primary recreation;
- drinking water; and
- cultural and spiritual.

The water quality guidelines (Department of Environment and Science, 2022) inform the development of water quality guidelines to enhance or protect the 'aquatic ecosystem' EV for Queensland waters, in accordance with the provisions of the EPP Water and Wetland Biodiversity. The guidelines (Department of Environment and Science, 2022) outline protocols for comparing test site water quality against relevant WQO recognised under the EPP Water and Wetland Biodiversity.

Section 2.7 of the Queensland Water Quality Guidelines (Department of Environment and Heritage Protection, 2009) provides guidance on the approach taken to identify EV, water quality indicators and guidelines (as a basis for WQO) in groundwater. Where local EV and WQO have been scheduled under the EPP Water and Wetland Biodiversity for groundwaters, these are the applicable reference source for decision making.

In the absence of scheduled data, the EPP Water and Wetland Biodiversity identifies applicable EV and potential sources for water quality guidelines to inform decision making. The EP Act identifies that groundwater quality is an EV to be protected and therefore the groundwater quality should be maintained within the range of natural quality variations. Natural quality variations should be established through baseline characterisation.

In the absence of scheduled data, the default management intent is that there should be 'no change' to the natural variation in groundwater quality. From the Queensland Water Quality Guidelines (Department of Environment and Heritage Protection, 2009), no change in the natural variation in groundwater quality is deemed to have occurred if there are no detectable changes to the 20th, 50th and 80th percentiles of the natural distribution of values. Where review of local data indicates that some groundwater systems are clearly impacted, then in these cases, the management intent would be to improve quality, and more stringent percentiles may be used to derive guideline values.

Generally, the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (AWQG, 2018) should apply to the quality of both surface waters and groundwaters since the EVs which they protect relate to above-ground uses (e.g. irrigation, drinking water, farm animal or fish production and maintenance of aquatic ecosystems).

The Department of Regional Development, Manufacturing and Water (DRDMW) Groundwater Database (GWDB) contains groundwater quality data from registered groundwater bores. Where sufficient data exist, water quality guidelines are developed at aquifer/sub-aquifer level based on existing conditions, using groundwater quality data sourced from the DRDMW GWDB or from local monitoring data. Following the definition and mapping of chemistry zones, the groundwater quality data are used to calculate a range of percentiles for available indicators for each chemistry zone.

Where there is potential for groundwater to be impacted by activities such as mining, it is important to acquire localised reference (or baseline) data prior to commencement of the activity. In this situation, the local pre-development data would be used as reference data. Where the groundwater quality is slightly disturbed due to anthropogenic contamination or from naturally occurring groundwater chemistry, the slightly disturbed water guideline applies. Where groundwater is moderately or highly disturbed, more stringent percentiles may be applied as follows:

- high ecological value (HEV) groundwaters guideline: 20/50/80th percentiles of the waters in the sub-aquifer chemistry zones;
- slightly disturbed (SD) groundwaters guideline: 20/40/70th percentiles of the waters in the sub-aquifer chemistry zones; and
- waters potentially impacted by human activities – guideline: no change to the 20/50/80th percentiles of local pre-development data.

2.1.3. Environmental authority

In order to amend an EA, Section 227AA of the EP Act requires that the EA amendment application for the project must be supported by the following specific information on the exercise of underground water rights:

- *a statement describing the proposed exercise of underground water rights and a description of the timing and location of the proposed activities;*
- *a description of each aquifer and the movement of water within each aquifer affected by the proposed activities;*
- *an assessment of the extent of depressurisation in each aquifer due to the proposed activities;*
- *the predicted quantity of associated water taken from each aquifer during the proposed activities;*
- *a description of the impacts of the proposed activities on environmental values;*
- *a description of the effects of the proposed activities on groundwater quality; and*
- *a description of any strategies to manage or mitigate the impacts of the proposed activities.*

2.2. Commonwealth

The EPBC Act is administered by the DoEE and is designed to protect national environmental assets, known as Matters of National Environmental Significance (MNES). Under the 2013 amendment to the EPBC Act, impacts on groundwater resources, in relation to coal seam gas (CSG) development and large coal mining development were included and are known as the 'water trigger'.

A project may be declared a controlled action by the DoEE, with water resources being one of the controlling provisions. The Independent Expert Scientific Committee (IESC) is a statutory body under the EPBC Act that provides scientific advice to the DoEE and relevant state ministers on CSG or large coal mining development proposals. Guidelines have been developed in order to assist the IESC in reviewing these proposals. Whilst the Project is not considered to be a large coal mining development, the IESC information requirements checklist is presented in Table 2-1, with details on where aspects have been addressed and documented within the report.

Table 2-1 IESC information requirements checklist

Information requirements	Section addressed
Description of the proposal	
Provide a regional overview of the proposed project area including a description of the: ▪ *geological basin;* ▪ *coal resource;* ▪ *surface water catchments;* ▪ *groundwater systems;* ▪ *water-dependent assets; and* ▪ *past, present and reasonably foreseeable coal mining and CSG developments.*	Sections 4 and 5
Describe the statutory context, including information on the proposal's status within the regulatory assessment process and any applicable water management policies or regulations.	Section 2
Describe the proposal's location, purpose, scale, duration, disturbance area, and the means by which it is likely to have a significant impact on water resources and water-dependent assets.	Sections 1, 5.8, 6.2, 7
Describe how impacted water resources are currently being regulated under state or Commonwealth law, including whether there are any applicable standard conditions.	Section 2
Risk assessment	
Identify and assess all potential environmental risks to water resources and water-related assets, and their possible impacts. In selecting a risk assessment approach consideration should be given to the complexity of the project, and the probability and potential consequences of risks.	Section 6
Assess risks following the implementation of any proposed mitigation and management options to determine if these will reduce risks to an acceptable level based on the identified environmental objectives.	Section 7
Incorporate causal mechanisms and pathways identified in the risk assessment in conceptual and numerical modelling. Use the results of these models to update the risk assessment.	Section 6
The risk assessment should include an assessment of: ▪ *all potential cumulative impacts which could affect water resources and water-related assets; and* ▪ *mitigation and management options which the proponent could implement to reduce these impacts.*	Sections 6 and 7
Groundwater – Context and Conceptualisation	
Describe and map geology at an appropriate level of horizontal and vertical resolution including: ▪ *definition of the geological sequence(s) in the area, with names and descriptions of the formations and accompanying surface geology, cross-sections and any relevant field data.* ▪ *geological maps appropriately annotated with symbols that denote fault type, throw and the parts of sequences the faults intersect or displace.*	Section 4
Define and describe or characterise significant geological structures (e.g., faults, folds, intrusives) and associated fracturing in the area and their influence on groundwater – particularly groundwater flow, discharge or recharge. ▪ *Site-specific studies (e.g., geophysical, coring / wireline logging etc.) should give consideration to characterising and detailing the local stress regime and fault structure (e.g., damage zone size, open/closed along fault plane, presence of clay/shale smear, fault jogs or splays).* ▪ *Discussion on how this fits into the fault's potential influence on regional-scale groundwater conditions should also be included.*	Sections 4 and 5
Provide site-specific values for hydraulic parameters (e.g., vertical and horizontal hydraulic conductivity and specific yield or specific storage characteristics including the data from which these parameters were derived) for each relevant hydrogeological unit. In situ observations of these parameters should be sufficient to characterise the heterogeneity of these properties for modelling.	Sections 5, 5.3
Provide time series level and water quality data representative of seasonal and climatic cycles	Sections 5.2, 5.4 and 5.7

Information requirements	Section addressed
Provide data to demonstrate the varying depths to the hydrogeological units and associated standing water levels or potentiometric heads, including direction of groundwater flow, contour maps, and hydrographs. All boreholes used to provide this data should have been surveyed.	Section 5.4
Provide hydrochemical (e.g., acidity/alkalinity, electrical conductivity, metals, and major ions) and environmental tracer (e.g., stable isotopes of water, tritium, helium, strontium isotopes, etc.) characterisation to identify sources of water, recharge rates, transit times in aquifers, connectivity between geological units and groundwater discharge locations.	Section 5.7
Describe the likely recharge, discharge and flow pathways for all hydrogeological units likely to be impacted by the proposed development.	Section 5.4
Assess the frequency (and time lags if any), location, volume and direction of interactions between water resources, including surface water/groundwater connectivity, inter-aquifer connectivity and connectivity with sea water.	Sections 5.4 and 5.5
Groundwater – Analytical and Numerical Modelling	
Provide a detailed description of all analytical and/or numerical models used, and any methods and evidence (e.g., expert opinion, analogue sites) employed in addition to modelling.	Section 6.1
Undertake groundwater modelling in accordance with the Australian Groundwater Modelling Guidelines (Barnett et al. 2012), including independent peer review.	Section 6.1
Calibrate models with adequate monitoring data, ideally with calibration targets related to model prediction (e.g., use baseflow calibration targets where predicting changes to baseflow).	Section 6.1.3
Describe each hydrogeological unit as incorporated in the groundwater model, including the thickness, storage and hydraulic characteristics, and linkages between units, if any.	Section 6.1
Describe the existing recharge/discharge pathways of the units and the changes that are predicted to occur upon commencement, throughout, and after completion of the proposed project.	Sections 5.4 and 6
Describe the various stages of the proposed project (construction, operation and rehabilitation) and their incorporation into the groundwater model. Provide predictions of water level and/or pressure declines and recovery in each hydrogeological unit for the life of the project and beyond, including surface contour maps for all hydrogeological units.	Sections 1 and 6.1.2
Identify the volumes of water predicted to be taken annually with an indication of the proportion supplied from each hydrogeological unit.	Section 6.2.1
Undertake model verification with past and/or existing site monitoring data.	Section 6.1
Provide an explanation of the model conceptualisation of the hydrogeological system or systems, including multiple conceptual models if appropriate. Key assumptions and model limitations and any consequences should also be described.	Section 5.8
Consider a variety of boundary conditions across the model domain, including constant head or general head boundaries, river cells and drains, to enable a comparison of groundwater model outputs to seasonal field observations.	Section 6.1
Undertake sensitivity analysis and uncertainty analysis of boundary conditions and hydraulic and storage parameters, and justify the conditions applied in the final groundwater model (see Middlemis and Peeters [in press]).	Section 6.2.4
Provide an assessment of the quality of, and risks and uncertainty inherent in, the data used to establish baseline conditions and in modelling, particularly with respect to predicted potential impact scenarios.	Section 6.2.4
Undertake an uncertainty analysis of model construction, data, conceptualisation and predictions (see Middlemis and Peeters [in press]).	N/A
Provide a program for review and update of models as more data and information become available, including reporting requirements. Section 8.2	Section 7
Provide information on the magnitude and time for maximum drawdown and post-development drawdown equilibrium to be reached.	Section 6.2.3
Groundwater – Impacts to Water Resources and Water-dependent Assets	
Provide an assessment of the potential impacts of the proposal, including how impacts are predicted to change over time and any residual long-term impacts. Consider and describe: ▪ *any hydrogeological units that will be directly or indirectly dewatered or depressurised, including the extent of impact on hydrological interactions between water resources, surface water/groundwater connectivity, interaquifer connectivity and connectivity with sea water.*	Section 6

Information requirements	Section addressed
▪ *the effects of dewatering and depressurisation (including lateral effects) on water resources, water-dependent assets, groundwater, flow direction and surface topography, including resultant impacts on the groundwater balance.* ▪ *the potential impacts on hydraulic and storage properties of hydrogeological units, including changes in storage, potential for physical transmission of water within and between units, and estimates of likelihood of leakage of contaminants through hydrogeological units.* ▪ *the possible fracturing of and other damage to confining layers.* ▪ *for each relevant hydrogeological unit, the proportional increase in groundwater use and impacts as a consequence of the proposed project, including an assessment of any consequential increase in demand for groundwater from towns or other industries resulting from associated population or economic growth due to the proposal.*	
Describe the water resources and water-dependent assets that will be directly impacted by mining or CSG operations, including hydrogeological units that will be exposed/partially removed by open cut mining and/or underground mining.	Sections 4, 5, 5.6.2, 6
For each potentially impacted water resource, provide a clear description of the impact to the resource, the resultant impact to any water-dependent assets dependent on the resource, and the consequence or significance of the impact.	Section 6
Describe existing water quality guidelines, environmental flow objectives and other requirements (e.g., water planning rules) for the groundwater basin(s) within which the development proposal is based.	Sections 2 and 5.7.2
Provide an assessment of the cumulative impact of the proposal on groundwater when all developments (past, present and/or reasonably foreseeable) are considered in combination.	Section 6.7
Describe proposed mitigation and management actions for each significant impact identified, including any proposed mitigation or offset measures for long-term impacts post mining.	Section 7
Provide a description and assessment of the adequacy of proposed measures to prevent/minimise impacts on water resources and water-dependent assets.	Section 7
Groundwater – Data and Monitoring	
Provide sufficient data on physical aquifer parameters and hydrogeochemistry to establish pre-development conditions, including fluctuations in groundwater levels at time intervals relevant to aquifer processes.	Section 5
Develop and describe a robust groundwater monitoring program using dedicated groundwater monitoring wells – including nested arrays where there may be connectivity between hydrogeological units – and targeting specific aquifers, providing an understanding of the groundwater regime, recharge and discharge processes and identifying changes over time.	Sections 5 and 7
Develop and describe proposed targeted field programs to address key areas of uncertainty, such as the hydraulic connectivity between geological formations, the sources of groundwater sustaining GDEs, the hydraulic properties of significant faults, fracture networks and aquitards in the impacted system, etc., where appropriate.	Section 7
Provide long-term groundwater monitoring data, including a comprehensive assessment of all relevant chemical parameters to inform changes in groundwater quality and detect potential contamination events.	Section 5.7
Ensure water quality monitoring complies with relevant National Water Quality Management Strategy (NWQMS) guidelines (ANZECC/ARMCANZ 2000) and relevant legislated state protocols (e.g., QLD Government 2013).	Section 5.7
Cumulative Impacts – Context and Conceptualisation	
Provide cumulative impact analysis with sufficient geographic and temporal boundaries to include all potentially significant water-related impacts.	Section 6.7
Consider all past, present and reasonably foreseeable actions, including development proposals, programs and policies that are likely to impact on the water resources of concern in the cumulative impact analysis. Where a proposed project is located within the area of a bioregional assessment consider the results of the bioregional assessment.	Section 6.7
Cumulative Impacts – Impact	
Provide an assessment of the condition of affected water resources which includes: ▪ *identification of all water resources likely to be cumulatively impacted by the proposed development;* ▪ *a description of the current condition and quality of water resources and information on condition trends;* ▪ *identification of ecological characteristics, processes, conditions, trends and values of water resources;* ▪ *adequate water and salt balances; and,*	Section 6.7

Information requirements	Section addressed
▪ *identification of potential thresholds for each water resource and its likely response to change and capacity to withstand adverse impacts (e.g., altered water quality, drawdown).*	
Assess the cumulative impacts to water resources considering: ▪ *the full extent of potential impacts from the proposed project, (including whether there are alternative options for infrastructure and mine configurations which could reduce impacts), and encompassing all linkages, including both direct and indirect links, operating upstream, downstream, vertically and laterally;* ▪ *all stages of the development, including exploration, operations and post closure/decommissioning;* ▪ *appropriately robust, repeatable and transparent methods;* ▪ *the likely spatial magnitude and timeframe over which impacts will occur, and significance of cumulative impacts; and,* ▪ *opportunities to work with other water users to avoid, minimise or mitigate potential cumulative impacts.*	Section 6.7
Cumulative Impacts – Mitigation, Monitoring and Management	
Identify modifications or alternatives to avoid, minimise or mitigate potential cumulative impacts. Evidence of the likely success of these measures (e.g., case studies) should be provided.	Section 7
Identify cumulative impact environmental objectives.	Section 7
Identify measures to detect and monitor cumulative impacts, pre and post development, and assess the success of mitigation strategies.	Section 7
Describe appropriate reporting mechanisms.	Section 7
Propose adaptive management measures and management responses.	Section 7

3. Baseline conditions

3.1. Climate

Bureau of Meteorology (2016) classifies the area around the VCM as subtropical, with mostly hot dry summers and mild winters. In terms of rainfall, the area is classified as summer rainfall dominant with annual rainfall generally between 550 mm and 650 mm, and the majority of the rain falling between November and March. Table 3-1 (and Figure 3-1) summarises the local climatic data obtained from SILO point climate data (Queensland Government, 2020) for the VCM (latitude -22.35°, longitude 148.20°, time period January 1889 to January 2020), showing the long term rainfall and evaporation averages.

The average monthly rainfall varies between 16 mm/month in autumn or winter to 109 mm/month in summer. The average annual rainfall is 590 mm, and when comparing precipitation with evaporation (estimated Actual Aerial Evapotranspiration – AAET (Chiew *et al.*, 2002)), average evaporation exceeds average precipitation for all months of the year, potentially leading to groundwater recharge deficit.

Table 3-1 Average monthly precipitation and evaporation

Month	Mean monthly precipitation (mm)	Mean monthly evaporation (mm)
Jan	109.33	137.43
Feb	99.57	120.71
Mar	65.18	118.57
Apr	31.06	86.62
May	27.98	57.23
Jun	31.23	39.59
Jul	22.05	43.74
Aug	20.14	64.72
Sep	16.77	85.54
Oct	31.47	109.47
Nov	50.28	120.87
Dec	85.35	136.32
Σ	590.41	1120.80
min	16.77	39.59
max	109.33	137.43

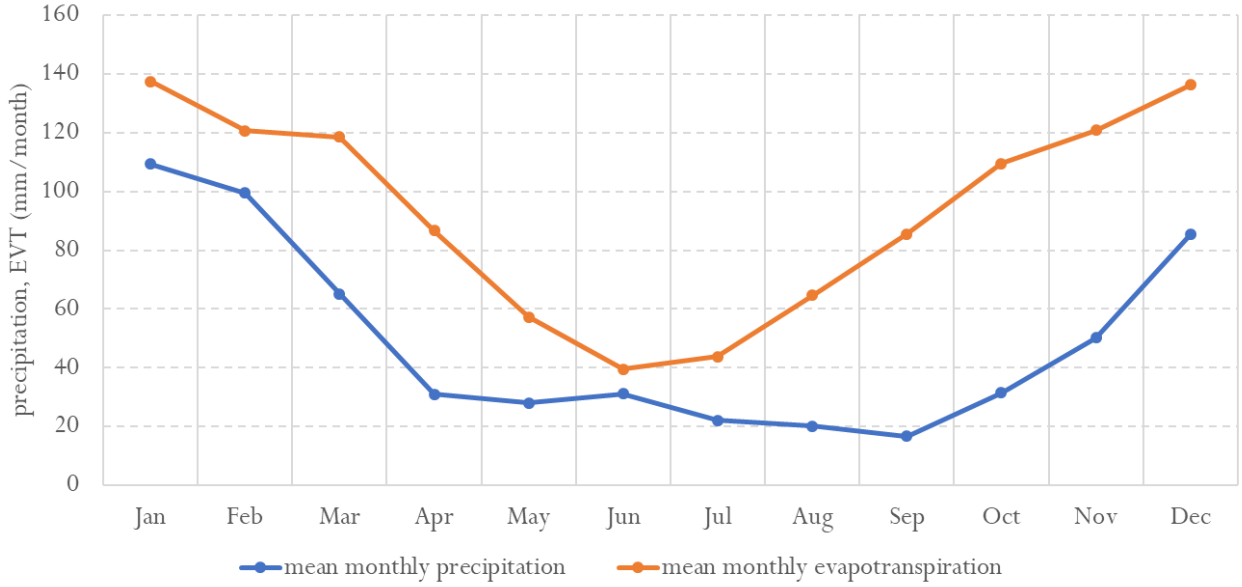


Figure 3-1 Average monthly precipitation and evaporation

One of the indicators describing long-term precipitation trend is a 'cumulative rainfall departure' – CRD (Xu & Tonder, 2001). The CRD indicates 'drier' periods (periods of lower than average rainfall) by downwards direction of the indicator line. Conversely, 'wetter' periods (periods of higher than average rainfall) are indicated by upward direction of the indicator line. The CRD calculation was based on the monthly averages calculated over the full time period of available data (131 years – see Table 3-1).

The trends represented by CRD analysis (Figure 3-2) show long-lasting dryer than average conditions between 1918-1940, 1960-71 and 2001-2007 and above average rainfall between 1953-1960, 1973-1979, 2007-2011. Periods of approximately average rainfall can be observed between 1941 and 1944, 1970 and 1973, 1982 and 1988, and 2011– 2017. The area around the VCM has recently (beginning of 2018 till end of 2019) gone through a lower-than-average precipitation period.

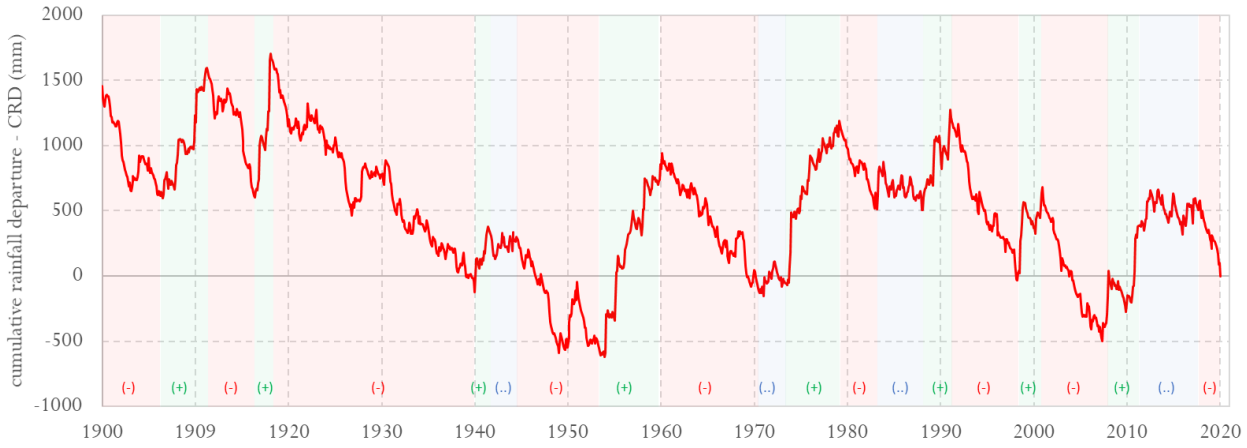


Figure 3-2 Precipitation trend – cumulative rainfall departure (CRD)

3.2. Topography and drainage

The Project area slopes from the Harrow Range in the west to the Isaac River east of the Project area (Figure 3-3). Surface elevations reach approximately 500 mAHD approximately 25 km to the west of the Project area. The surface elevation within the Project area is generally between 280 mAHD and 225 mAHD.

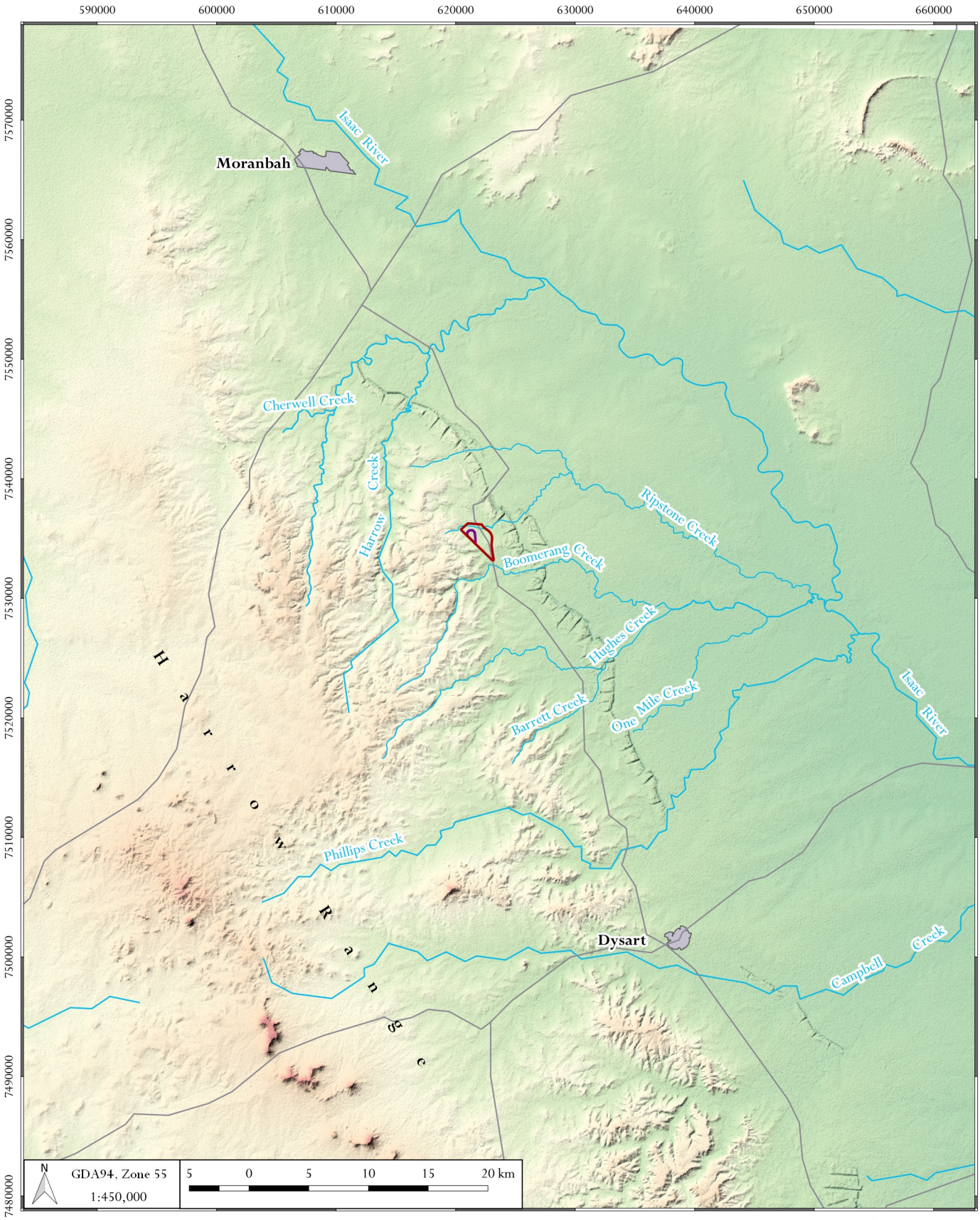
The Project area is surrounded by a number of ephemeral catchments (Figure 3-3) which drain from the west to the east, including the following creeks:

- Harrow Creek;
- Boomerang Creek;
- Hughes Creek;
- Barrett Creek;
- Phillips Creek; and
- Campbell Creek.

A tributary of Ripstone Creek flows through the Project area to the east, extending through the neighbouring Saraji Mine.

A number of surface water diversions have been constructed in association with the existing coal mines to the east of the Project area. These include diversions on Ripstone Creek, Harrow Creek, Boomerang Creek and Hughes Creek. These diversions are all located downstream of the Project area and have been constructed by BHP. Surface water flow data captured and maintained by BHP indicates these creeks are all ephemeral.

The ephemeral creeks surrounding the Project area have limited flow, and typically only discharge after heavy rainfall events. The largest local surface water catchment near the Project area is Phillips Creek (20 kms to the south of the Project area), which flows into the Isaac River. The confluence of these two surface water systems is located approximately 25 km to the east of the Project area.



LEGEND

- ML700060
- Matilda pit
- Watercourse
- Major road

Elevation (mAHD)

120	240	360	480	600	720
160	280	400	520	640	760
200	320	440	560	680	

DATE
21/06/2022

hydrogeologist.com.au

Vulcan Coal Mine EA amendment - Groundwater Impact Assessment (4124)

Topography and drainage

FIGURE No.
3.3

©2022 Oasis Hydrogeology Pty Ltd - trading as hydrogeologist.com.au

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.
Z:\4000_Projects\4124_Metserve_Matilda Pit\3_GIS\3_11_Workspaces_QGIS\03_03_4124_Matilda_Vulcan South_Topography and drainage.qgz

Whilst Hughes Creek and Boomerang Creek are much closer to the proposed pit, Phillips Creek is the only watercourse with publicly available stream flow data. Figure 3-4 and Figure 3-5 are from the DRDMW Water Monitoring Information Portal (WMIP) (https://water-monitoring.information.qld.gov.au/), visited on 14 June 2022. Figure 3-4 shows discharge and water level data for the historic gauging station (130409A) on Phillips Creek at Tayglen. Figure 3-4 shows that flows within Phillips Creek are ephemeral, with short-duration flows generally occurring over the summer months. Based on daily flow data between 1968 and 1988, Figure 3-5 shows that Phillips Creek flows less than 25 percent of the time, with less than 10% probability of flows exceeding 0.1 m^3/s (8.64 ML/day) and less than 2% probability of flows exceeding 10 m^3/s (864 ML/day).

The reader is directed to the Vulcan Coal Mine – Surface Water Impact Assessment report for further information analysis and impact assessment regarding surface water systems in the Project area.

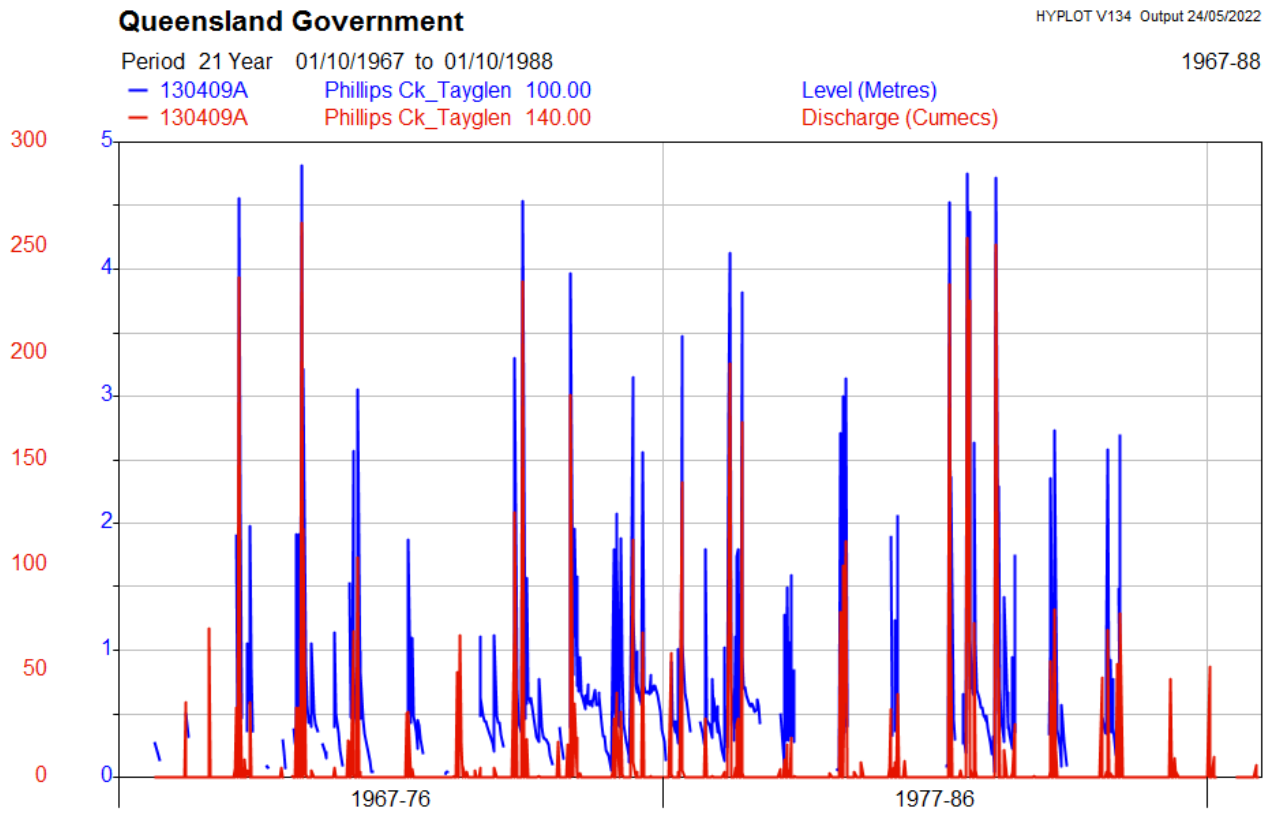


Figure 3-4 Discharge and water level, Phillips Creek at Tayglen (from DRDMW Water Monitoring Information Portal)

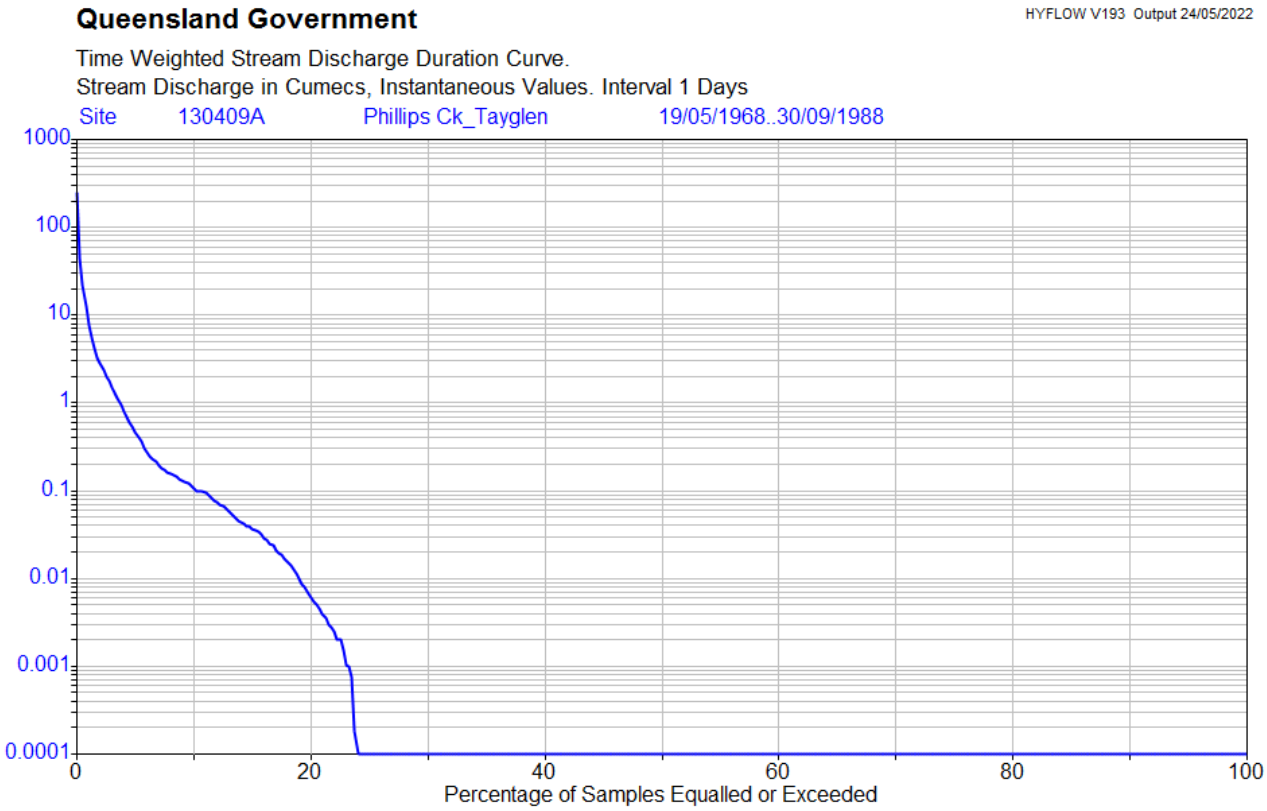


Figure 3-5 Daily flow duration, Phillips Creek at Tayglen (from DRDMW Water Monitoring Information Portal)

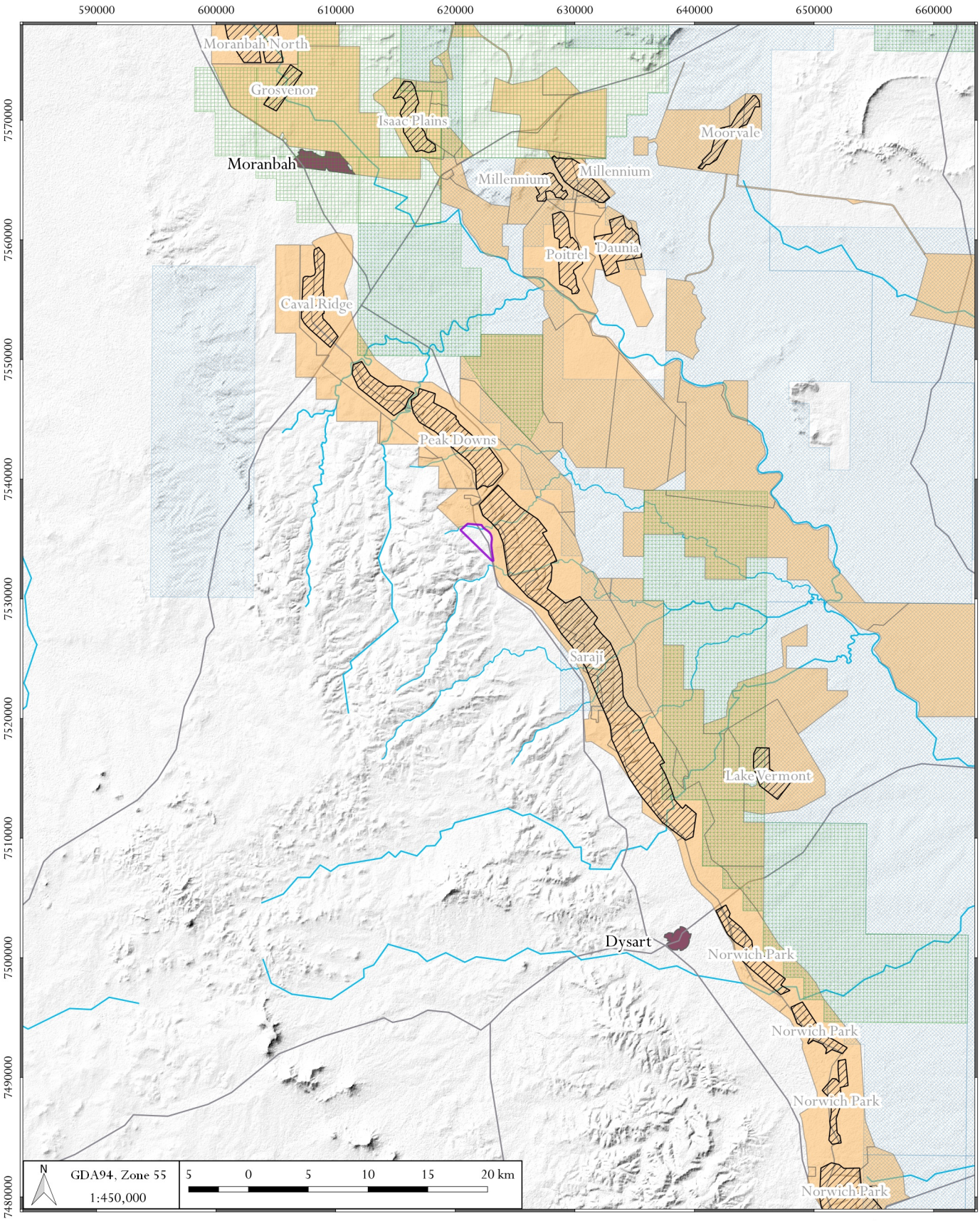
3.3. Land use

Land use is dominated by coal exploration and mining, beef cattle grazing, and CSG exploration and operations.

The individual coal mines in close proximity to the Project area are the proponents VCM, BHP Saraji Mine and BHP Peak Downs Mine (Figure 3-6). Caval Ridge Mine is located to the north of Peak Downs Mine and Norwich Park Mine is located to the south of Saraji Mine. These series of coal mines are owned by BHP, however Norwich Park Mine is currently in care and maintenance.

Peak Downs Mine and Saraji Mine commenced coal production in the early 1970s with mining covering an area some 50 km in length and 2 km to 5 km in width. The mines generally follow the strike of the coal seams within the Moranbah Coal Measures and the mines extract coal seams that are stratigraphically higher in the Moranbah Coal Measures than the coal seams to be mined as part of the Project.

Lake Vermont Mine is located to the south-east of Saraji Mine and is owned by the Jellinbah Group. Lake Vermont currently has a production capacity of 8 Mtpa and was last expanded in 2012/2013.



LEGEND

- Mining lease
- Established mining operation
- ML 700060
- Exploration permits for petroleum
- Petroleum leases
- Watercourse
- Major road

DATE
29/07/2022

hydrogeologist.com.au

Vulcan Coal Mine EA amendment - Groundwater Impact Assessment (4124)

Mining tenure

FIGURE No.
3.6

©2022 Oasis Hydrogeology Pty Ltd - trading as hydrogeologist.com.au
Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.
Z:\4000_Projects\4124_Metserve_Matilda Pit\3_GIS\3_11_Workspaces_QGIS\03_06_4124_Matilda_Vulcan South_Mining tenure.qgz

4. Geology

The Project is located on the western limb of the northern Bowen Basin, in a northerly plunging syncline, and at the southern end of the Collinsville Shelf (AECOM, 2016). The target coal seams are subcropping in a north-west to south-east direction, dipping to the north-east.

Regional cross-section D-D' of URS (2012) extends near the Project area and is reproduced as Figure 4-1. The section extends from the west/south-west to the east/north-east. The Project area would plot between ~140,000 m and ~142,000 m, characterised by sub-cropping Moranbah Coal Measures beneath the surficial sediments. Beneath the Moranbah Coal Measures, the Back Creek Group forms the Permian basement and extensively outcrops to the west of the site. The Triassic units (notably the Rewan Group) are absent locally and occur further to the east. The local surface geology is shown in Figure 4-2.

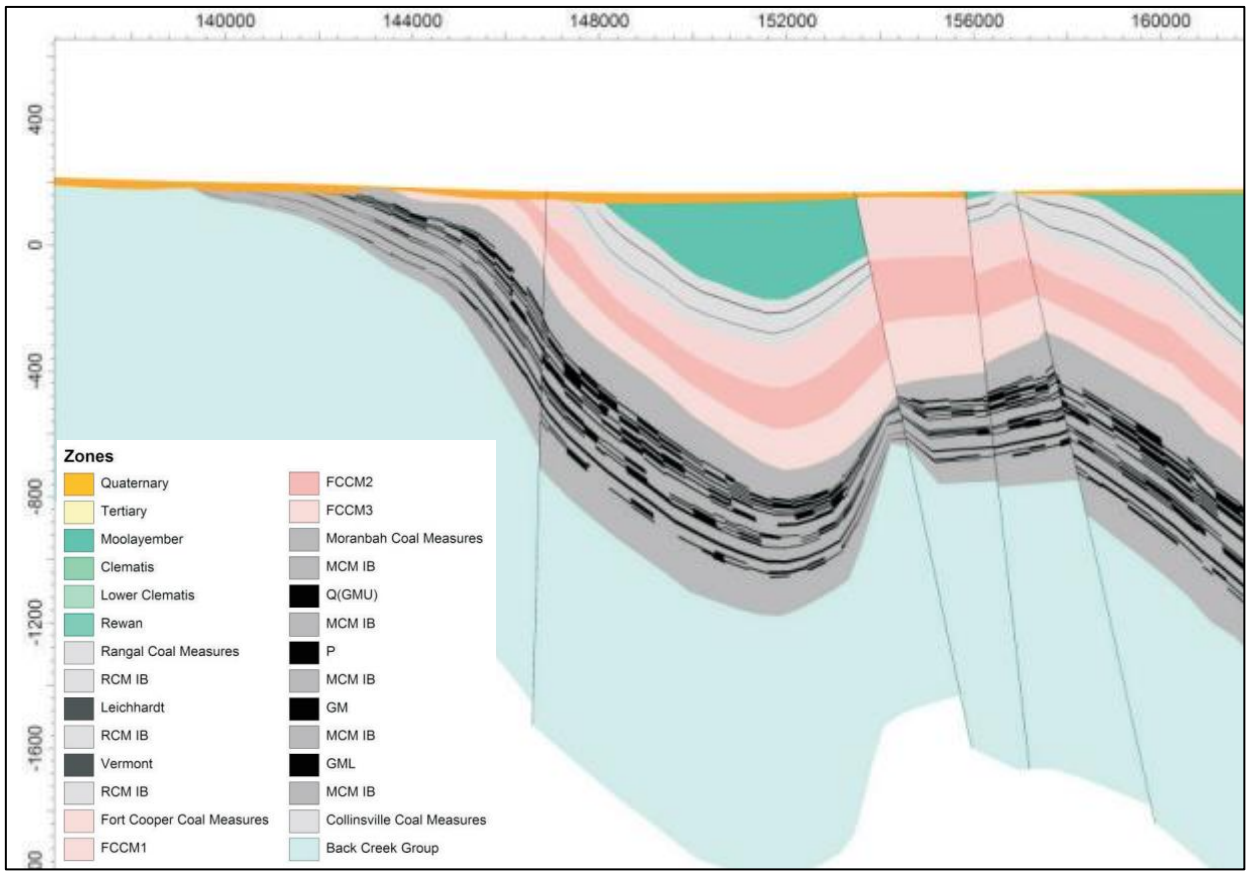
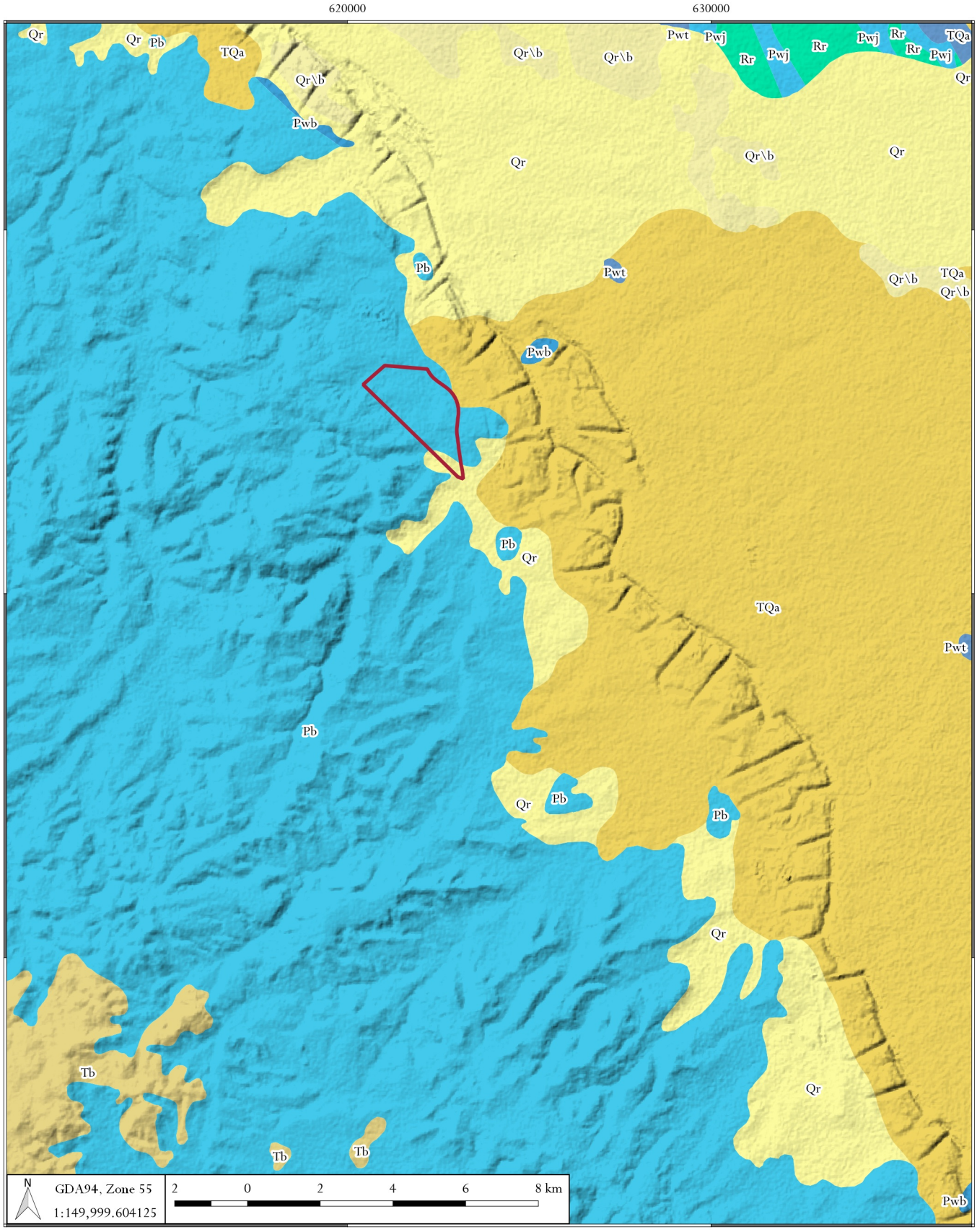


Figure 4-1 Cross-section D-D' from URS (2012)



LEGEND

ML 700060

Geology - surface

- Pb - Back Creek Group
- Pwt - Fort Cooper Coal Measures
- Pwb - Moranbah Coal Measures
- Qr\b - Colluvium
- Qr - Colluvium
- Pwj - Rangal Coal Measures
- Rr - Rewan Group
- Tb - Basalt
- TQa - Alluvium

DATE
29/07/2022

hydrogeologist .com.au

Vulcan Coal Mine EA amendment - Groundwater Impact Assessment (4124)

Local surface geology

FIGURE No.
4.2

©2022 Oasis Hydrogeology Pty Ltd - trading as hydrogeologist.com.au

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.
Z:\4000_Projects\4124_Metserve_Matilda Pit\3_GIS\3_11_Workspaces_QGIS\04_04_4124_Matilda_Vulcan South_Local surface geology.qgz

4.1. Quaternary sediments

Quaternary sediments are mapped within the Project area as sporadically exposed colluvial and residual deposits comprising clay, silt, sand and gravel soils. The closest mapped Quaternary alluvium is in excess of 10 kms to the north and south, there is no mapped Quaternary alluvium within the Project area.

4.2. Tertiary sediments

The Tertiary sediments are mapped as present to the east of the Project area. AECOM (2016) describe the Tertiary aged sediments as heterogeneously distributed lensoidal sand deposits separated by a low permeability clay-rich matrix. Lithologically, the Tertiary sediments comprise unconsolidated to consolidated fluvial sediments which include clay, silty clay, sandy clay, clayey sand, sand and gravel with clay predominant (AECOM, 2016). Weathering of the Tertiary sediments is evident (AGE, 2011) (quoted in AECOM, 2016) and the lithologies can vary from heavily leached, mottled white and maroon soils to sandy soils. The Tertiary sediments are defined by an unconformable boundary with the underlying Permian coal measures which characterises the Permian topography prior to deposition of the Tertiary sediments (AECOM, 2016).

Typically, the Tertiary sediments are less than 3 m in thickness. This is confirmed by the lithology of drill hole VSW020_C2 located in the south of the Project area (RGS, 2020). The lithology also confirms the base of weathering and the top of ALEX Seam at approximately 7 m and 8 m depth, respectively.

Furthermore, **hydrogeologist.com.au** has drilled and constructed several groundwater monitoring bores within the Project area. The term "*weathered Permian*" is used to describe the lithology intersected above the fresh Permian coal measures. It is assessed that within the Project area, the lithology intersected above the fresh Permian coal measures does not constitute Tertiary-aged sediments, rather a weathering profile that developed during the Tertiary on the Permian strata. There was no evidence of an unconformable horizon in the drill hole observations and the material intersected, graded from highly weathered, generally clay bound material at the surface to the unweathered Permian coal measures that typically occurred between 1 m to 20 m below ground level. This geological interpretation is currently supported by the exposure of geology in the VCM.

4.3. Permian coal measures

4.3.1. Blackwater Group

Coal seams within the Permian coal measures of the Blackwater Group form the main economic resource of the numerous mines in the region. In increasing depth (age) order, the major coal measures of the Blackwater Group include the:

- Rangal Coal Measures;
- Fort Cooper Coal Measures; and
- Moranbah Coal Measures.

The VCM currently mines the ALEX and Dysart Lower-Lower (DLL) coal seam of the Moranbah Coal Measures. Outcropping at surface to the west of the Project is the basal section of the Moranbah Coal Measures, locally mapped by Vitrinite as a sequence of sandstones and siltstones. This sequence is capped in a resistant, quartzose medium to coarse grained sandstone, locally referred to as the Mesa Sandstone due to the characteristic mesa plateaus that have formed in the region. The base unit of the Moranbah Coal Measures is locally referred to as the Mesa Siltstone (Tom O'Malley Vitrinite, per.comm., 2019).

The ALEX coal seam is about 1 m thick of high quality and low ash content, overlying the Mesa Sandstone. The DLL consists of a 2.5 m thick seam with four plies; and a separate basal ply, with high ash and good quality coal. An additional 1 m thick coal seam makes the entire sequence to be mined approximately 3.5 m thick. The regional sediments dip approximately eastward at about 4° in the Project area (Tom O'Malley Vitrinite, per.comm., 2019).

East of the Project area, at the Saraji Mine, the Permian coal measures are generally undisturbed and have a gentle regional dip of 2° to 5° towards the east (AECOM, 2016). Minor faults are mapped within the existing Saraji Mine which locally steepen the coal seams to approximately 9° to 10°. The Saraji South Fault is located south of the Saraji Mine, near Phillips Creek. The Saraji South Fault is a high angle, north north-west trending normal fault, with throws mapped between 10 m and 50 m (AGE, 2011 in AECOM, (2016)). The Downs Creek Fault is a north north-west trending normal fault with a maximum throw of 60 m and is located south of the Project area, near Lotus Creek Road.

At Saraji Mine, the Permian coal measures comprise overburden of sandstone, siltstone, claystone, mudstone, coal, coal parting materials and sub-coal (underburden) strata. The Moranbah Coal Measures include the Dysart series, Harrow Creek group, P, Q and R coal seams. Of these, the Harrow Creek Upper (H16) and Dysart Lower (D24 and D14) coal seams are mined at Saraji Mine (AECOM, 2016). The H16 seam is the uppermost of the two targeted coal seams and sub-crops to the west of the Saraji Mine with an easterly dip.

Near the Caval Ridge Mine, the Permian coal measures generally dip from west to east, at between 3° and 6°. The sequence within the northern extension of the Peak Downs Mine (located to the south of the Caval Ridge Mine and to the north of Saraji Mine) shows considerable deformation with strata dipping to 30° and along strike flexures in excess of 10°. Faulting and seam splitting is common, producing local steepening of the coal seams (over 10°). Minor faulting occurs in the seams in the Caval Ridge Mine area. Vertical displacement along faults ranges from less than 1 m to 36 m along the regional Harrow Creek Fault in the Peak Downs Mine (URS, 2009). Near the Olive Downs Coal Project, the coal measures dip around 7° to the east, which steepens in the south to 15° (HydroSimulations, 2018).

4.3.2. Back Creek Group

The Back Creek Group outcrops to the west of, and in the western portion of the Project area (Figure 4-2). The Exmoor and Blenheim Formations of the Back Creek Group are interpreted to be conformably underlying the Moranbah Coal Measures. The top of the Exmoor Formation is characterised by prominent coarse-grained siliceous boulder sandstone in outcrop, whilst the top of the Blenheim Formation is easily identifiable by the stratigraphic marker of the fossiliferous and worm burrowed sandstone, locally termed the Worm Burrow Sandstone.

Coal seams within the Back Creek Group (not currently targeted by the Project) include the May (MAY) coal seam that has been interpreted to be within the Dingo Siltstone of the Exmoor Formation, and the Matilda (MAT) coal seam within the MAT Siltstone of the Blenheim Formation. The MAT coal seam is the target of the Matilda pit and associated EA amendment.

5. Hydrogeology

An aquifer is generally defined as a geological unit that can transmit and store significant quantities of groundwater. Within the region, Tertiary sediments and Permian coal measures yield low volumes of groundwater and hence they would not typically be classified as aquifers in most hydrogeological settings. In reality, they would be called either poor aquifers or aquitards. However, there may be individual lithological units within these formations that have higher hydraulic conductivities than the intervening units, and as groundwater in these formations are to be assessed for the determination of impact, they are referred to as aquifers for the purposes of this report. This approach is consistent with URS (2009), URS (2012), AECOM (2016) and HydroSimulations (2018).

5.1. Hydrostratigraphy

Within the project area, the groundwater generally occurs in three hydrostratigraphic units, as outlined below and shown in Table 5-1:

- the Tertiary sediments/regolith;
- the Moranbah Coal Measures; and
- the underlying Back Creek Group.

Table 5-1 Local hydrostratigraphic units

Age	Stratigraphic unit	Lithology	Aquifer type
Tertiary	Unconsolidated, semi-consolidated sediments; weathered profile	Clay, silt, sand, gravel, colluvium, fluvial and lacustrine deposits including cross-bedded quartz sandstone, conglomerate, claystone	Unconfined, poor aquifer, aquitard
Late Permian	Moranbah Coal Measures	Coal, sandstone, siltstone, mudstone, carbonaceous mudstone	Confined aquifer (coal) and confining unit (interburden)
Middle Permian	Back Creek Group	Sandstone, siltstone, carbonaceous shale, minor coal and sandy coquinite	Confined aquifer (coal) and confining unit (interburden)

The following sections define the hydrogeology of the various hydro-stratigraphic units for the Project and further discuss groundwater flow, quality and the hydraulic characteristics.

5.1.1. Tertiary sediments

The term Tertiary sediments refers to a mix of specific Tertiary aged sediments and the weathered zone or regolith material that has formed on top the Permian coal measures. As described in Section 4.2, the Tertiary sediments are sporadically distributed and consist of lenses of palaeochannel gravels and sands separated by sandy silts, sandy clays and clays) with limited thicknesses. Together with the underlying weathering zone of the Permian coal measures, Tertiary sediments are not of significance in groundwater flow within the Project area.

In terms of aquifer material, the silts and clays are densely compacted, hard and generally dry. Potential for groundwater, however, exists within sandy and gravely sections, and represents an unconfined to confined aquifer depending on location. Most of the clean sand and gravel lenses are permeable but are of limited lateral and vertical extent (URS, 2009).

Historically, mining issues associated with Tertiary sediment derived groundwater at the Peak Downs Mine appear limited to pit wall instability rather than ongoing problems with groundwater inflow. This generally indicates low hydraulic conductivity and limited lateral extent of the more permeable areas (URS, 2009). It was assessed by **hydrogeologist.com.au** (2019) that the lithology intersected above the fresh Permian coal measures in the Project area did not constitute Tertiary aged sediments, rather a weathering profile that had developed during the Tertiary period on the Permian strata. Within the monitoring bores drilled for the Project, the depth of weathering typically occurred between 1 m to 20 m below ground level and the weathered profile was generally unsaturated. Current observations indicate that the Tertiary sediments in the Project area are generally unsaturated.

5.1.2. Moranbah Coal Measures

Throughout the Bowen Basin, the coal seams are considered to be poor aquifers within the Permian coal measures, and the adjacent overburden and interburden sediments are generally considered as aquitards. URS (2009) noted, in the context of overall low yields and therefore low hydraulic conductivity, that historical mining issues with groundwater in the Permian coal measures at Peak Downs Mine were limited to pit wall instability rather than ongoing problems with groundwater inflow, indicating the generally low hydraulic conductivities of the Permian coal measures on site.

The coal seams generally are considered dual-porosity strata where primary-porosity is provided by the matrix and a secondary porosity is the result of the presence of fractures (joints and cleats). Natural cleats within the coal seams are likely the dominant space for groundwater storage; the main pathway for groundwater movement is dependent on fracture interconnectivity (URS, (2009) and AECOM, (2016)). The coal seam aquifers are generally confined above and below by the low permeability interburden and overburden (AECOM, 2016).

The non-coal-bearing interburden and overburden units comprise low permeability claystone, mudstone, sandstone, siltstone and shale. They can, however, provide localised supplies of variable, generally low yielding and poor quality groundwater (AECOM, 2016). The interburden and overburden units in several mines in the northern Bowen Basin (e.g. Broadlea Coal Mine, Burton Mine and Ellensfield Coal Mine) have been described as essentially impervious to groundwater movement (AGE, 2007 in AECOM, 2016).

Within the Project area, the coal seams of the Permian coal measures (including the targeted ALEX and DLL coal seams of the Moranbah Coal Measures), are regarded as confined, poor aquifers and the interburden (including over- and under-burden) as aquitards. The Permian coal measures within the VCM are partially unsaturated.

5.1.3. Back Creek Group

The Back Creek Group comprises sandstone, siltstone, shale and minor coal; and is considered a semi-pervious lower boundary for groundwater flow to the overlying Blackwater Group (URS, 2012). The Back Creek Group is normally considered as the base layer for numerical models (the base of a model, by definition is impervious). The Exmoor Formation of the Back Creek Group is locally mapped by Vitrinite as the Dingo Sandstone, Dingo Siltstone and Wallaby Hill Sandstone (from top down) but contains recognised and laterally extensive coal seams (MAY and MAT seams) that, together with the sandstones, can potentially form poor aquifers similar to those interpreted in the Blackwater Group. The non-coal-bearing interburden and overburden units of the Back Creek Group are assessed to be aquitards. As discussed above, the Permian coal measures (which includes the Back Creek Group) within the VCM are partially unsaturated.

5.2. Groundwater monitoring network

A total of fifteen active groundwater monitoring bores have been constructed over the wider Vitrinite mining tenements, with twelve bores drilled in June 2019 and three drilled in 2022. Among them, seven active monitoring bores have been installed in the vicinity of the VCM area; the monitoring bore MB13 was drilled in early 2021, MB14 was drilled to replace MB04, and MB15 and MB16 drilled down hydraulic gradient from two VCM mine water storages.

Table 5-2 summarises the location, target unit and construction details for each VCM monitoring bore which forms the VCM groundwater monitoring network. Monitoring bores from the wider Vitrinite mining tenement (termed 'regional' bores) are also summarised in Table 5-2. The monitoring bores are shown in Figure 5-1 along with the registered groundwater bores associated with the DRDMW GWDB. MB06 and MB10 are nested monitoring bores drilled on the same site.

Table 5-2 VCM and regional monitoring bores

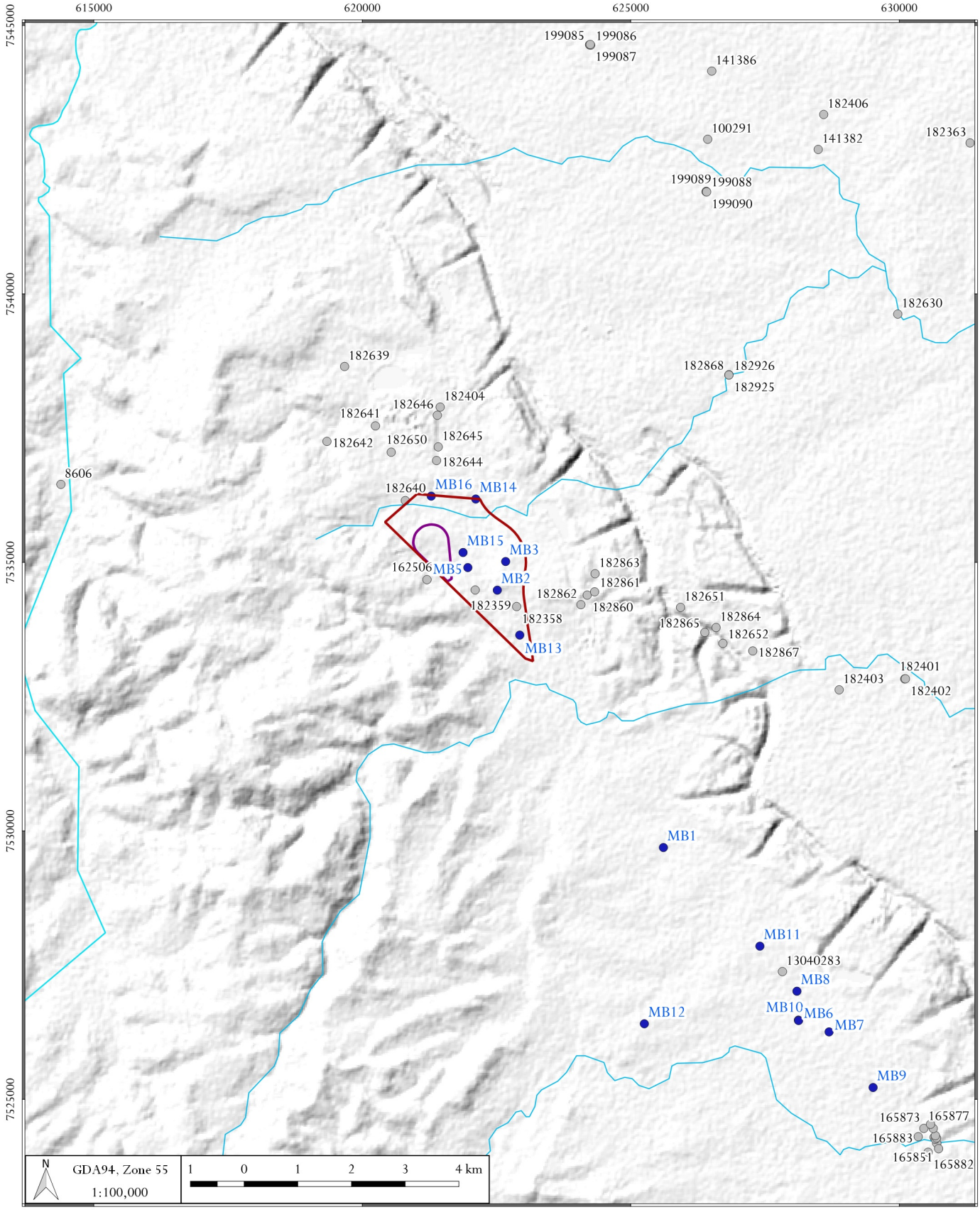
ID	Area	Easting	Northing	Target unit	Casing height (maGL)	Hole depth (mbGL)	Screen interval (mbGL)	Airlift yield (L/min)	Casing elevation (mAHD)
MB01	Regional	625606	7529691	DLL coal seam	0.70	24.9	21.9 – 24.9	Dry	222.91
MB02	VCM	622513	7534483	DLL coal seam	0.71	12.0	9.0 – 12.0	Dry	254.69
MB03	VCM	622668	7535017	DLL coal seam	0.70	33.8	30.8 – 33.8	<0.1	257.68
MB05	VCM	621964	7534905	MAT coal seam	0.77	40.9	37.9 – 40.9	0.5	252.70
MB06	Regional	628119	7526476	Weathered Permian	0.70	24.6	21.6 – 24.6	Dry	214.61
MB07	Regional	628691	7526258	Weathered Permian	0.67	43.0	40.0 – 43.0	0.1	215.99
MB08	Regional	628092	7527015	Weathered Permian	0.70	24.0	21.0 – 24.0	Dry	212.24
MB09	Regional	629511	7525222	DLL coal seam	0.65	34.4	31.4 – 34.4	0.1	208.98
MB10	Regional	628123	7526469	DLL coal seam	0.70	40.3	37.3 – 40.3	<0.1	214.60
MB11	Regional	627403	7527854	DLL coal seam	0.70	29.9	26.9 – 29.9	Dry	225.66
MB12	Regional	625251	7526409	Back Creek Group	0.66	38.2	32.2 – 38.2	1	241.43
MB13	VCM	622931	7533648	MAT coal seam	0.63	36.92	33.5 – 36.5	-	223.13
MB14	VCM	622111	7536181	DLL coal seam	TBA	29.5	23.5 – 29.5	-	242.38
MB15	VCM	621875	7535185	Permian interburden	TBA	10	7 - 10	-	251.55
MB16	VCM	621282	7536235	Permian interburden	TBA	10	7 - 10	-	248.36

Notes: *Easting and northing coordinates are in GDA94, Zone 55*

maGL – metres above ground level

mbGL – metres below ground level

The DLL coal seam (Dysart Lower Lower) is in the Mesa Siltstone (Lower Moranbah Coal measures); the MAT seam is in the Dingo Siltstone of the Exmoor Formation (Back Creek Group).



LEGEND

ML700060

Matilda pit

Monitoring bore

Registered bore

DATE
05/08/2022

hydrogeologist.com.au

Vulcan Coal Mine EA amendment - Groundwater Impact Assessment (4124)

Groundwater monitoring bore network

FIGURE No.
5.1

©2022 Oasis Hydrogeology Pty Ltd - trading as hydrogeologist.com.au
Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.
Based on or contains data provided by the State of Queensland [2019]
Z:\4000_Projects\4124_Metserve_Matilda Pit\3_GIS\3_11_Workspaces_QGIS\05_01_4124_Matilda_Vulcan South_Groundwater monitoring bore network.qgz

5.2.1. Rationale

The groundwater monitoring network was established based on available information relating to the general understanding of groundwater flow conditions (west to east), the coal resource and general geology of the region and the available mining and exploration tenure. The rationale for locating the monitoring bores was to have an upstream and downstream bore plus an understanding of groundwater conditions within the Project area and to the north and south. The groundwater within the Permian coal measures is often brackish to saline which restricts the environmental value of the groundwater (Section 5.7.2) which is typically limited to livestock watering and industrial use.

The VCM monitoring bores were designed to target the Permian coal measures and the Tertiary regolith as there is no mapped Quaternary alluvium within or in close proximity to the Project area. A number of the VCM and regional monitoring bores targeting the Permian coal measures and the Tertiary sediments have been dry since installation.

The target coal seams of the Permian coal measures (Section 4.3) generally strike in a north north-west to south south-east orientation and dip to the east. This local orientation of geology spatially constrains the groundwater monitoring network to the west of the VCM (Figure 5-1). As a result, monitoring bore MB05 has been constructed within the MAT seam of the Back Creek Group (see Section 4.3 and Section 5.1.2). The Back Creek Group underlies the Moranbah Coal Measures. The general groundwater flow conditions are from west to east and a suitable upstream monitoring site in the target coal seam(s) was not able to be practically established. However, it is assessed that MB05 will be able to provide an appropriate site for the monitoring of drawdown that may propagate through the Back Creek Group.

The Project area is adjacent to existing mining leases which are operated by BHP. The establishment of Project specific groundwater monitoring bores on the BHP mining leases to the east is not practical or achievable therefore mining tenure has spatially constrained the groundwater monitoring network to the east of the VCM. Monitoring bores MB02, MB03 and MB14 were all located and designed on existing cleared drill pads (to minimise land and vegetation clearances) to target the DLL coal seam. The three monitoring bores were spatially distributed so far as was reasonably practical to do so to provide an adequate spatial spread of the data.

The regional groundwater monitoring bores are located in association with an additional coal resource to the south of the VCM. The spatial constraints associated with local geology and mining tenure also affected the location of the southern groundwater monitoring bores.

The groundwater monitoring network is considered to be fit for purpose for this assessment. The groundwater monitoring plan (GWMP) is described in Section 5.2.2 below, and the adaptive management strategy for groundwater is described in Section 7.2.

5.2.2. Current monitoring plan

A GWMP has been developed for the VCM that lists monitoring sites, procedures, and monitoring frequencies for the groundwater monitoring network. The GWMP was developed to satisfy conditions within EA0002912. In summary, the EA approval conditions prescribe the GWMP; specifying the locations of monitoring points and sampling frequency (Table 5-3), groundwater hydrochemistry (Table 5-4), and trigger values with respect to groundwater levels and water quality (Table 5-5).

The VCM groundwater monitoring network has been designed around the following considerations:

- An existing monitoring network has been designed to observe water levels, water quality and hydrochemistry to provide baseline information for the VCM (Figure 5-1).
- The groundwater monitoring network and the GWMP is linked to various conditions within the EA (EA0002912) which prescribe the requirements for monitoring locations, frequency and parameters.
- Exceedances of groundwater quality limits and groundwater level triggers as defined in the current EA trigger a mandatory notification and investigation process.
- A GWMP has been developed and is to be updated every two years as required.
- The VCM monitoring network comprises selected bores (MB05 and MB13) from the current monitoring network, two locations based down gradient of mine affected water dams MWD1 and MWD3 (MB15 and MB16), and MB14 in the north-east of ML 700060.

Table 5-3 summarises the current monitoring locations and frequencies as defined in the current EA. Table 5-4 and Table 5-5 summarises the proposed groundwater quality triggers and limits and groundwater level triggers as defined in the current EA.

Table 5-3 Groundwater monitoring location and frequency (Table E1)

Bore	MB05	MB13	MB14	MB15	MB16
Latitude (GDA94)	-22.28721	-22.2985	-22.2757	-22.2848	-22.2752
Longitude (GDA94)	148.1839	148.1934	148.1852	148.1831	148.1772
Aquifer	Back Creek Group	Back Creek Group	Moranbah CM	Moranbah CM	Moranbah CM
Monitored unit	MAT coal seam**	MAT coal seam**	DLL coal seam*	Permian interburden	Permian interburden
Surface RL (mAHD)	252.70	223.13	242.38	251.55	248.36
Depth (mbGL)	40.9	35	38.2	10	10
Monitoring Frequency	Quarterly			Monthly	

Notes: **DLL = Dysart Lower Lower coal seam*
***MAT = Matilda coal seam*
mbGL = metres below ground level
mAHD = metres above the Australian Height Datum
Surface RL = Reduced Standing Water Level

Table 5-4 Proposed groundwater quality triggers and limits (Table E2)

Parameter	Bores	Limit	Comments
pH (field) (pH units)	All bores	5.5 - 8.0	Broad range to encompass all bores, adapted from data and ANZG (2018)
Electrical Conductivity (field) (µS/cm)	MB05	2,832*	Site specific 95th percentile
	MB13	4,373*	Site specific 95th percentile
	MB14	12,849*	Site specific 95th percentile
	MB15	TDB	Refer to condition E12
	MB16	TDB	Refer to condition E12
Metals and Metalloids			
Sulphate (mg/L)	MB05	284*	Site specific 95th percentile
	MB13	577	Deep WQO
	MB14	176*	Site specific 95th percentile
	MB15	TDB	Refer to condition E12
	MB16	TDB	Refer to condition E12
Aluminium (dissolved) (mg/L)	MB05	6.2*	Site specific 95th percentile
	MB13	6*	Site specific 95th percentile
	MB14	4.8*	Site specific 95th percentile
	MB15	TDB	Refer to condition E12
	MB16	TDB	Refer to condition E12
Arsenic (dissolved) (mg/L)	All bores	0.013	ANZG (2018)
Iron (dissolved) (mg/L)	MB05	2.9*	Site specific 95th percentile
	MB13	2.8*	Site specific 95th percentile
	MB14	288*	Site specific 95th percentile
	MB15	TDB	Refer to condition E12
	MB16	TDB	Refer to condition E12
Lead (dissolved) (mg/L)	All bores	0.008	ANZG (2018)
Mercury (dissolved) (mg/L)	All bores	0.0006	ANZG (2018)
Molybdenum (dissolved) (mg/L)	MB05, MB14, MB15, MB16	0.034	ANZG (2018)
	MB13	0.06	Site specific 95th percentile
Selenium (dissolved) (mg/L)	All bores	0.005	ANZG (2018) 99th percentile
**TRH C6-C9 (µg/L)	All bores	< 20	LOR
**TRH C10-C36 (µg/L)	All bores	< 50	LOR

Notes: * *Site specific values using 95th percentiles*

** *Total Recoverable Hydrocarbons (TRH)*

Table 5-5 Groundwater level monitoring (Table E3)

Monitoring location	Monitored unit	Pre-mining baseline level (mAHD)	Level threshold (mAHD)
MB05	MAT coal seam	237.13	234.86
MB13	MAT coal seam	202.71	200.44
MB14	DLL coal seam	233.50	232.07
MB15	Permian interburden	246.40	247.08
MB16	Permian interburden	243.97	244.43

Note: [1]90th percentile predicted maximum cumulative drawdown over the life of the Project beyond any background non-mining related influence, except where specifically identified.

Groundwater level monitoring

The groundwater level monitoring of the groundwater monitoring network was initially carried out monthly, then quarterly thereafter. All monitoring bores were equipped with data loggers or pressure transducers, which automatically collect readings every four to six hours. The use of dataloggers will continue as part of on-going groundwater level monitoring. The manual groundwater level measurements collected at the site are summarised in Table 5-6.

From Table 5-6, it is observed that the groundwater elevations are generally between 230 mAHD and 240 mAHD in the Project area. The depth to groundwater measurements indicates that, except for MB04, the depth to groundwater is between 14 m to 37 m below ground level. Groundwater elevations are generally a subdued reflection of topography, that is deep beneath high land elevation (hills) and shallow beneath low land elevation (valleys). The ground elevation at MB04 is approximately 10 m below the other monitoring bores in the Project area which explains the shallow groundwater observed in this bore.

In some instances (e.g., MB03), the depth to groundwater measurement collected after airlift development was influenced by the drilling and construction process, and in other instances the low permeability of the intersected formation (e.g., MB12). For this reason, the earlier measurements in Table 5-6 may not be representative. Figure 5-2 shows the groundwater elevation hydrographs at the six monitoring bores (note that the hydrographs for MB04 and MB05 overlap) over a 12-month period from June 2019 through to September 2021. Except for the spikes in data observed at MB04, MB05 and MB12, the groundwater elevation hydrographs demonstrate a static system with no or very little (~centimetre magnitude) temporal variations in groundwater level. The notable spikes in data in mid-July, mid-August and mid-September are associated with the groundwater sampling events. The bores with the spikes (MB04, MB05 and MB12) are constructed within low hydraulic conductivity formations and the groundwater is slow to recover following purging.

Table 5-6 Summary of manual groundwater level measurements

Site ID	Casing elevation (mAHD)	Standing Water Level (mAHD)																
		Jun 2019	Jul 2019	Aug 2019	Sep 2019	Oct 2019	Dec 2019	Mar 2020	Jun 2020	Aug 2020	Oct 2020	Dec 2020	Mar 2021	May 2021	Jul 2021	Sep 2021	Dec 2021	Mar 2022
MB1	222.91	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
MB2	254.69	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
MB3	257.68	239.38	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
MB5	252.70	238.17	238.01	237.99	238.23	238.69	238.55	238.10	227.77	235.95	236.62	236.53	236.37	236.72	236.41	236.04	235.81	236.30
MB6	214.61	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
MB7	215.99	181.19	179.71	179.77	179.79	180.31	180.12	180.40	189.79	179.92	179.87	179.91	179.99	179.91	179.96	180.03		
MB8	212.24	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
MB9	208.98	181.57	181.34	181.36	181.39	181.81	181.48	182.12	181.88	181.24	180.98	181.29	181.35	181.33	181.32	181.43		
MB10	214.60	182.09	182.15	182.20	182.29	183.04	183.00	183.04	188.10	182.49	182.50	182.55	182.60	182.56	182.61	182.65		
MB11	225.66	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
MB12	241.43	215.36	216.22	216.41	216.66	218.00	218.39	216.94	215.71	216.55	216.56	216.53	215.85	215.60	215.61	214.85		
MB13	223.13	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	209.12	208.53	208.49	208.63	208.67	208.63

Notes: *Easting and northing coordinates are in GDA94, Zone 55 from differential GPS*

SWL – standing water level

mAHD – metres above Australian Height Datum from differential GPS

mbTOC – metres below top of casing (PVC)

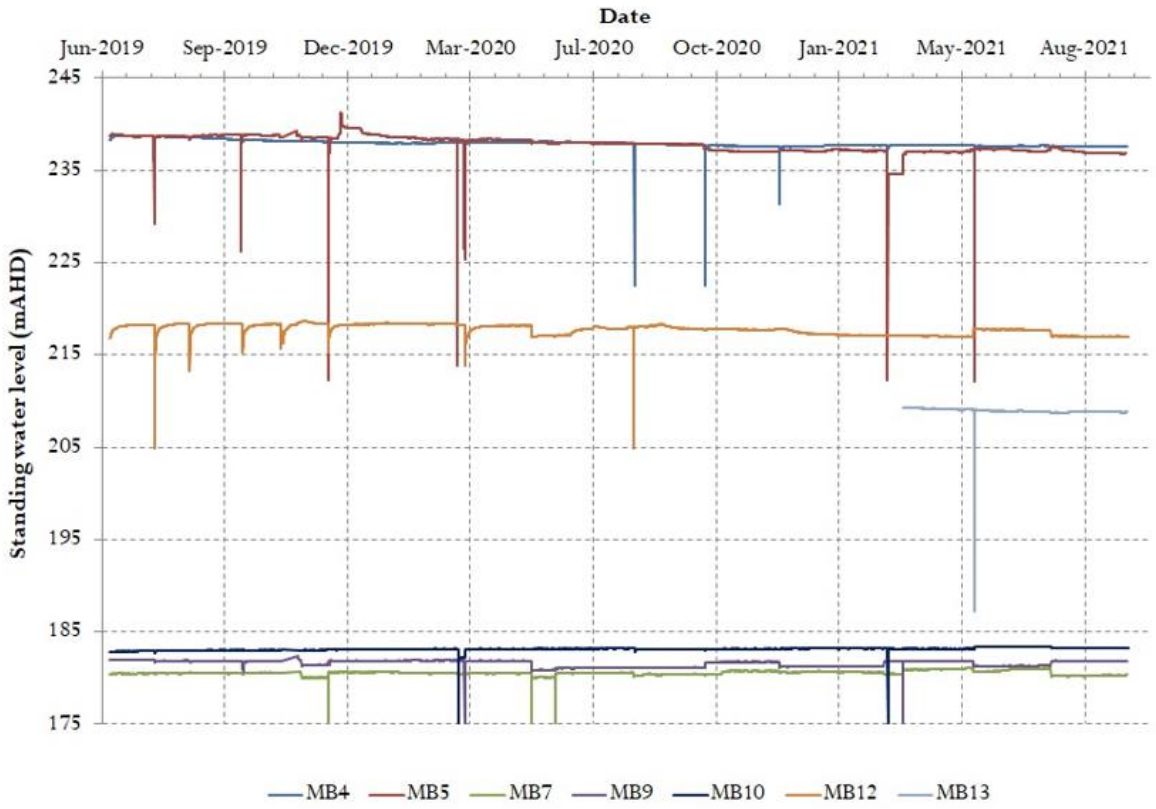


Figure 5-2 Groundwater hydrographs for Vulcan Coal Mine monitoring bores

Groundwater sampling

Groundwater sampling is also regularly carried out (on a quarterly basis) across the monitoring network to collect representative samples for baseline characterisation and for the derivation of trigger levels and contaminant limits (DES, 2021). The groundwater quality parameters monitored are consistent with those provided in the DES (2017) Guideline: Model mining conditions. The monitoring and sampling of the groundwater monitoring network is planned for and carried out in consideration of the Queensland Monitoring and Sampling Manual (DES, 2018a).

Section 5.7 provides further discussion on groundwater quality including site specific data.

5.3. Hydraulic properties

Hydraulic testing in the form of slug testing and constant head testing was performed on the VCM and regional groundwater monitoring network summarised in Table 5-2. Slug testing (falling head tests) was completed on the monitoring bores recording a groundwater level, whereas constant head testing was completed on the dry monitoring bores. The recovery curve method was carried out for MB12 given the slow recovery response following sampling. The results of the testing are summarised below in Table 5-7.

Table 5-7 Summary of hydraulic testing from the VCM and regional monitoring bores

Site ID	Area	Target unit	Test method	Hydraulic conductivity (m/d)
MB01	Regional	DLL coal seam	Constant head	3.9×10^{-2}
MB02	VCM	DLL coal seam	Constant head	5.3×10^{-2}
MB03	VCM	DLL coal seam	Constant head	3.2×10^{-2}
MB05	VCM	MAT coal seam	Slug test (Hvorslev, 1951)	2.4×10^{-2}
MB06	Regional	Weathered Permian	Constant head	>0.1
MB07	Regional	Weathered Permian	Slug test (Hvorslev, 1951)	0.21
MB08	Regional	Weathered Permian	Constant head	>0.1
MB09	Regional	DLL coal seam	Slug test (Hvorslev, 1951)	2.0×10^{-2}
MB10	Regional	DLL coal seam	Slug test (Hvorslev, 1951)	0.41
MB11	Regional	DLL coal seam	Constant head	2.9×10^{-2}
MB12	Regional	Back Creek Group	Recovery test	2.8×10^{-4}

For two of the dry monitoring bores (MB06 and MB08), the rate at which the bore accepted water was higher than the rate it could be fed in. Therefore, it is assumed that the hydraulic conductivity of the intersected lithology at these monitoring bores is higher than 0.1 m/d.

The hydraulic testing of the monitoring bores indicates that generally the highest hydraulic conductivities are for the weathered Permian, moderate values for the DLL and MAT coal seams and the lowest results are for the Permian underburden. The following order of magnitude is observed in relation to hydraulic conductivities:

- Weathered Permian: low 10^{-1} m/d;
- DLL and MAT coal seams: 10^{-2} m/d; and
- Permian underburden: 10^{-4} m/d.

The horizontal hydraulic conductivities collated from various studies in the Moranbah-Dysart region are summarised in Table 5-8. Spatial variability, local geology, the different methods used to acquire data and uncertainties in interpretation explain the wide range of values which in some instances cover three or four orders of magnitude. Notwithstanding the above, the results in Table 5-7 are consistent with the description of the hydrogeology (Section 5.1) and the majority of hydraulic conductivity ranges presented in Table 5-8.

Table 5-8 Horizontal hydraulic conductivity estimates (m/d) from studies in the Moranbah-Dysart region

Formation	URS (2009)	URS (2012)*	CDM Smith (2013)*	URS (2014)	AECOM (2016)	HydroSim. (2018)	Arrow (2016)
Tertiary sediments/regolith	-	0.1 to 10**	-	-	1×10^{-3} to 1×10^{-2}	1×10^{-1} to 6×10^{-1}	0.1 to 1
Triassic (Rewan F.)	-	5×10^{-4} to 5×10^{-2}	1×10^{-5} to 1×10^{-1}	-	-	2×10^{-6} to 5×10^{-3}	-
Permian coal measures	-	1×10^{-4} to 5×10^{-2}	-	-	-	-	0.2 to 1
Permian coal seams	1×10^{-2} to 5×10^{-1}	-	1×10^{-6} to 5	0.002 to 0.16	1×10^{-3} to 1×10^{-2}	5×10^{-4} to 1×10^{-1}	-
Permian interburden	2×10^{-2} to 3×10^{-2}	-	1×10^{-4} to 1×10^{-1}	-	-	6×10^{-7} to 6×10^{-3}	-
Permian Back Creek Group	-	1×10^{-4} to 1×10^{-2}	1×10^{-3} to 1×10^{-2}	-	-	-	-

*Note: *Collated data from literature ** (0.005 to 0.5 m/d for Duaringa Formation)*

The following sections provide commentary on the hydraulic parameters collated in Table 5-8.

Tertiary sediments

As discussed in Section 4.2, on-site observations during the construction of the VCM monitoring bores indicate that the lithology intersected above the fresh Permian coal measures did not constitute Tertiary aged sediments, rather a weathering profile that had developed during the Tertiary on the Permian coal measures. As stated in Section 5.1.1, for the purposes of this report, Tertiary regolith are defined as a mix of specific Tertiary aged sediments and the weathered zone or regolith material.

For a mix of specific Tertiary aged sediments and the weathered zone or regolith, hydraulic conductivities are in the order of 10^{-1} m/d appear reasonable (as provided by HydroSimulations, 2018, and Arrow Energy, 2016; in Table 5-8).

Permian coal measures

Throughout the Bowen Basin, the Permian coal seams are understood to be the main water bearing horizon within the Permian coal measures and the confining overburden, underburden and interburden strata are considered to be aquitards. Table 5-8 therefore lists the horizontal hydraulic conductivities for the coal measures (coal and over- and interburden), coal seams, and interburden (including overburden).

The coal seams are considered dual-porosity strata where primary-porosity is provided by the matrix and a secondary porosity is the result of the presence of fractures (joints and cleats). These secondary porosity features within the coal seams likely dominate groundwater storage; and the main pathway for groundwater movement is dependent on the interconnectivity of these fractures (URS, 2009 and AECOM, 2016). Hence, the hydraulic conductivity of the coal seams is expected to vary considerably spatially and also decrease with increasing depth of burial as the fractures close under increasing overburden pressure (HydroSimulations, 2018).

For the reasons listed above, the horizontal hydraulic conductivities in Table 5-8 cover a wide range. A range between 1 x 10^{-2} m/d and 1 x 10^{-1} m/d appears to be reasonable and consistent with the descriptions provided in Section 4.3 for the upper coal seams. For the interburden, a range between 1 x 10^{-5} m/d and 1 x 10^{-3} m/d appears to be realistic. For the coal measures (coal seams and inter- and overburden together), horizontal hydraulic conductivities between 1 x 10^{-4} m/d and 1 x 10^{-2} m/d appear to be reasonable. For the Permian Back Creek Group, horizontal hydraulic conductivities between 1 x 10^{-4} m/d and 1 x 10^{-2} m/d appear to be realistic and consistent with the material descriptions provided.

5.4. Groundwater flow, recharge and discharge

5.4.1. Tertiary sediments

Recharge to the Tertiary regolith is likely from creek flow (losing ephemeral streams) events and from surface infiltration of rainfall and overland flow. The general recharge mechanism is presented in Figure 5-3 below. The schematic diagram represents the infiltration of surface waters through the vadose zone and into the underlying Tertiary regolith and Permian coal measures involved within the Project area. This would be observed as localised mounding beneath the creeks and surface water systems. Otherwise, diffuse rainfall recharge would be expected to occur over a large area. The clayey nature of the Tertiary regolith would result in very low recharge rates.

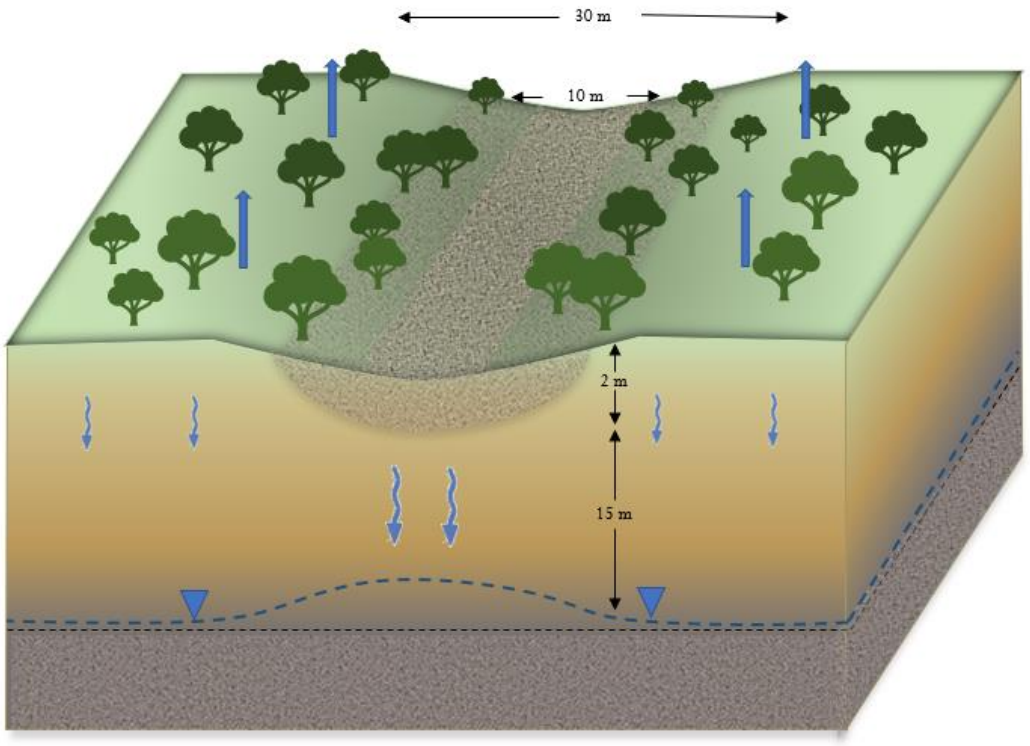


Figure 5-3 Schematic diagram of recharge processes

Discharge from the Tertiary sediments, where they outcrop and the water table is shallow, may occur through evapotranspiration. The Tertiary sediments may also discharge to the Permian coal measures as, in general, there is a downward vertical hydraulic gradient between the Tertiary sediments and Permian coal measures.

Observations from open pits at Saraji Mine (AECOM, 2016) indicate that groundwater discharges relatively slowly from the sandy horizons within the Tertiary sediments. Based on these observations, the Tertiary sediments were considered by AECOM (2016) to contain a series of poorly connected aquifers of low to moderate permeability, with drainage from the upper to lower aquifers delayed by lower permeability horizons. Groundwater ingress rates are low as evaporation rates are higher than the seepage rate, hence groundwater does not report directly or require management in the pits (AECOM, 2016).

Groundwater flow in the Tertiary sediments is expected to follow topography and surface water drainage patterns. Groundwater levels within the Tertiary sediments from monitoring bores near the Saraji Mine were reported to be at depths shallower than the recorded water strikes from drilling and installation, interpreted by AECOM (2016) to indicate that groundwater is semi-confined to confined by the clayey sediments in the upper sections of the sequence (AECOM, 2016).

5.4.2. Permian coal measures

Within the Project area, the Permian coal measures are known to be partially unsaturated and site-specific monitoring bores have confirmed this. Figure 5-4 illustrates the groundwater table in the Permian coal measures over the Project area from the south-west, to the north-east.

As for the Tertiary sediments, groundwater recharge to the Permian coal measures is likely from creek flow (losing ephemeral streams) events; and from surface infiltration of rainfall and overland flow, where the Permian coal measures are exposed, and no substantial clay barriers occur in the shallow sub-surface. Recharge may also occur from overlying Tertiary sediments under downward vertical hydraulic gradient and along faults and other structural features (AECOM, 2016).

Discharge from the Permian coal measures, where they outcrop and the water table is shallow, may occur through evapotranspiration or along faults and by groundwater extraction from bores and mine dewatering/depressurisation (AECOM, 2016 and HydroSimulations, 2018).

As for the Tertiary sediments, groundwater flow in the Permian coal measures is expected to follow topography and surface water drainage patterns, although the similarity to surface water drainage for the deeper confined units will be less pronounced than that for a shallow unconfined aquifer. Within the Permian coal measures, due to the low hydraulic conductivity of the interburden material, groundwater would largely flow along the bedding planes of the coal seams (HydroSimulations, 2018). In the vicinity of active mine dewatering sites, groundwater would flow into the pits but the spatial extent of the interference zone of individual pits would be limited because of the low hydraulic conductivity and storativity of the coal measures.

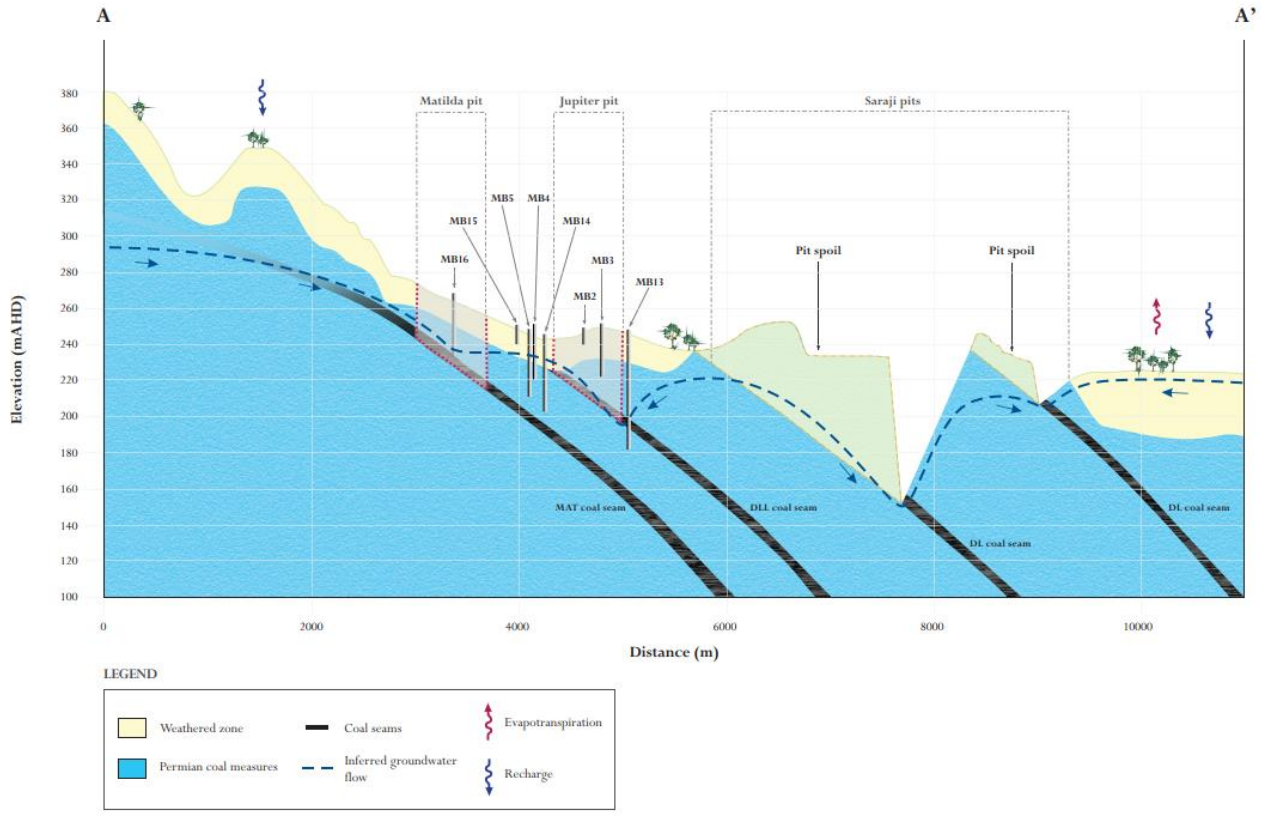


Figure 5-4 Hydrogeological cross section showing the saturation extent of the Permian coal measures in the Project area

5.4.3. Recharge and discharge rates

While the literature generally agrees on the recharge and discharge mechanisms, the rates of recharge and discharge vary significantly. AECOM (2016) used a recharge rate of 0.89 mm/yr for their model domain. URS (2012) and Arrow (2016) used a minimum of 1 mm/yr for Triassic/Permian strata (Arrow Energy, 2016).

HydroSimulations (2018) used model calibrated recharge rates of 0.15 mm/yr for Tertiary sediments and 0.06 mm/yr for outcropping Permian coal measures. These recharge rates are summarised in Table 5-9 together with indicative long-term average recharge/rainfall percentages.

Table 5-9 Estimates of recharge rates (mm/yr)

Reference	Tertiary sediments	Permian coal measures
AECOM (2016)	0.89 (0.1%)	0.89 (0.1%)
URS (2012)	1 (0.1%)	1 (0.1%)
HydroSimulations (2018)	0.15 (0.02%)	0.06 (0.009%)

Note: Value in brackets is the percent of recharge assuming an annual rainfall of 660 mm/yr.

HydroSimulations (2018) also refer to recharge rates used in Arrow Energy's Bowen Gas Project and other nearby projects (not sighted during the preparation of this report). According to HydroSimulations (2018), recharge at Lake Vermont was simulated as the equivalent of 2% mean annual rainfall and at Isaac Plains it was simulated as 0.5% (mean annual rainfall) to alluvium and 0.25% (mean annual rainfall) elsewhere. For the Arrow Energy Bowen Gas Project, recharge to the Tertiary sediments was simulated as 0.3 mm/yr or 3 mm/yr, 0 mm/yr for the Rewan Group and 0.33 mm/yr to 3 mm/yr for outcropping Permian coal measures.

For discharge, URS (2012) and Arrow (2016) modelled the difference between potential and actual evapotranspiration with an extinction depth of 10 m in their respective numerical models. HydroSimulations (2018) applied maximum potential evaporation rates using actual evapotranspiration values with an average value (600 mm/yr) used as the transient calibration evapotranspiration rate. Extinction depths were set to 2 m below ground across the model domain.

5.4.4. Groundwater flow

Based on the literature reviewed in this report, and published groundwater contour maps, horizontal (lateral) regional groundwater flow is expected to follow the same patterns as topography and the surface water drainage from all hydrogeological units, although the resemblance to surface water drainage for the deeper confined units will be less pronounced than that for the shallow unconfined aquifer.

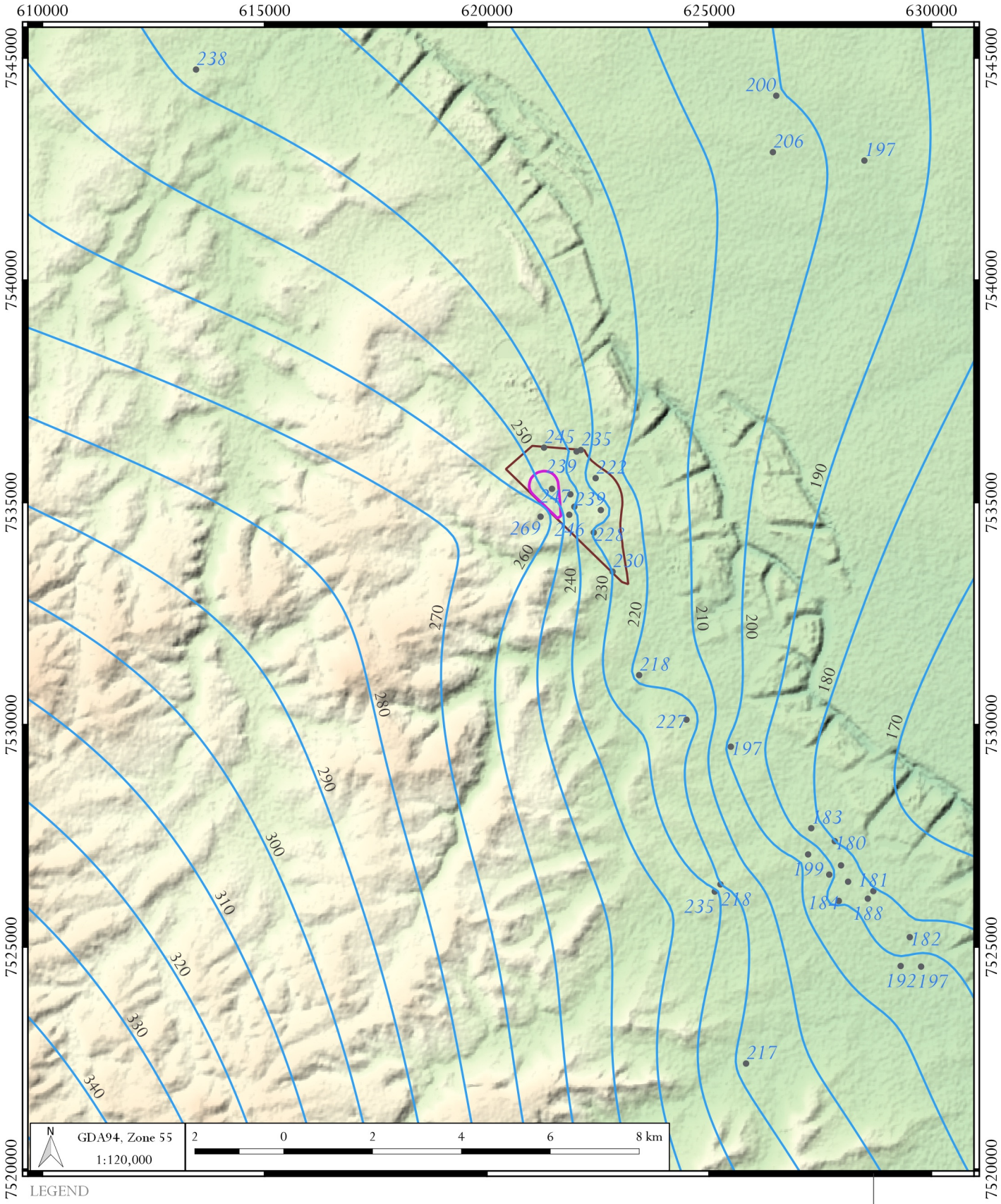
URS (2012) presented regional groundwater elevations (not reproduced in this report) for the Permian Blackwater Group. Average groundwater "levels" (i.e., elevations) were used to create the map, both from non-coal units and coal seams, hence both temporal and vertical changes (within the Blackwater Group) in groundwater elevation were disregarded. URS (2012) indicated, in general, that groundwater flows from the west (north-west) to the east (south-east), mimicking the surface water drainage pattern. URS (2012) commented that groundwater flow may also be constrained by major N-S strike fault systems. The interpretation of **hydrogeologist.com.au** is that there may be an indication for such influence on groundwater flow, however, it is difficult to say with certainty at the scale provided.

Groundwater contours by AGE 2012a (a memorandum on predicted inflows and drawdown for the Saraji East Underground Mine) in AECOM (2016; Saraji Mine) indicate generally west to east flow pattern, similar to the URS (2012; Bowen Gas Project) interpretation. The pre-mining groundwater contours are model generated, and the elevations are typically up to 20 m different to the regional contours presented by URS.

Figure 5-5 shows composite regional groundwater elevation contours, prepared by **hydrogeologist.com.au**. The groundwater elevation contours are based on 50 individual datapoints collated from the DRDMW GWDB, site specific monitoring bores and Project exploration drill holes and groundwater elevations summarised as part of neighbouring projects (AECOM, 2016). For each datapoint, the depth to groundwater measurements were considered and corrected to an elevation based on surveyed or reported elevations or derived from an STRM (one second) digital elevation model (DEM). Notwithstanding that, the contours represented in Figure 5-5 are a composite groundwater elevation map (groundwater elevations from different times and from various hydro-stratigraphic units), it clearly indicates groundwater flow to the east near the Project area. To the east of the Project area, the inferred direction of groundwater flow turns to the south-east and eventually follows the alignment of the Isaac River, in agreement with the findings of HydroSimulations (2018).

Based on the literature reviewed and presented in this report, horizontal (lateral) regional groundwater flow is expected to follow the same patterns as topography and the surface water drainage for all hydrogeological units, although the resemblance to surface water drainage for the deeper confined units will be less pronounced as for the shallow unconfined groundwater systems. Near the Project area, the statement above would suggest a west to east groundwater flow, and this is consistent with the data assessed.

Vertically, the highest groundwater elevations were measured in the Quaternary and Tertiary units and upper Permian coal seams. Groundwater elevations also appear to decrease with the depth within the coal seams (URS, 2009 and AECOM, 2016). Vertical hydraulic gradients, where reported, are downward, suggesting potential downward leakage between the hydrogeological units (although HydroSimulations (2018) reported a single observation deep in the Permian where the vertical hydraulic gradient within the Permian coal measures reversed, coinciding with a decrease in hydraulic conductivity with depth). Groundwater elevations measured by AECOM (2016) in nested bores indicate downward hydraulic gradients in all measured bores between the Tertiary and Permian units and within the Permian units in all but one bore. These observations are consistent with those made by HydroSimulations (2018).



LEGEND

- Matilda pit
- ML700060
- Groundwater elevation contours
- Groundwater elevation points

DATE
15/07/2022

hydrogeologist.com.au

Vulcan Coal Mine EA amendment - Groundwater Impact Assessment (4124)

Groundwater elevation contours

FIGURE No.
5.5

©2022 Oasis Hydrogeology Pty Ltd - trading as hydrogeologist.com.au
Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.
C:\4124_Metserve_Matilda Pit\4_Processing\4124_Groundwater elevation contours_V3.qgz

Effect of mining

AECOM (2016) noted that:

"Groundwater levels in the alluvium (MB2), Tertiary (PZ02A and PZ04A) and Permian (MB31, MB33 to MB37) strata, measured over time, do not indicate any impacts of mine dewatering even though coal mining at Saraji Mine has been undertaken since 1974". The monitoring bores referred to above are located between 600 m (MB2) and 1,500 m (MB33 and MB34) of the existing Saraji Mine open cut pits. The monitoring data would indicate that the zone of influence (or interference) is restricted to an area immediately adjacent to the open cut pit. This is likely due to low permeability of the mined strata and Permian overburden. AECOM (2016) therefore considered that the long term mine activities do not markedly impact on regional groundwater resources.

hydrogeologist.com.au concurs with this interpretation. The low hydraulic conductivity / transmissivity for most units, combined with low storage, would result in mine interference zones limited in lateral extent, except in areas where secondary porosity (fractures) opened extensive preferential pathways in the coal seams.

Structural control

CSIRO (2002) presents the distribution of faults, dykes and sills within the Project area and this is reproduced as Figure 5-6. In Figure 5-6, red lines represent thrust faults with > 3m throw, blue lines indicate normal fault with 1 m to 3 m throw, and turquoise lines show normal faults with > 3 m throw, and purple rectangles signify inferred basement structures. The approximate location of the Project area is indicated on the figure to show the location relative to the Jellinbah Thrust Fault Zone and the structures mapped at Saraji Mine and Peak Downs Mine. The VCM may be influenced to some degree by local structure mapped at the adjacent Saraji Mine and Peak Downs Mine. However, it is understood that no significant faults have been intersected by mining at the VCM.

The main geological structure in the region is the Jellinbah Thrust Fault Zone. The Jellinbah Thrust Fault Zone is highly faulted with several easterly dipping thrust faults. It is a north-west trending zone of thrust faults with throws in the order of 100 m to 500 m (URS, 2012). The Olive Downs Coal Project (HydroSimulations, 2018) is located within the Jellinbah Thrust Fault Zone and discusses several regional fault structures with a dominant north-north-west trend, including the Iffley Fault Zone (up to 100 m displacement). On the western side of the Olive Downs Coal Project is the Isaac Thrust Fault, which has up to 500 m vertical displacement.

The Jellinbah Thrust Fault Zone is truncated by the Tertiary unconformity, with little to no fault activity during the Cainozoic (CSIRO, 2002 and HydroSimulations, 2018). Faulting can result in higher permeabilities within strata parallel with the fault plane, and lower permeabilities within strata perpendicular to the fault plane. However, this can be dependent on whether faults are currently active or not. Faulting has been inactive within the Bowen Basin for over 140 million years, indicating that the fault zones are less likely to act as conduits to flow (HydroSimulations, 2018). This relates to filling of the fractured pore spaces over time through hydrothermal alteration and mineralisation. Drill core logs from the Olive Downs Coal Project show that where fractures and faults have been geologically logged, many fractures are "healed" with calcite and siderite. This indicates that, although the system is a fractured network, many of the existing fractures are cemented with the likely effect of reducing effective permeability when compared to any open fracture network.

The behaviour of faults was also assessed as part of the Bowen Gas Project using the movement of water and gas across a series of faults utilising stable isotope and water quality analyses. Higher gas production rates were observed on either side of a major fault, with differences in isotopic compositions of produced water for wells north and south of a major fault line at similar depths, implying little communication across the fault boundary, and suggesting that the fault acts as a barrier to water and gas flow. The results of the study showed that compartmentalisation was evident and that this was due to the structural geology (faulting) in the basin (HydroSimulations, 2018).

The Jellinbah Thrust Fault Zone occurs some 10 km to 15 km to the east of the VCM and would be extremely unlikely to influence groundwater flow at the VCM. On a regional scale, however, the presence of the Jellinbah Thrust Fault Zone would act as a low permeability zone in the regional flow system of the Permian strata. The experience of **hydrogeologist.com.au**, with the Jellinbah Thrust Fault Zone, is that lateral groundwater flow within the fault zone is to the east (north-east). To the west of the fault zone, the presence of 'dense' groundwater head/elevation contours suggest a steep horizontal hydraulic gradient while to the east of fault zone the gradient is flatter, indicating that the fault zone is acting as an impediment, i.e., the hydraulic conductivity of the fault zone is lower than that of the host rocks.

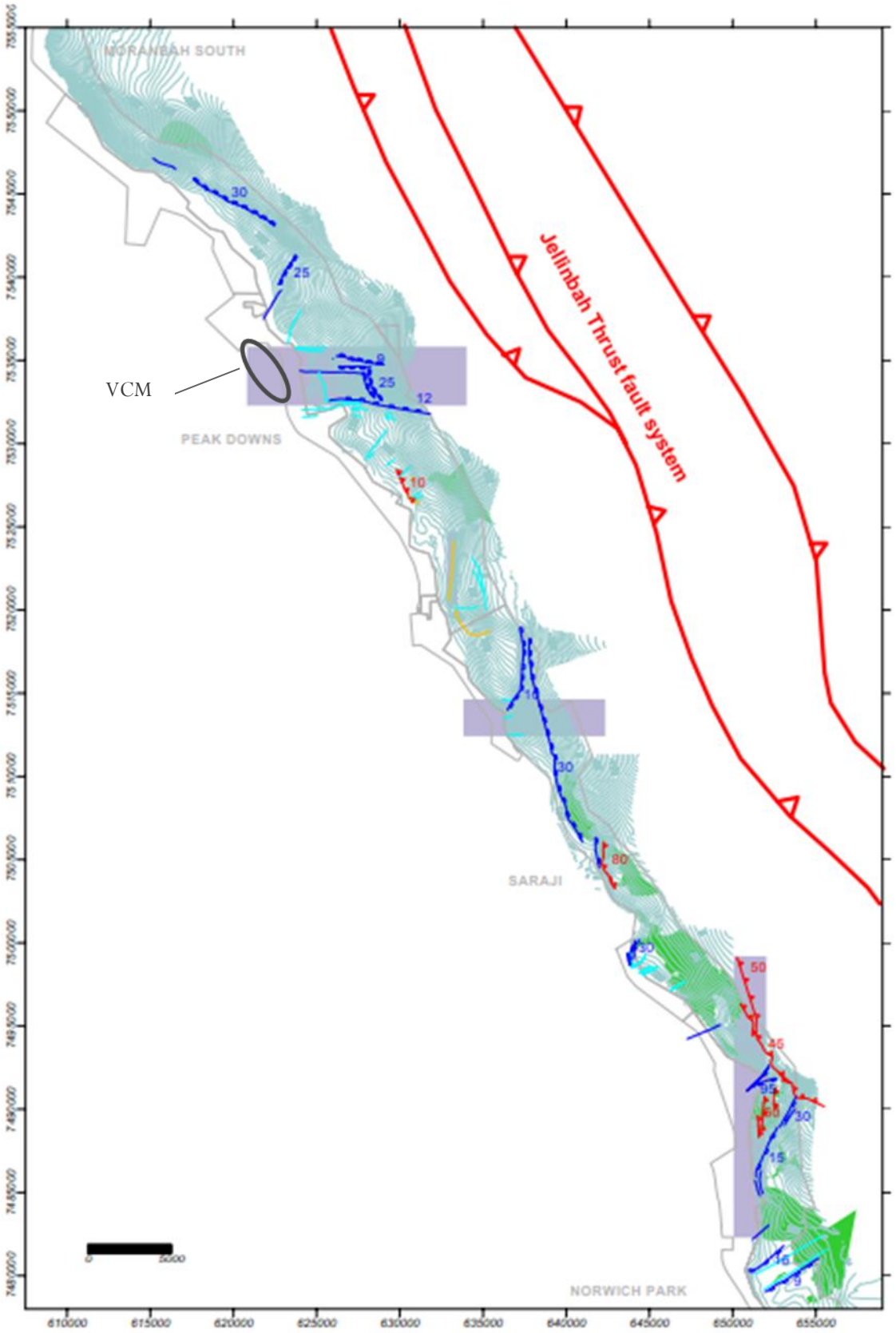


Figure 5-6 Faults with >1 m throw mapped in the Dysart seam of the Middle Tile, after CSIRO (2002)

5.5. Surface-groundwater interaction

Surface-groundwater interaction was investigated for the Olive Downs Coal Project (HydroSimulations, 2018), approximately 20 km to the north-east of the Project area. Despite the distance between the projects, the assessment appears to be directly transferable because the numerical groundwater model domain of HydroSimulations (2018) extends westward sufficiently enough to cover all important watercourses in the Project area.

In addition, HydroSimulations (2018) have:

- developed a conceptual hydrogeological model that is consistent with that presented in this report in Section 5.8;
- addressed surface water-groundwater interaction with the same or similar modelling tools used and described in Section 5.5;
- relied on a dataset almost identical to that available for this report because the most important stream gauging station, Phillips Creek at Tayglen (Figure 3-3) was closed in late 1988 (https://water-monitoring.information.qld.gov.au/, visited 21 August 2019); and
- the groundwater report and model of HydroSimulations (2018) appears to be the most recent and comprehensive groundwater assessment in the vicinity of the Project area.

Further, a careful evaluation of the differences between the Olive Downs Coal Project and the Project area suggests that surface and groundwater interact to a lesser degree at the Project area than at Olive Downs Coal Project:

- the Project area is to the west and at higher elevation than the Olive Downs Coal Project, resulting in generally deeper groundwater table and less flow in the watercourses than those at the Olive Downs Coal Project;
- the Quaternary alluvium of the Isaac River, through which most surface-groundwater interaction at the Olive Downs Coal Project occurs, is absent in the Project area; and
- the importance of the Isaac River (and its associated alluvium) on the groundwater regime of the Project area is significantly less, not just because of the distance, but because of the Jellinbah Thrust Fault Zone which is situated in between the Isaac River and the Project area, compartmentalising groundwater flow in the Permian strata.

In Section 5.4 (Figure 5-3), the mechanism of recharge from surface water systems in the Project area is presented. The ephemeral nature of the surface water systems means that the creeks are dry for the majority of time. The groundwater table beneath the creeks occurs within either the Tertiary regolith or Permian coal measures at depth (greater than 10 m below ground level) and forms part of the regional groundwater table. There is a significant thickness (generally greater than 10 m) of unsaturated material beneath the creek and above the groundwater table. For the reasons stated above, it is assessed that there is no significant surface-groundwater interaction in the Project area.

5.6. Groundwater use

Groundwater users in the vicinity of the Project area include mining companies (industrial use), private users (livestock beef cattle watering) and, potentially GDEs (springs, surface water, stygofauna, wetlands etc).

5.6.1. Third party users

Third party groundwater use has previously been assessed through two mechanisms:

- consideration of the registered bores within 5 km of the numerical flow model domain on the DRDMW GWDB; and
- discussion with private landholders within 5 km of the proposed open pit.

The Groundwater Database – Queensland (DRDMW GWDB) stores registered water bore data from private water bores and Queensland Government groundwater investigation and monitoring bores. Data includes bore location, water levels, construction details, strata log and water quality. As such the DRDMW GWDB is the most reliable source of desktop information on groundwater use for the Project area.

The previous search (2020) of the DRDMW GWDB considered records within a 5 km distance of the numerical model domain (Section 6.1). Of the 83 DRDMW GWDB records within 5 km of the numerical flow model domain, the following was concluded:

- 65 (78%) were existing;
- 11 (13%) were abandoned and destroyed; and
- 7 (8%) were abandoned but still useable.

There were 69 records classifying bore use or purpose within 5 km of the numerical flow model domain. These records suggested that the overwhelming use of bores is for mining:

- 51 (74%) were for monitoring (41 for mine, 5 for petroleum or gas and 5 for sub-artesian monitoring);
- 14 (20%) were for water supply (these may be for mine supply or private supply as water supply is used as a broad term); and
- 4 (6%) were for investigation (stratigraphic, exploration or water resources investigation).

It is the experience of **hydrogeologist.com.au** that the name of a bore may also reveal its purpose, i.e., bore names containing long numbers, company abbreviations or sequences such as "MB" or "INV" or "PIEZO" are for monitoring or investigation while private bores are named after the farm or local features. Of the 62 records with names available, 52 (84%) appeared to be for the purpose of mine investigation and monitoring.

Groundwater quality is an important consideration for groundwater use because high salinity will generally preclude or limit certain uses. For this reason, groundwater salinity data was also analysed. For the 5 km vicinity of the numerical flow model domain, most of the groundwater salinity information in DRDMW GWDB is provided as field electrical conductivity (EC). Using the classification of Mayer *et.al*. (2005) that is provided in Table 5-10, the 153 field EC records could be summarised as:

- none were fresh;
- one was marginal;
- 29 were brackish;
- 91 were saline; and
- 32 were highly saline.

The above statistics on field EC may somewhat be biased towards bores that are represented by several results (at different dates). The interpretation of **hydrogeologist.com.au** is that most bores in the vicinity of the Project area are for monitoring and investigation purposes (mostly for mining) and only a small fraction may be used for private groundwater use, probably for limited stock watering because of the high salinity of the groundwater.

A contemporary search of the DRDMW GWDB was carried to ensure no additional water supply bores have been drilled and constructed within the likely area of project impact. Additional bores were identified within 5 km of the project mining lease, however all of these additional bores were assessed to be mine monitoring bores associated with the existing BHP coal mining operations. No additional water supply bores were identified within the likely area of project impact.

The registered bores on the DRDMW GWDB are shown in Figure 5-1. Private landholder bore (RN162506) is the only bore situated within 3 km of the VCM, the next closest is RN13040283, a Queensland government monitoring bore approximately 8 km to the south-east of the proposed pit. The remaining bores shown on the map have been drilled by BHP for the purposes of mine monitoring.

Discussions have been held with the owners of the following property descriptions and Vitrinite to understand whether there are any groundwater bores on the property that may not be registered on the DRDMW GWDB:

- Lot 10 SP208611;
- Lot 2 SP296877;
- Lot 59 SP235297;
- Lot 7 CNS144;
- Lot 11 CNS394;
- Lot 14 CNS382; and
- Lot 9 SP235297.

The outcomes of the discussions indicate that there are no other groundwater supply bores in the Project area that are used by the local landholders. Potential impacts to third party groundwater users are discussed in Section 7.

5.6.2. Groundwater dependent ecosystems

A GDE is an ecosystem that requires access to groundwater on a permanent or intermittent basis to meet all, or some of its water requirements. For GDEs such as springs, wetlands, rivers and vegetation, groundwater plays an important role in sustaining aquatic and terrestrial ecosystems. A GDE therefore is a plant and/or animal community that is dependent on the availability of groundwater to maintain its structure and function.

The GDE Atlas (GDE Atlas, Bureau of Meteorology, 2016) was developed as a national dataset of Australian GDEs to inform groundwater planning and management. It is the first and only national inventory of GDEs in Australia. The GDE Atlas web-based mapping application allows the visualisation, analysis and downloading of GDE information for an area of interest (http://www.bom.gov.au/water/groundwater/gde/, visited 21 August 2019).

The GDE Atlas classifies ecosystems based on the potential for dependence on groundwater. Classification is based on multiple lines of scientific evidence, with categories for high, moderate or low potential, allocated as follows:

- high potential for groundwater interaction (indicating a strong possibility the ecosystem is interacting with groundwater);
- moderate potential for groundwater interaction; or
- low potential for groundwater interaction (indicating it is relatively unlikely the ecosystem will be interacting with groundwater).

BOM (2018) maps areas for both aquatic and terrestrial GDE's and indicates that the following are mapped in the vicinity of the Project area:

- Aquatic GDEs rely on the surface expression of groundwater, including surface water ecosystems which may have a groundwater component such as rivers, wetlands and springs. Aquatic GDEs associated with a number of separate wetlands along the Moranbah – Dysart Road, between Phillips Creek and Boomerang Creek and close to the Project area, are mapped as having a low, moderate or high potential to be associated with the surface expression of groundwater (Figure 5-7). These wetland features all appear to be manmade impoundments associated with Saraji Mine or pastoral properties.
- Terrestrial ecosystems rely on the subsurface presence of groundwater. This includes all vegetation ecosystems. Terrestrial GDEs to the west of Moranbah – Dysart Road are mapped generally as having a low to moderate potential to be dependent on the subsurface expression of groundwater (Figure 5-8). No subterranean GDEs (cave and aquifer ecosystems) have been identified by BOM (2018) in the vicinity of the Project.

Aquatic GDEs with high or moderate potential for groundwater interaction are most likely to occur in areas where the seasonally high groundwater potentiometric heads are above or close to the corresponding surface water heads. This is necessary to maintain a hydraulic gradient from the groundwater to surface water, or at least have a hydraulically 'connected' system. Within or adjacent to the Project area, the surface water systems are generally well above the groundwater table (see Section 5.5) and the surface water system is hydraulically disconnected from the groundwater system.

In addition, groundwater in the Project area is brackish to saline and therefore unsuitable for the maintenance of freshwater GDEs (see Section 5.7 for further information on groundwater quality).

The depth to groundwater table map in Figure 5-9 was produced by subtracting the groundwater elevation grid (compiled and generated from publicly available information – see Figure 5-5) from the ground surface (SRTM data used for the regional area and LIDAR used for the local Project area) grid.

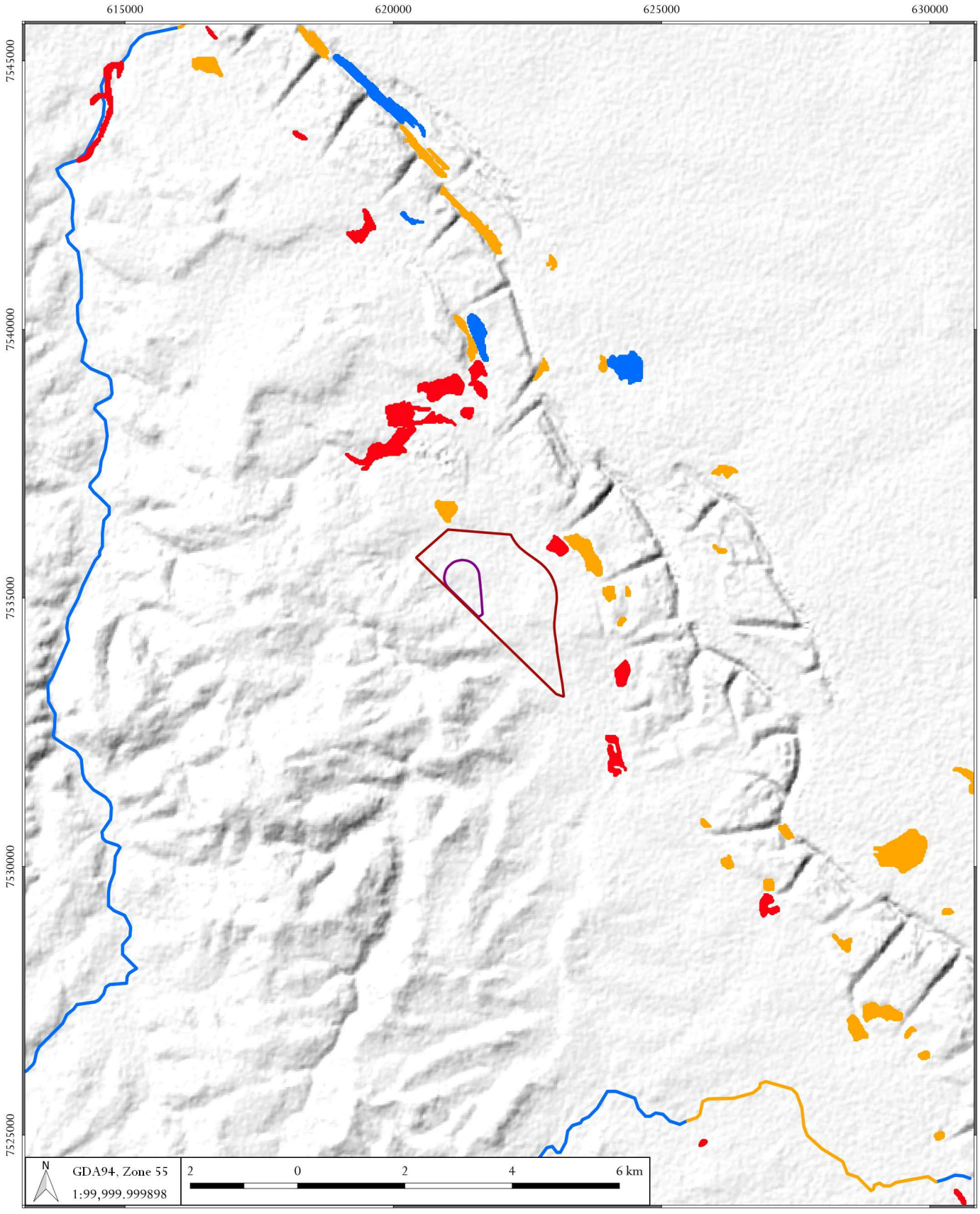
Figure 5-9 indicates that groundwater is between 5 and 30 m deep at the VCM. The nearest areas with depth to groundwater less than 5 m (orange colours) are on the northern Project area boundary and to the immediate south-west of the Project area. These areas of shallow depth to groundwater do not correlate with the aquatic GDEs presented in Figure 5-7.

In the experience of **hydrogeologist.com.au**, terrestrial GDEs with high or moderate potential for groundwater interaction are most likely to occur in areas where depth to groundwater is less than 10 m (i.e., the groundwater table is shallow, including alluvial deposits) and likely to be outside of the accessible reach of Eucalypt vegetation (Zolfaghar *et al*. 2014).

For the reasons stated above, it is the interpretation of **hydrogeologist.com.au** that there are no aquatic or terrestrial GDEs within 3 km of the VCM. The reader is directed to the Vulcan Coal Mine – Ecological Impact Assessment report for further information regarding the presence of aquatic or terrestrial GDEs.

In addition, the Queensland Government maintains an inventory of identified springs in the Queensland Springs Database (https://data.qld.gov.au/dataset/springs/resource/4cdc89ef-b583-446e-a5c7-0836a91a3767, visited 21 August 2019) that can also be reviewed through QLD globe. No springs have been identified in the vicinity of the Project area; with the nearest spring being situated at a distance greater than 100 km to the west.

A search of the EPBC Act 'Protected Matters Report' (http://www.environment.gov.au/epbc/pmst/index.html, visited 21 August 2019) found that there are no internationally or nationally important wetlands within 50 km of the Project area. Lake Elphinstone is the closest nationally important wetland, located approximately 100 km north of the Project area.



LEGEND

ML700060

Matilda pit

Aquatic groundwater dependent ecosystem

High potential GDE - from national assessment

High potential GDE - from regional studies

Moderate potential GDE - from national assessment

Low potential GDE - from national assessment

DATE
21/06/2022

hydrogeologist .com.au

Vulcan Coal Mine EA amendment - Groundwater Impact Assessment (4124)

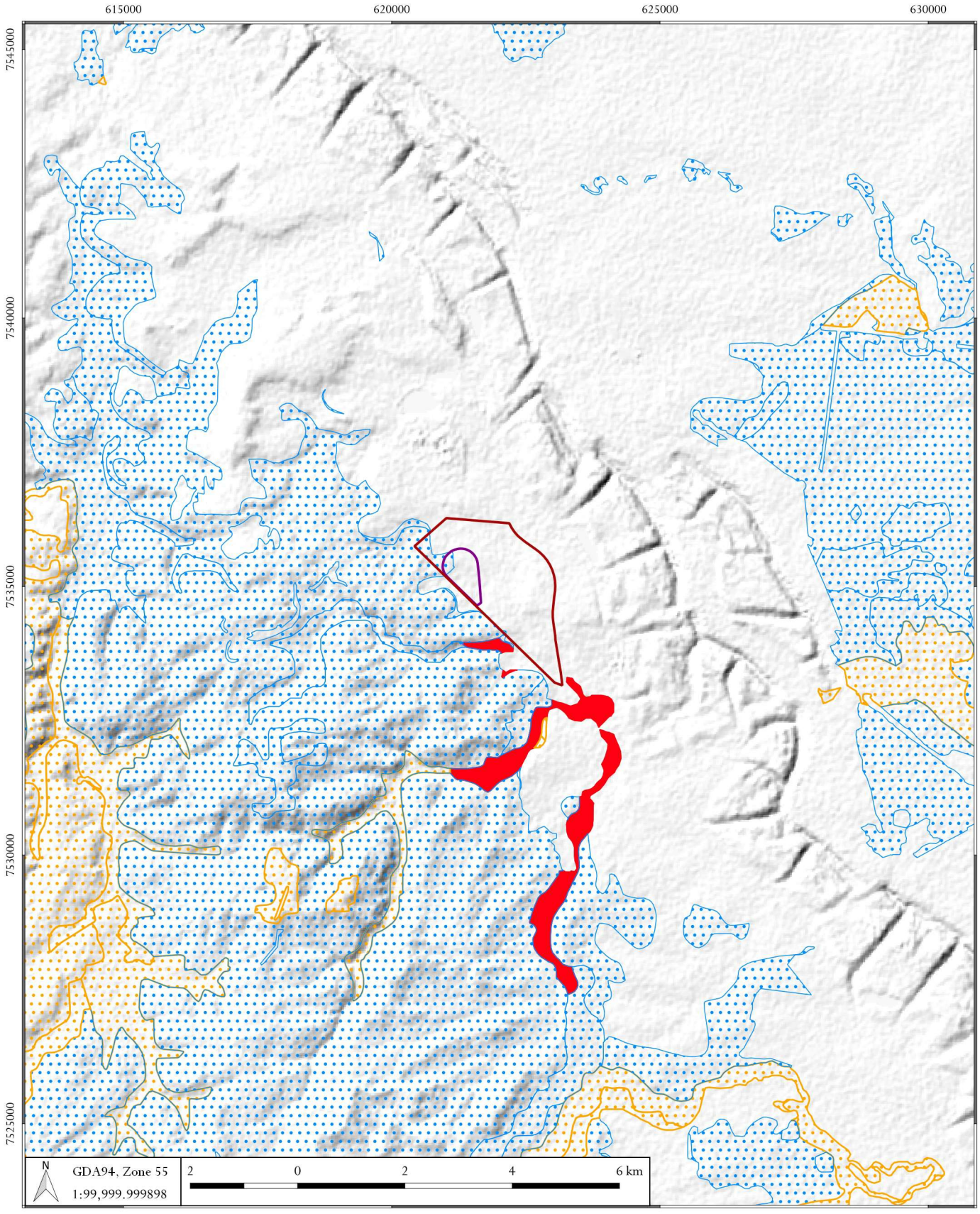
Aquatic groundwater dependent ecosystems

FIGURE No.
5.7

©2022 Oasis Hydrogeology Pty Ltd - trading as hydrogeologist.com.au

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.

Z:\4000_Projects\4124_Metserve_Matilda Pit\3_GIS\3_11_Workspaces_QGIS\05_08_4124_Matilda_Vulcan South_Aquatic GDEs.qgz



LEGEND

- ML700060
- Matilda pit

Terrestrial groundwater dependent ecosystem

- High potential GDE - from national assessment
- Moderate potential GDE - from national assessment
- Moderate potential GDE - from regional studies
- Low potential GDE - from national assessment

DATE
21/06/2022

hydrogeologist .com.au

Vulcan Coal Mine EA amendment - Groundwater Impact Assessment (4124)

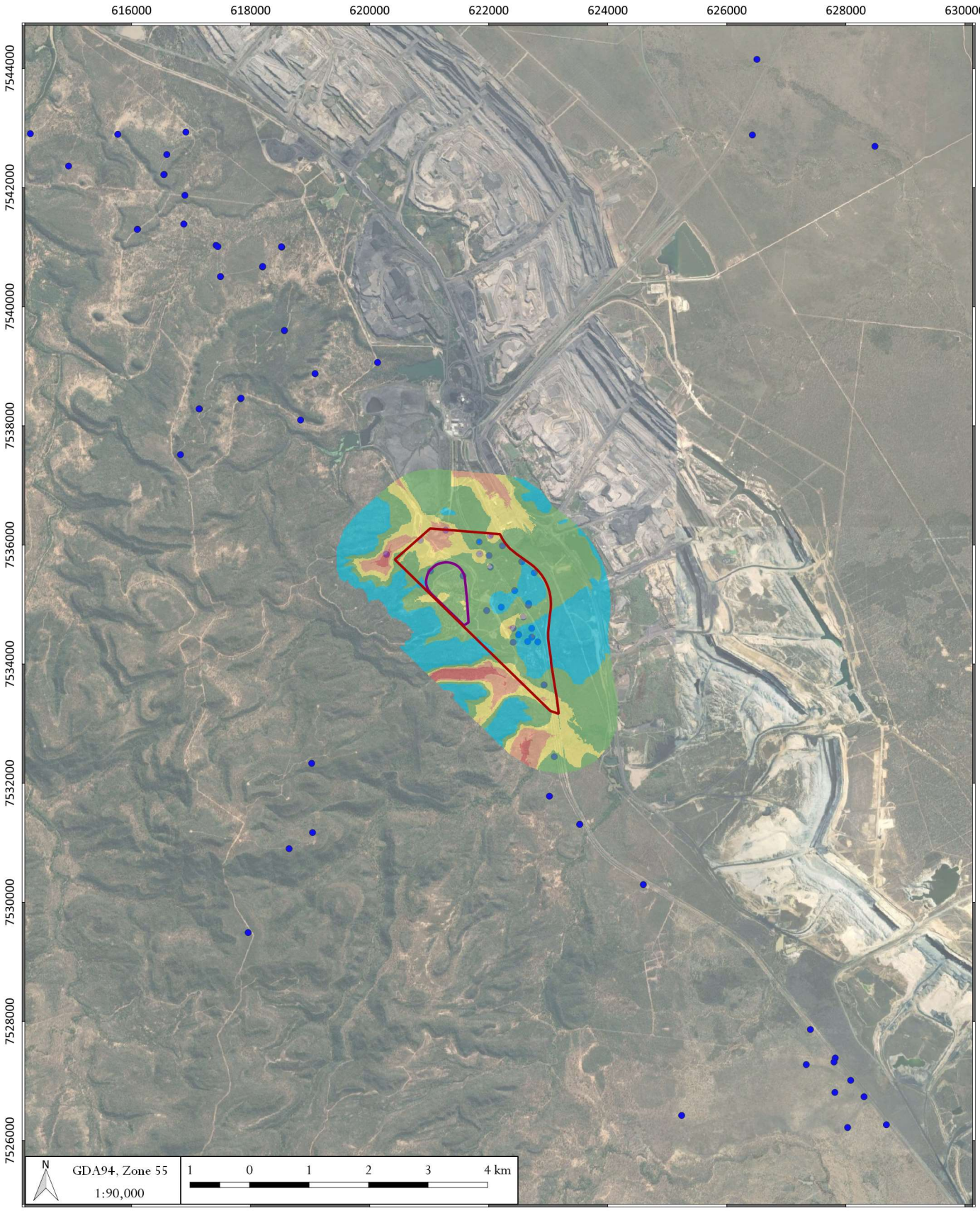
Terrestrial groundwater dependent ecosystems

FIGURE No.
5.8

©2022 Oasis Hydrogeology Pty Ltd - trading as hydrogeologist.com.au

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.

Z:\4000_Projects\4124_Metserve_Matilda Pit\3_GIS\3_11_Workspaces_QGIS\05_09_4124_Matilda_Vulcan South_Terrestrial GDEs.qgz



LEGEND

ML700060

Matilda pit

Groundwater elevation data point

Depth to groundwater (m)

<= 0

0 - 5

5 - 10

10 - 20

20 - 50

DATE
21/06/2022

hydrogeologist .com.au

Vulcan Coal Mine EA amendment - Groundwater Impact Assessment (4124)

Depth to groundwater

FIGURE No.
5.9

©2022 Oasis Hydrogeology Pty Ltd - trading as hydrogeologist.com.au

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.

Z:\4000_Projects\4124_Metserve_Matilda Pit\3_GIS\3_11_Workspaces_QGIS\05_10_4124_Matilda_Vulcan South_Depth to Groundwater.qgz

5.7. Groundwater quality

5.7.1. Site specific data

At the time of completing this report, seventeen rounds of analytical laboratory and field results were available from the VCM groundwater monitoring network (see Section 5.2 and Table 5-2). The monitoring and sampling of the groundwater monitoring network is carried out in consideration of the Queensland Monitoring and Sampling Manual (DES, 2018a).

Groundwater salinity was classified by **hydrogeologist.com.au** (2019) using a system based on local experience. In this report, however, the classification of Mayer *et.al*. (2005, http://www.water.wa.gov.au/water-topics/water-quality/managing-water-quality/understanding-salinity, visited on 14 June 2022) will be used because it is more widely used and contains more categories, especially a 'marginal' category between fresh- and brackish water (Table 5-10).

Table 5-10 Groundwater salinity classification based on Mayer *et.al*. (2005)

Salinity status	Electrical Conductivity* (µS/cm)	Description and use
Fresh	<750	Drinking and all irrigation
Marginal	750 – 1,500	Most irrigation, adverse effects on ecosystems become apparent
Brackish	1,500 – 3,000	Irrigation certain crops only; useful for most stock
Saline	3,000 – 15,000	Useful for most livestock
Highly saline	15,000–52,000	Very saline groundwater, limited use for certain livestock
Brine	>52,000	Seawater; some mining and industrial uses exist

*Note: *converted from total dissolved solids (TDS in mg/L) using a conversion factor of 0.67; rounded values*

The field EC and pH of groundwaters are summarised in Table 5-11 and Table 5-12. None of the samples are assessed as fresh or marginal, with all samples returning a field EC above 2,600 µS/cm and some above 20,000 µS/cm (MB12). Using the classification of Mayer *et al*. (2005), groundwater from the Project area is brackish (MB05); to saline (MB04, MB07, MB09, MB10 and MB13) to highly saline (MB12).

Table 5-11 Historical summary of field electrical conductivity (µS/cm)

Bore ID	Jun 2019	Jul 2019	Aug 2019	Sep 2019	Oct 2019	Dec 2019	Mar 2020	Jun 2020	Aug 2020	Oct 2020	Dec 2020	Mar 2021	May 2021	Jul 2021	Sep 2021	Dec 2021	Mar 2022	Salinity status*
MB04[1)]	~~2,520~~	9,510	9,346	10,409	10,703	11,709	12,913	12,734	12,782	12,752	12,048	11,122	10,904	12,592	10,901	11,800	-	Saline
MB05	2,960	3,042	2,737	2,753	2,739	2,719	2,720	2,720[#]	2,840	2,757	2,754	2,651	2,858	2,712	2,625	2,760	2,790	Brackish to saline
MB07	5,680	6,091	5,739	5,819	5,882	5,830	-	5,184	5,141	5,383	5,393	5,358	5,196	5,307	5,412	5,547	6,132	Saline
MB09	~~5,520~~	13,758	15,130	13,909	13,566	11,582	12,117	11,989	11,933	11,909	11,845	11,735	11,506	12,064	11,403	12,438	11,737	Saline to highly saline
MB10	-	5,668	4,846	4,322	4,353	4,034	4,170	4,121	4,028	3,980	3,876	3,881	3,818	3,806	3,762	3,852	3,794	Saline
MB12	22,800	19,469	17,854	17,231	20,878	16,725	15,644	22,200[#]	22,444	22,178	22,840	22,533	21,998	21,953	21,470	22,094	22,851	Highly saline
MB13	-	-	-	-	-	-	-	-	-	-	-	4,110	4,021	4,084	3,970	4,230	4,450	Saline

Notes: ** from the classification of Mayer et al. (2005) and excluding the initial June samples for MB04 and MB09*

[#] laboratory data substituted for field data

Strike through text (e.g., ~~2,520~~) is considered anomalous data or outliers

[1)] MB04 has been decommissioned, and has been replaced by MB14

Table 5-12 Historical summary of field pH

Bore ID	Jun 2019	Jul 2019	Aug 2019	Sep 2019	Oct 2019	Dec 2019	Mar 2020	Jun 2020	Aug 2020	Oct 2020	Dec 2020	Mar 2021	May 2021	Jul 2021	Sep 2021	Dec 2021	Mar 2022
MB04	~~7.92~~	5.93	5.90	5.79	5.84	5.73	5.54	5.75	5.57	5.66	5.53	6.04	6.31	6.29	5.84	5.13	-
MB05	~~8.55~~	7.00	7.02	6.92	6.94	6.89	6.96	7.49[#]	6.84	6.90	6.67	7.21	7.63	7.44	6.92	7.65	7.81
MB07	~~8.78~~	7.04	7.00	6.75	6.93	6.78	-	6.74	6.72	6.91	6.86	7.08	7.23	7.42	6.94	6.77	6.53
MB09	~~8.58~~	6.90	7.00	6.90	6.87	6.93	7.08	6.78	6.64	6.72	6.71	7.26	7.21	7.51	6.96	6.87	6.91
MB10	-	6.78	6.94	6.88	6.97	6.81	7.03	6.89	6.86	6.91	6.89	7.20	7.29	7.43	7.07	6.93	6.76
MB12	~~8.29~~	6.86	6.79	6.66	6.57	6.62	6.78	7.08[#]	6.38	6.37	6.57	7.08	6.96	7.01	6.61	6.61	6.22
MB13	-	-	-	-	-	-	-	-	-	-	-	7.04	6.97	6.99	6.69	7.38	7.7

Notes: Strike through text (e.g., ~~2,520~~) is considered anomalous data or outliers

[1] MB04 has been decommissioned, and has been replaced by MB14

The Durov diagram (Figure 5-10) is best considered as a series of joint diagrams with the right side of Figure 5-10 being a scatter graph of sodium (as a percentage of all cations) vs TDS. The bottom diagram is a scatter of chloride (as a percentage of all anions) vs pH. The innermost square is the projection of the two scatters, i.e., it shows sodium (as a percentage of all cations) vs. chloride (as a percentage of all anions). The two ternary diagrams are for anion percentages (top) and cation percentages (left).

Figure 5-10 indicates that most of the site's groundwater is strongly dominated by sodium (Na) and moderately to strongly dominated by chloride (Cl). All the site-specific groundwater would fall into the sodic waters of marine origin category of Raymond and McNeil (2011). Chloride, as a percentage of anions, varies between 40% and nearly 100%; however, some samples (MB05, MB10 and MB07) indicate the presence of moderate bicarbonate (HCO_3). There does not appear to be a simple relationship between the hydro-stratigraphic unit and groundwater quality. For example, the markers for MB05, the deepest sampled coal seam (MAT), are indicating the lowest salinity and chloride percentage, contrary to the general observations made by URS (2012) and Arrow Energy (2016) indicating increase in salinity with increasing depth. There are three bores (MB04, MB09 and MB10) targeting the DLL seam, and as Figure 5-10 indicates, the markers for these bores are widely spread.

The Piper diagram in Figure 5-11 shows the major cation percentages on the left and the anion percentages on the right, the observations from the ternary diagram are next projected to the top rhomboid. The rhomboid indicates that all groundwater is of sodium-potassium (Na_K> 50%) and sulphate-chloride (SO_4-Cl (>50%) type. The ternary diagrams provide further breakdown, i.e., that the groundwater is dominated by sodium-potassium cations combined with mostly chloride as the dominant anion; although the MB05 samples contain 30-40% bicarbonate (HCO_3).

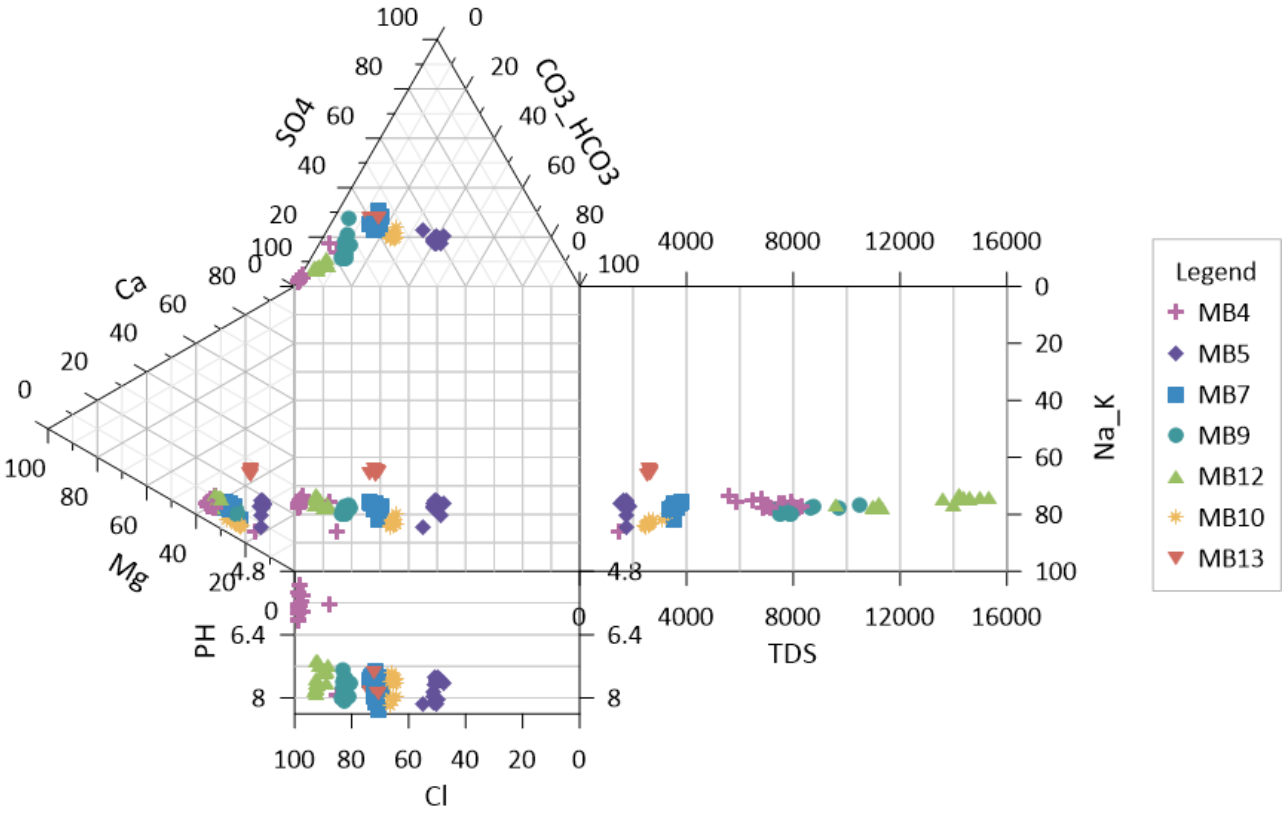


Figure 5-10 Extended Durov diagram for site specific monitoring bores

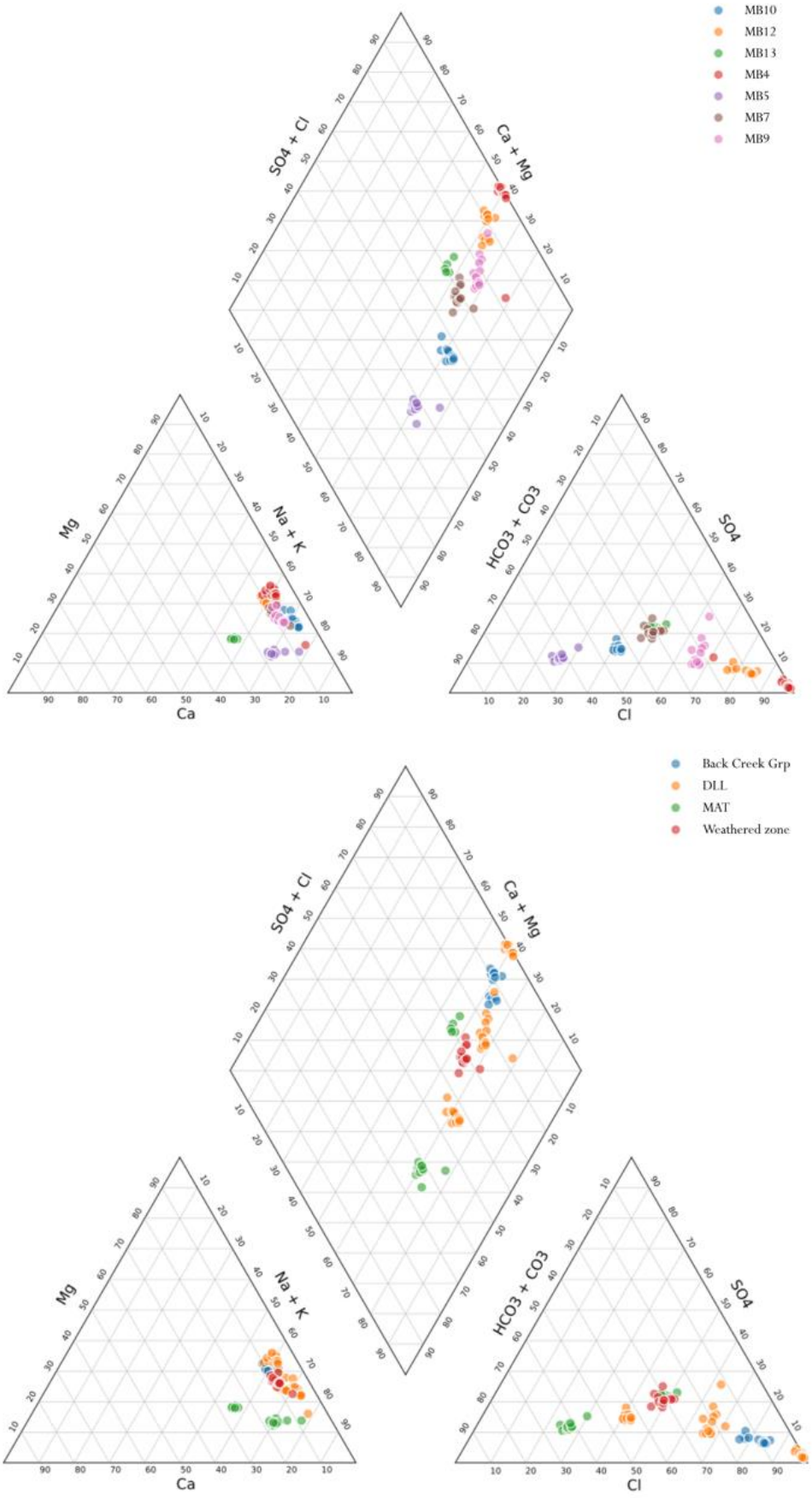


Figure 5-11 Piper diagram for site specific monitoring bores

5.7.2. Environmental values

As described in Section 2.1.1, the Isaac River Sub-basin Environmental Values and Water Quality Objectives (Department of Environment and Heritage Protection, 2011) is made pursuant to the provisions of the EPP Water and Wetland Biodiversity, which is subordinate legislation under the EP Act. The EPP Water and Wetland Biodiversity provides a framework for identifying EVs for Queensland waters, and deciding the WQO to protect or enhance those EV. The Isaac River Sub-basin Environmental Values and Water Quality Objectives (Department of Environment and Heritage Protection, 2011) document contains EV (Section 2, Table 1) and WQO for waters (including groundwaters) in the Isaac River Sub-basin.

For Isaac groundwaters, the EVs selected for protection are listed as follows:

- aquatic ecosystems;
- irrigation;
- farm supply/use;
- stock water;
- primary recreation;
- drinking water; and
- cultural and spiritual.

An assessment of groundwater quality is presented below, in terms of the relevant EV used in the Isaac River Sub-basin Environmental Values and Water Quality Objectives (Department of Environment and Heritage Protection, 2011). Although the EVs are not selected for protection of industrial use, this has also been included for completeness as mine water use is an important aspect given the number of coal mines operating in the catchment.

Aquatic ecosystems

The WQO, for aquatic ecosystems, where groundwaters interact with surface waters, is that groundwater quality should not compromise the identified EV and WQO for those waters. For example, Table 1 lists a WQO of <720 µS/cm for Upper Isaac River catchment waters. **hydrogeologist.com.au** interprets that groundwater that is identified to support the Upper Isaac River catchment surface waters should not exceed 720 µS/cm. None of the site monitoring bores reported such a low salinity; with all reporting field ECs > 2,700 µS/cm.

The deep groundwater (Section 5.2) in all bores with the exception of MB05, in addition to the brackish to highly saline groundwater quality and the absence of significant groundwater-surface water interaction in the Project area (Section 5.5) would render almost all the local groundwater unsuitable for use for GDEs because it is mostly out of reach (too deep for terrestrial flora) and its quality could not support fresh or marginal water ecosystems.

Farm Use / Irrigation

Table 3 of the Isaac River Sub-basin Environmental Values and Water Quality Objectives (Department of Environment and Heritage Protection, 2011) refers to the suitability for farm supply/use WQO as "*Objectives as per AWQG*". The AWQG (2018), however, bundles the guidelines, in Section 4.2, for irrigation and general water use. Hence, these EVs will be discussed together.

The objectives for pathogens and metals are provided in Tables 8 and 9 of the Isaac River Sub-basin Environmental Values and Water Quality Objectives (Department of Environment and Heritage Protection, 2011). For indicators other than pathogens and metals, the WQOs are those included in the AWQG (2018). For most pastures and loams and clays, the salinity threshold in Table 4.2.5 of the AWQG (2018) is between 1,000 µS/cm and 7,300 µS/cm.

In addition, the AWQG (2018) warns that certain combinations of salinity and sodium adsorption ratio (SAR) are likely to induce degradation of soil structure and corrective management may be required (e.g., application of lime or gypsum). Groundwater within the Project area would be classified as "marginal quality" in Figure 4.2.2 of the AWQG (2018) (i.e., soil degradation may occur if the water was used for irrigation depending on soil and rainfall) and would therefore need caution if used for irrigation.

hydrogeologist.com.au interprets that the brackish to highly saline groundwater, and all the indications for low sustainable bore yields (low airlift rates, low hydraulic conductivities and thin coal seams) preclude the potential use of the local groundwater for irrigation supply. In other words, neither the quantity nor the quality of local groundwater is suitable for irrigation.

Livestock watering

The review of DRDMW GWDB and the bore census data indicate that groundwater in the area may be used for limited livestock beef cattle watering. There are 14 records within 5 km of the numerical flow model domain previously classified as "*water supply*" (Section 5.6.1). Some of these may be used for mine supply and others for private farm supply that may or may not include livestock watering.

Information (Section 5.7.1) from local monitoring bores suggests that groundwater quality (salinity) varies from brackish to highly saline. Although some groundwater is within the guidelines for livestock watering, Section 4.3.3.5 of the AWQG (2018) states that loss of production and a decline in animal health occurs if stock is exposed to high salinity water for prolonged periods. For beef cattle, decline or loss may occur if the EC is between 7,463 µS/cm and 14,925 µS/cm.

Of the local groundwater, MB05, MB07 and MB10 have EC that is less than 7,463 µS/cm, with the maximum of 5,890 µS/cm; MB04 and MB09 are mostly between 7,463 µS/cm and 14,925 µS/cm. Groundwater at MB12 is greater than 14,925 µS/cm.

At the Saraji Mine, adjacent to the Project area, the regional (Tertiary and Permian) groundwater was generally not considered suitable for livestock (AECOM, 2016). **hydrogeologist.com.au** concurs with this interpretation but notes that, although the local groundwater is generally not considered suitable for livestock, limited livestock watering may occur and therefore should be recognised as an EV because of the three monitoring bores that returned EC less than 7,463 µS/cm.

Primary recreation

This category of EV is considered not applicable to local groundwater. There are no groundwater springs in the Project area (Section 5.6.2) that could be considered for recreational use. This EV is more common for surface water features that are readily accessible for recreation.

Drinking water suitability

The site-specific groundwater quality data, as presented in Section 5.7.1, indicates that groundwater is generally unsuitable for human consumption before treatment primarily due to elevated levels of salinity. The WQO in Table 4 of the Isaac River Sub-basin Environmental Values and Water Quality Objectives (2011) specifies an EC of 400 µS/cm as suitable for drinking quality and none of the site monitoring bores yield groundwater of such low EC. All reported field ECs are greater than 2,700 µS/cm and the median field EC for all local samples (Table 5-11) is 5,752 µS/cm, 14 times higher than specified by Isaac River Sub-basin Environmental Values and Water Quality Objectives (2011).

Table 4 of the Isaac River Sub-basin Environmental Values and Water Quality Objectives (2011) also refers to a sodium objective of 30 mg/L and a total hardness objective of 150 mg/L as $CaCO_3$ in raw water. The local groundwater contains both sodium and total hardness well in excess of such objectives. The minimum concentration of sodium in any of the groundwater samples to date is 389 mg/L, and the minimum concentration of total hardness is 242 mg/L.

Groundwater within the Project area is therefore not considered suitable for drinking because it would require significant treatment.

Cultural and spiritual values

There are no groundwater springs or seeps (Section 5.6.2) that supply surface water bodies in the Project area known to have significant indigenous and/or non-indigenous cultural heritage associations.

Industrial Use

Table 3 of the Isaac River Sub-basin Environmental Values and Water Quality Objectives (Department of Environment and Heritage Protection, 2011) provides no defined WQOs for industrial uses:

"Water quality requirements for industry vary within and between industries. The AWQG do not provide guidelines to protect industries, and indicate that industrial water quality requirements need to be considered on a case-by-case basis. This EV is usually protected by other values, such as the aquatic ecosystem EV".

The nearest industries to the Project area are coal mines. **hydrogeologist.com.au** understands that Vitrinite may intend to use some of the groundwater inflow to the proposed pit, if available after evaporation, for industrial purposes as inflows will be captured within the on-site water management system. This brackish to highly saline groundwater may be used for dust suppression during mining activities. No industrial users, other than mines, appear to be within close proximity of the Project area and the salinity of the groundwater would likely impede most industrial uses. It is the view of **hydrogeologist.com.au**, therefore, that the EV associated with industrial use should be recognised in this report.

Summary

In summary, the evaluation of groundwater EV in the Project area indicates that groundwater in the Tertiary regolith and/or Permian coal measures is of no, or limited value, for most uses and may potentially have the following EVs:

- livestock beef cattle watering (limited); and
- industrial purposes, limited to dust suppression in mining.

5.7.3. Water quality objectives

The Project area is adjacent to the Isaac-Dawson groundwater quality zone (No. 34) of Raymond and McNeil (2011). Groundwater within Zone 34 is described as slightly to moderately saline ('shallow' groundwater, within 30 mbgl) or slightly to very saline ('deep' groundwater, deeper than 30 mbgl). Groundwater within Zone 34, both shallow and deep, is of sodium-chloride (Na-Cl) type; that is, sodium is the dominant cation and chloride is the dominant anion.

WQOs have been developed to maintain or improve the quality of groundwater within the zone, i.e., maintain or reduce salinity. The percentile statistics provided in the WQOs are broad and it is expected by **hydrogeologist.com.au** that local groundwater within the Project area would naturally differ somewhat from the percentiles provided for the entire Zone 34. The statistics and percentiles presented in the WQOs provide a general indication of expected groundwater quality and are not to be used as triggers or exceedance criteria.

The WQOs for Zone 34 (Table 14 - Fitzroy groundwater: water quality objectives (aquatic ecosystem) according to water chemistry zones), provides the following EC percentiles for deep groundwaters in Zone 34:

- 20th percentile:3,419 µS/cm EC;
- 50th percentile or median: 6,100 µS/cm EC; and
- 80th percentile: 16,000 µS/cm.

Table 5-13 lists the statistics for Zone 34 (deep) for EC and other analytes. The data for Zone 34 (deep) are compared with the median of all data (maximum of 95 counts, from 17 rounds and up to seven bores in each round). Although the EC for these bores spans a wide range, the median for EC, 5,575 µS/ cm, is below the 50th percentile statistics provided for Zone 34 (deep), 6,100 µS/cm.

Of the major constituents and physical measures, the median of local monitoring data compares well with the Zone 34 statistics for Ca; while total hardness, observed alkalinity, Mg, SO_4 and HCO_3 are in excess of the 50th percentile statistics provided for Zone 34. The observed median lab pH, Cl, Na and SAR are below those of the Zone 34 statistics.

Of the minor constituents, the median of local monitoring data is below the Zone 34 statistics for observed silicon (as SiO_2). The results for dissolved metals (Cu, Fe, and Zn) are probably unduly affected (biased towards the small values) by the large proportion of less than detectable results (for the purposes of Table 5-13, a value equivalent of less than the detectable limit was ignored).

Table 5-13 Zone 34 deep percentiles and medians of preliminary local monitoring data

Analyte	Unit	20th	50th	80th	Median of local monitoring data*	Comments
EC	(µS/cm)	3,419	6,100	16,000	5,575	Lab EC excluding the initial results for June 2019# for MB04 and MB09
pH		7.4	7.8	8.03	7.60	Lab pH excluding the initial results for June 2019# for MB04 and MB09
SO_4	(mg/L)	25	138	398	560	
Fe	(mg/L)	0	0.05	0.246	0.64	As dissolved Fe, influenced by large number of less than detectable, <0.05 results

Note: **From 18 preliminary monitoring rounds*

 # As per Table 5-11, these values are considered anomalous.

5.8. Conceptual model

The southwest to northeast conceptual hydrogeological cross-section of **hydrogeologist.com.au** is presented in Figure 5-4. This conceptual cross-section is based on the review of various reports, data and information, as summarised in Sections 3 to 5.7 of this report.

The hydrogeological units shown in Figure 5-4 are as follows:

- Tertiary sediments / weathered zone / regolith (extensive, generally between 1 m to 30 m);
- Fort Cooper Coal Measures – Permian overburden;
- Moranbah Coal Measures – Permian overburden;
- DL coal seam (extracted at Saraji Mine);
- Moranbah Coal Measures – Permian interburden;
- DLL coal seam (extracted at VCM);
- Back Creek Group – Permian interburden;
- MAT coal seam (proposed to be extracted at the matilda pit); and
- Back Creek Group – Permian underburden.

The west to east section in Figure 5-4 is sub-parallel to the lateral groundwater flow direction (Section 5.4.4). The groundwater table is hosted by several units, from the outcropping/sub-cropping Back Creek Group in the west through the Tertiary sediments and Moranbah Coal Measures to the Fort Cooper Coal Measures in the east. As a result of the sloping groundwater table and the easterly dip of the hydrogeological units, some of the units may be partially unsaturated, particularly in the west, as is shown in Figure 5-4.

A minor component of rainfall recharge (Section 5.4) acts on the top of the land surface. Evapotranspiration occurs from groundwater that is situated within the extinction zone above the deeper groundwater table. Significant evaporation (Figure 5-9) is only likely to occur from the proposed and existing nearby mine pits. There is no interaction between surface and groundwater within and surrounding the Project area.

The western boundary in Figure 5-4 is a catchment and groundwater divide in the Harrow Range. The eastern, regional conceptual model boundary adopted is the Jellinbah Fault Zone, which is a north-west trending zone with several easterly dipping thrust faults with throws in the order of 100 m to 500 m (URS, 2012).

As can been seen from Figure 5-4, the DLL coal seam at the VCM and the DL coal seam at the Saraji Mine, have been depressurised and dewatered. Because of the low hydraulic conductivity and the low storage of the units within the Moranbah Coal Measures, the cones of depression surrounding the mines are expected to be deep (to pit depth) but laterally limited.

Once mining, depressurisation and dewatering cease, groundwater will start to recover and eventually will reach steady state in the backfilled material within the former pit. The recovery processes will largely be driven by the boundary conditions discussed above and the hydraulic parameters discussed in Section 5.3.

6. Impact assessment

6.1. Summary of numerical modelling

6.1.1. Objectives

The conceptual model presented in Section 5.8 has been used as the basis to develop a numerical groundwater flow model. This process, including model build, calibration and predictions is summarised in this section.

The objectives of the numerical model are to assess the quantitative impacts of the Project both in terms of drawdown and groundwater fluxes. Due to the existence of numerous coal mines, especially Saraji Mine within close vicinity of the Project, groundwater impacts will need to be quantified with respect to the Project only and cumulatively.

6.1.2. Design

The numerical groundwater flow model was originally developed to support the EA application for the Vulcan Coal Mine. The full model development and calibration has been previously presented and is summarised below.

The MODFLOW-USG (Panday *et al.*, 2015) code, based on the U.S. Geological Survey MODFLOW-2005 groundwater modelling code, was used. MODFLOW-USG simulates groundwater flow using a finite-difference approach and allows non-orthogonally structured grids to be used for groundwater flow simulations (Panday *et al.*, 2013). Model calibration and parameter sensitivity analysis was undertaken using Model-Independent Parameter Estimation and Uncertainty Analysis (or PEST, Doherty, 2019a and 2019b) and BEOPEST (or efficient parallel run management version of PEST, Doherty, 2012).

The model domain consists of a maximum of 22,492 cells per layer extending over a total area of 650 km^2. The area of individual cells varies between 5,000 m^2 and 911,000 m^2. In general, this area is small for cells close to the proposed pit (50 m x 100 m), existing mines (150 m x 250 m) and main surface water drainages; and is large towards the outer margins of the model (Figure 6-1). This is to improve the convergence and resolution of the numerical model in places with the most potential to present changes in groundwater drawdown and flux.

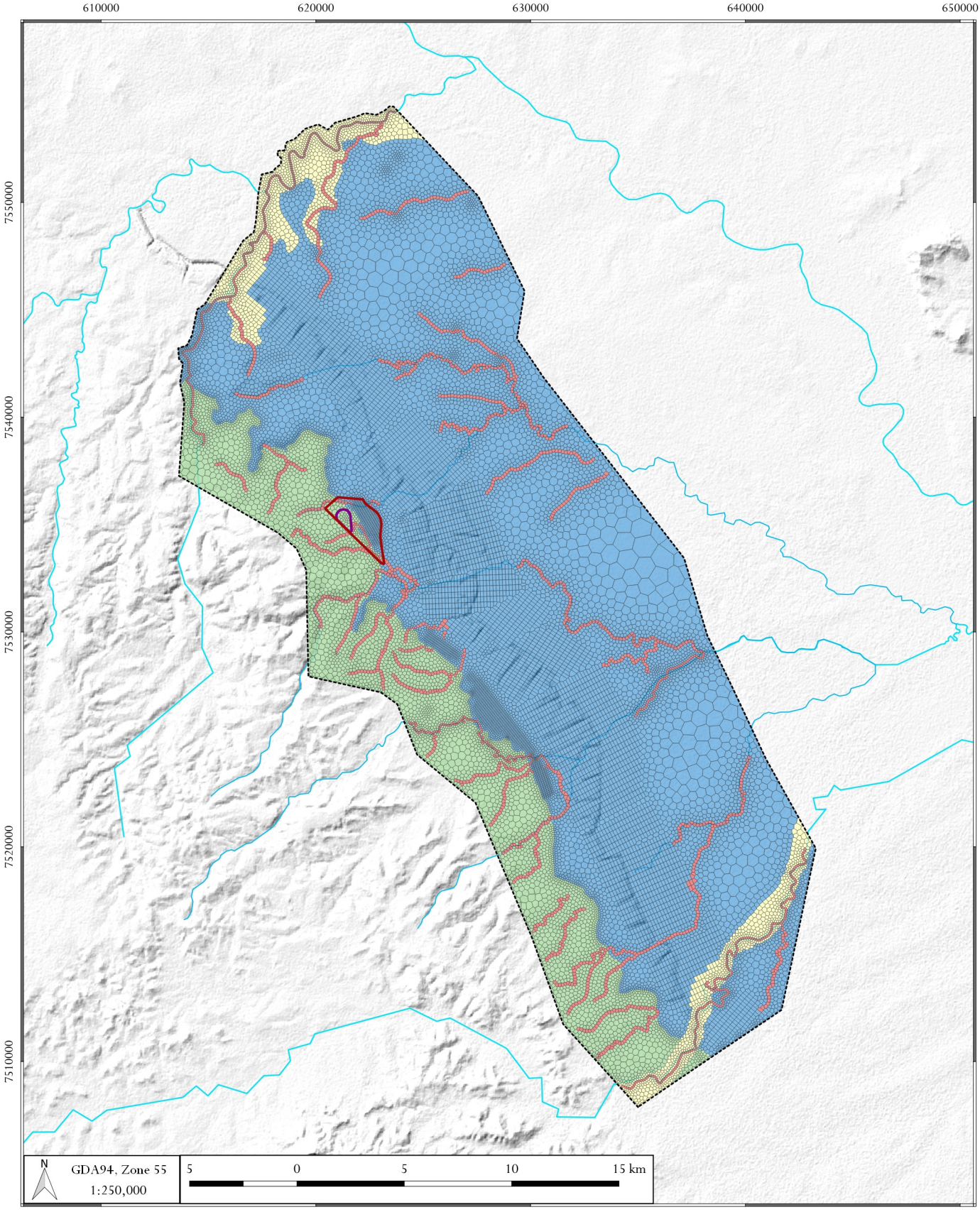
The temporal discretisation adopted consists of a pre-calibration steady state model leading into 48 year-long calibration period (1972 – 2019) and predictive (mining) period (Table 6-1).

Table 6-1 Temporal discretisation – calibration and predictive models

No. of stress periods	Stress period length	Dates	Modelling phase
Steady state	N/A	N/A	Pre-calibration
1 - 47	1 year	01/01/1972 – 31/12/2018	calibration
48 - 51	3 months	01/01/2019 – 31/12/2019	
52 - 55	3 months	01/01/2020 – 31/12/2020	prediction - mining
56 – 78	6 months	01/01/2021 – 30/06/2032	

The boundary conditions selected for the model are based on the description of the hydrogeology (Section 5, the numbers refer to Figure 6-2):

1. NW no-flow boundary (parallel to regional groundwater flow (Section 5.4.4) system in the north-west;
2. Jellinbah Fault Zone boundary;
3. SE no-flow boundary (parallel to regional groundwater flow (Section 5.4.4) system in the and south-east; and
4. SW no-flow boundary.



LEGEND

- ML700060
- Matilda pit
- Watercourse

Recharge zones

- 1 - Regolith
- 2 - Alluvium
- 3 - above DLL outcrop
- 4 - River cell

DATE
21/06/2022

hydrogeologist.com.au

Vulcan Coal Mine EA amendment - Groundwater Impact Assessment (4124)

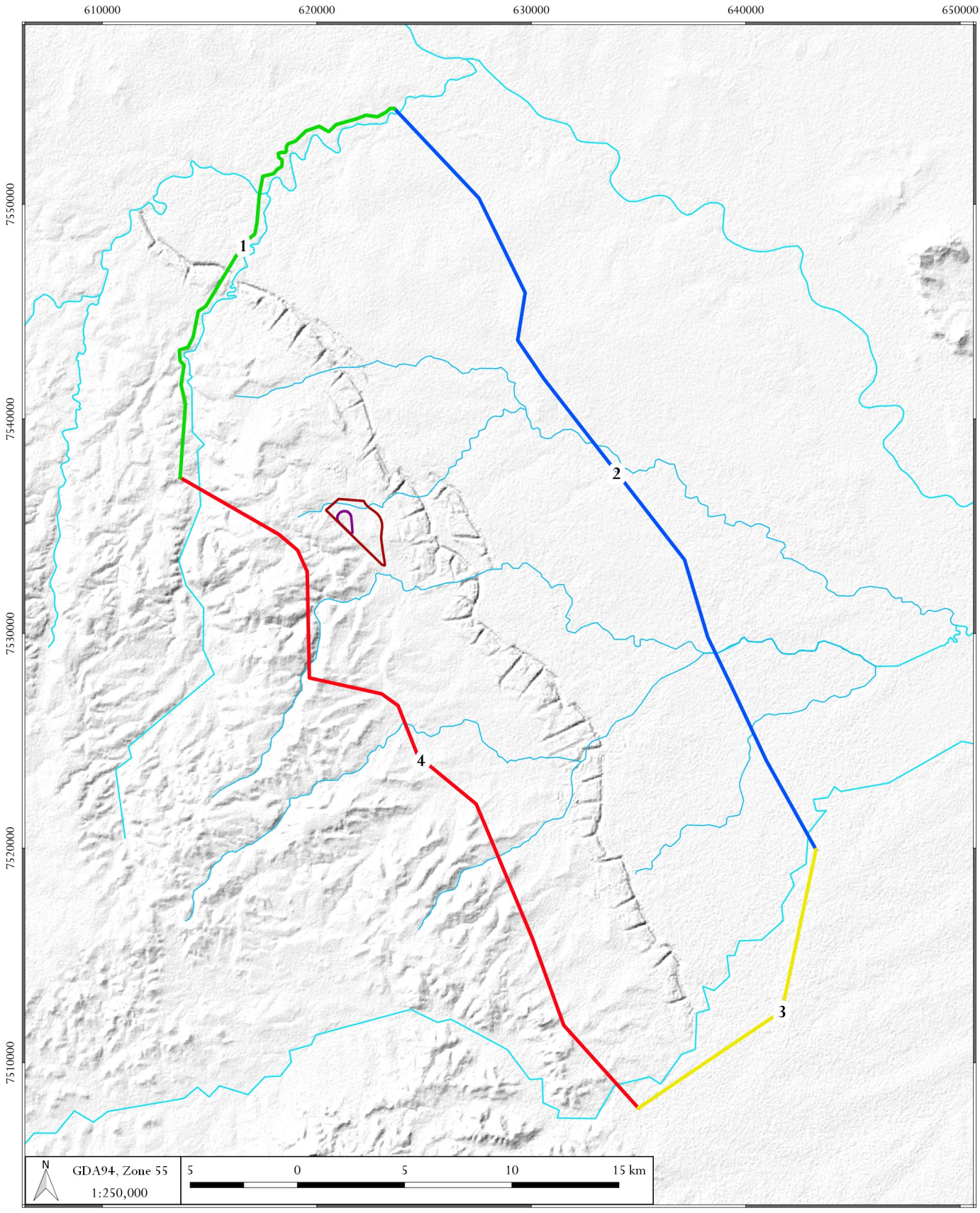
Model mesh and recharge zones

FIGURE No.
6.1

©2022 Oasis Hydrogeology Pty Ltd - trading as hydrogeologist.com.au

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.

Z:\4000_Projects\4124_Metserve_Matilda Pit\3_GIS\3_11_Workspaces_QGIS\06_01_4124_Matilda_Vulcan South_Model mesh_recharge zones.qgz



LEGEND

- ML700060
- Matilda pit
- Watercourse

Model boundaries

- 1 - NW no-flow boundary
- 2 - Jellinbah Fault Zone boundary
- 3 - SE no-flow boundary
- 4 - SW no-flow boundary

DATE
21/06/2022

hydrogeologist.com.au

Vulcan Coal Mine EA amendment - Groundwater Impact Assessment (4124)

Boundaries of the model domain

FIGURE No.
6.2

©2022 Oasis Hydrogeology Pty Ltd - trading as hydrogeologist.com.au
Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.
Z:\4000_Projects\4124_Metserve_Matilda Pit\3_GIS\3_11_Workspaces_QGIS\06_02_4124_Matilda_Vulcan South_Model domain boundaries.qgz

The hydro-stratigraphic units (Section 5.8) are represented by a total of eleven layers (Table 6-2), from discrete and isolated zones of Quaternary alluvium through to the lowermost and extensive Permian Back Creek Group. Several hydro-stratigraphic units (Fort Cooper Coal Measures and overburden, and the Moranbah Coal Measures interburden between the DL and DLL coal seams) are represented by two (split) layers to improve model convergence.

Key model layers for this assessment include layer 2 (Tertiary sediments) and layer 11 (representing mining from the Matilda pit). Model layer 7 represents the DL coal seam which is mined at Saraji Mine and model layer 10 (DLL coal seam) represents mining from the approved VCM pit.

Table 6-2 Model layering

Hydro-stratigraphic unit	Model layer
Quaternary alluvium	1
Tertiary sediments / weathered Zone / regolith	2
Fort Cooper Coal Measures	3
	4
Moranbah Coal Measures overburden	5
	6
DL coal seam	7
Moranbah Coal Measures interburden	8
	9
DLL coal seam	10
Back Creek Group	11

Surface water

Surface watercourses are represented by the MODFLOW-USG river (RIV) package. If the head (groundwater elevation) in the cell connected to the river drops below the bottom of the river bed, water enters the groundwater system from the river at a constant rate. If the head is above the bottom of the river, water will either leave or enter the groundwater system depending on whether the head is above or below the head in the river. The calculated water flux is proportional to the difference between the groundwater and river heads.

Recharge/discharge

Groundwater recharge from rainfall was applied to the uppermost saturated model layer as a percentage of rainfall. Zonation was applied to the modelled recharge to represent the following key areas (Figure 6-1, numbers correspond to the recharge zones) or systems:

1. regolith (east of DLL subcrop);
2. Quaternary alluvium (associated with major creeks);
3. regolith (west of DLL subcrop); and
4. river cells.

Recharge to the steady state model was applied as a percentage of the annual average rainfall from the SILO data (Section 3.1, 582 mm/yr). Recharge for the transient calibration period of 1972-2019 (Table 6-1) was applied as a percentage of actual rainfall data (SILO data) accumulated over the stress period[1]. Recharge for the predictive model was applied as a percentage based on long-term (1900-2018) averages (SILO data) for the stress period length. Evapotranspiration was not explicitly modelled as it was incorporated into the rainfall recharge applied to the model.

[1] Stress periods are used to define time intervals during which the inputs for the model remain constant.

Initial hydraulic parameters

The initial hydraulic parameters (starting values, upper bound and lower bound) were based upon the values derived from existing reports, site specific data and a general knowledge and experience in the region. These values were applied on a trial and error basis initially to inform the general behaviour of the model, then applied using PEST to develop the calibrated solution.

Drains

Mining (both historical and proposed) was simulated using the drain (DRN) package. Site specific information on the Project enabled an accurate representation of mine progression in accordance with the proposed mining schedule. The drains were applied to the Tertiary sediments (layer 2) and the MAT seam (layer 11) in the Matilda pit area.

For the representation of the Saraji Mine, historical mine development was captured in five yearly images downloaded from Landsat then digitised. The general extent of mining was then formulated into an annual sequence to approximate historical mine progression. The DRN cells were generally applied to the base of the DL coal seam (layer 7) for Saraji Mine. For the approved VCM, drains were applied to the DLL coal seam (layer 10).

6.1.3. Transient calibration

The numerical model includes a steady-state and a transient calibration (1972 to 2019). The transient calibration captures historical development at Saraji Mine and Peak Downs Mine which was based upon an interpolated mine progression assessed from Landsat imagery.

In accordance with the Australian groundwater modelling guidelines (Barnett *et al.*, 2012), the objective of a model calibration is to replicate the groundwater levels measured in the site monitoring network and other bores. A set of 55 selected observation points (and a total of 176 observations) were used in the calibration process, some with single values and some with time-series observations. The observation points included historical observation data from mining investigations (AECOM, 2016), publicly available sources (AECOM, 2016; Department of Natural Resources, Mines and Energy, 2019), and on-site data collected from open drill-holes and data collected from the new monitoring bores (**hydrogeologist.com.au**, 2019).

A scatter diagram of observed vs. modelled groundwater elevations (Figure 6-3) indicates that most points are situated close to the 1:1 line (perfect fit). While outliers do exist, most of the observations are within ±5 m of the 1:1 line. It is important to note that no significant or obvious trends or systematic departures appear to occur from the 1:1 line (the various colours representing different hydrogeological units scatter around the 1:1 line in a generally random pattern).

An overall (all observations and all time steps) transient calibration was achieved with an RMS (root mean square error) of 3.6 m and an SRMS (scaled root mean square error) of 4%. The SRMS value of 4% (3.6 m / 90.5 m=0.04 or 4%) indicates a good fit between measured and modelled data. Notwithstanding that, other criteria (such as good correlation between measured and modelled hydrographs and contour maps) also apply, an SRMS that is less than 10% may be acceptable (Barnett *et al.*, 2012) while an SRMS < 5% represents generally good calibration in the experience of **hydrogeologist.com.au**.

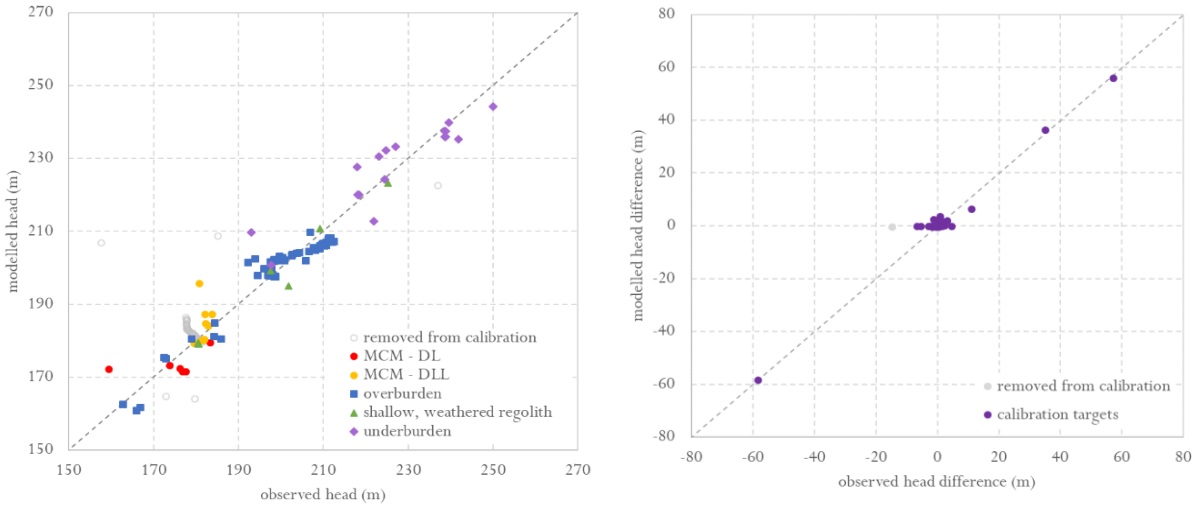


Figure 6-3 Model calibration scatter diagrams – observed and modelled heads and head differences

6.2. Predictions

The model predictions presented below are based upon 'mine' vs 'no mine' model scenarios to determine the true impact of the Project on the groundwater system. The 'mine' scenario simulates the Project (Matilda pit) along with the approved Vulcan Coal Mine, Saraji Mine and Peak Downs Mine; the 'no mine' scenario simulates the approved Vulcan Coal Mine, Saraji Mine and Peak Downs Mine only. The differences in drawdown and fluxes, between the 'mine' and 'no mine' scenarios, represent the impact of the Project on the groundwater system.

6.2.1. Mine inflows

Figure 6-4 shows the predicted inflow to the proposed Matilda pit. The prediction shows a maximum inflow of less than 3 m^3/d occurring in Year 1 (or 2023) of mining and gradually reducing thereafter.

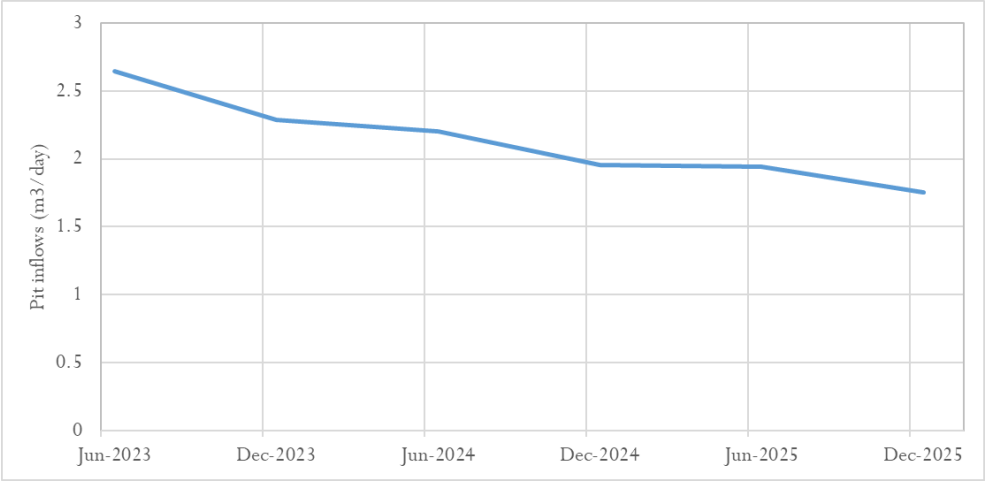


Figure 6-4 Predicted mine inflow rates

Table 6-3 summarises the predicted inflows rates and volumes for the proposed Matilda pit. The rate of inflow to the Matilda pit is consistent with Figure 6-4 and shows that the maximum inflow is less than 3 m^3/d occurring in Year 1 (or 2023) of mining. The maximum annual volume of predicted inflow to the Matilda pit is less than 1 ML/yr.

Table 6-3 Numerical model – zone budget – predicted inflow rates for the Project

SP	days	SP end	DRN inflow (m^3/day)	Volume (ML/year)
60	181	30/06/2023	2.648	0.900
61	184	31/12/2023	2.288	
62	182	30/06/2024	2.201	0.760
63	184	31/12/2024	1.952	
64	181	30/06/2025	1.945	0.675
65	184	31/12/2025	1.756	

Overall, the predicted groundwater seepage to the proposed pit is very low and will very likely be lost through evaporation on the pit face or as entrained moisture within the mined coal. Hence, seepage to the pit is very unlikely to be observed during the Project.

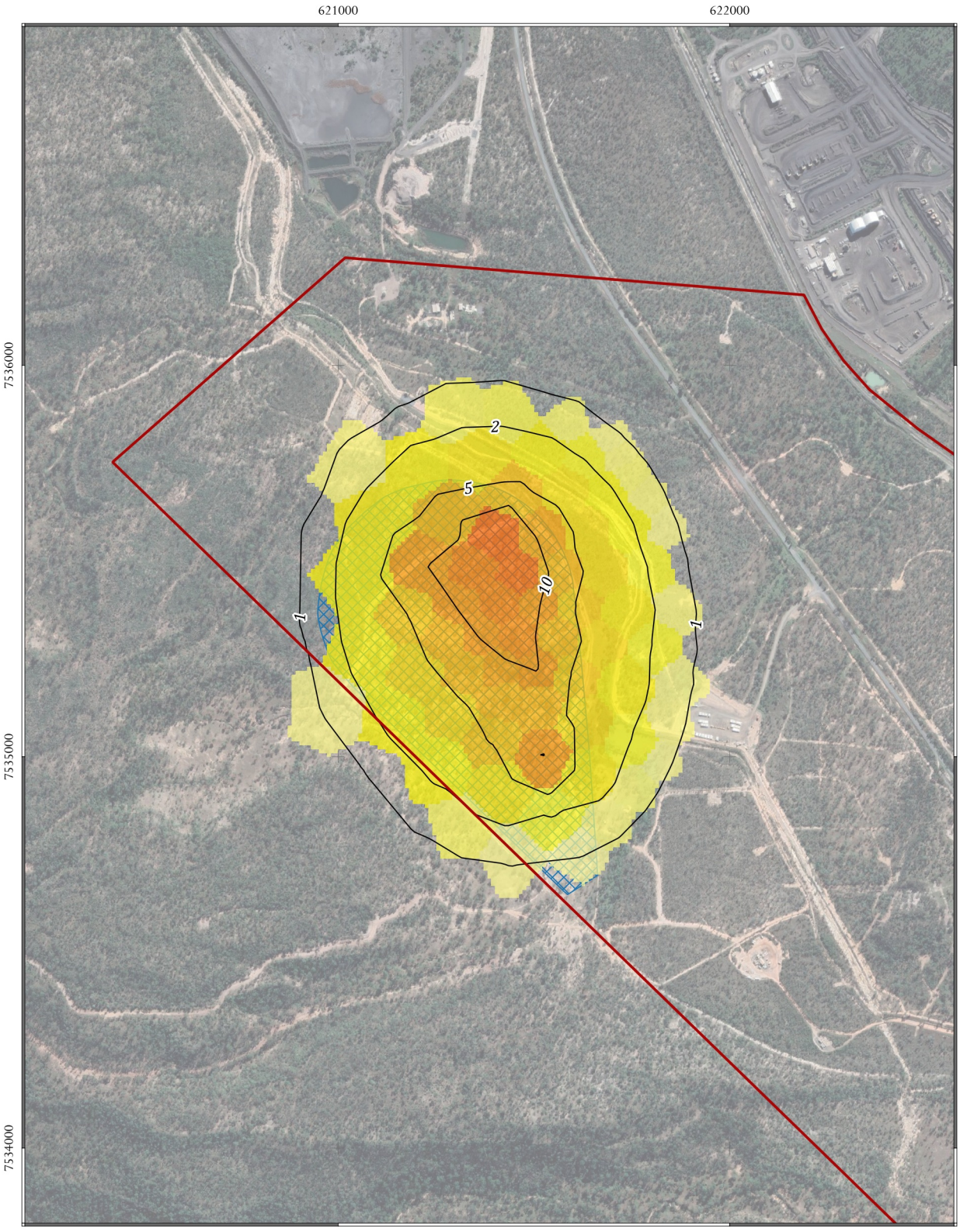
6.2.2. Drawdown

There is no predicted drawdown in the Tertiary / weathered zone (layer 2) as this layer is already dewatered in the 'no mine' scenario.

The predicted drawdown in the MAT seam (layer 11) is shown in Figure 6-5. The figure shows the maximum predicted drawdown throughout the model simulation. The drawdown represents the Project only drawdown and does not include the impacts of Saraji Mine, Peak Downs Mine, or the approved VCM pit.

The maximum predicted drawdown in layer 11 is less than 20 m in the vicinity of the proposed pit. The 1 m drawdown extent reaches up to 300 m from the proposed pit crest, indicating drawdown is very limited.

The proposed pit is to be backfilled following mining and therefore no residual drawdown is expected to occur post closure. There may be some minor change to the local groundwater elevations and flow directions post closure, however these are expected to the negligible and will not result in impact to the groundwater regime.



N

GDA94, Zone 55

1:15,000

0.5 0 0.5 km

LEGEND

- ML700060
- Matilda pit
- 1
- 2
- 5
- 10

DATE
05/08/2022

hydrogeologist .com.au

Vulcan Complex Project - Groundwater Impact Assessment (4124)

Predicted drawdown in MAT coal seam (L11)

FIGURE No.
6.5

©2022 Oasis Hydrogeology Pty Ltd - trading as hydrogeologist.com.au

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.

Z:\4000_Projects\4124_Metserve_Matilda Pit\3_GIS\3_11_Workspaces_QGIS\4124_matilda_sensitivity_max drawdown in L11.qgz

6.2.3. Sensitivity analysis

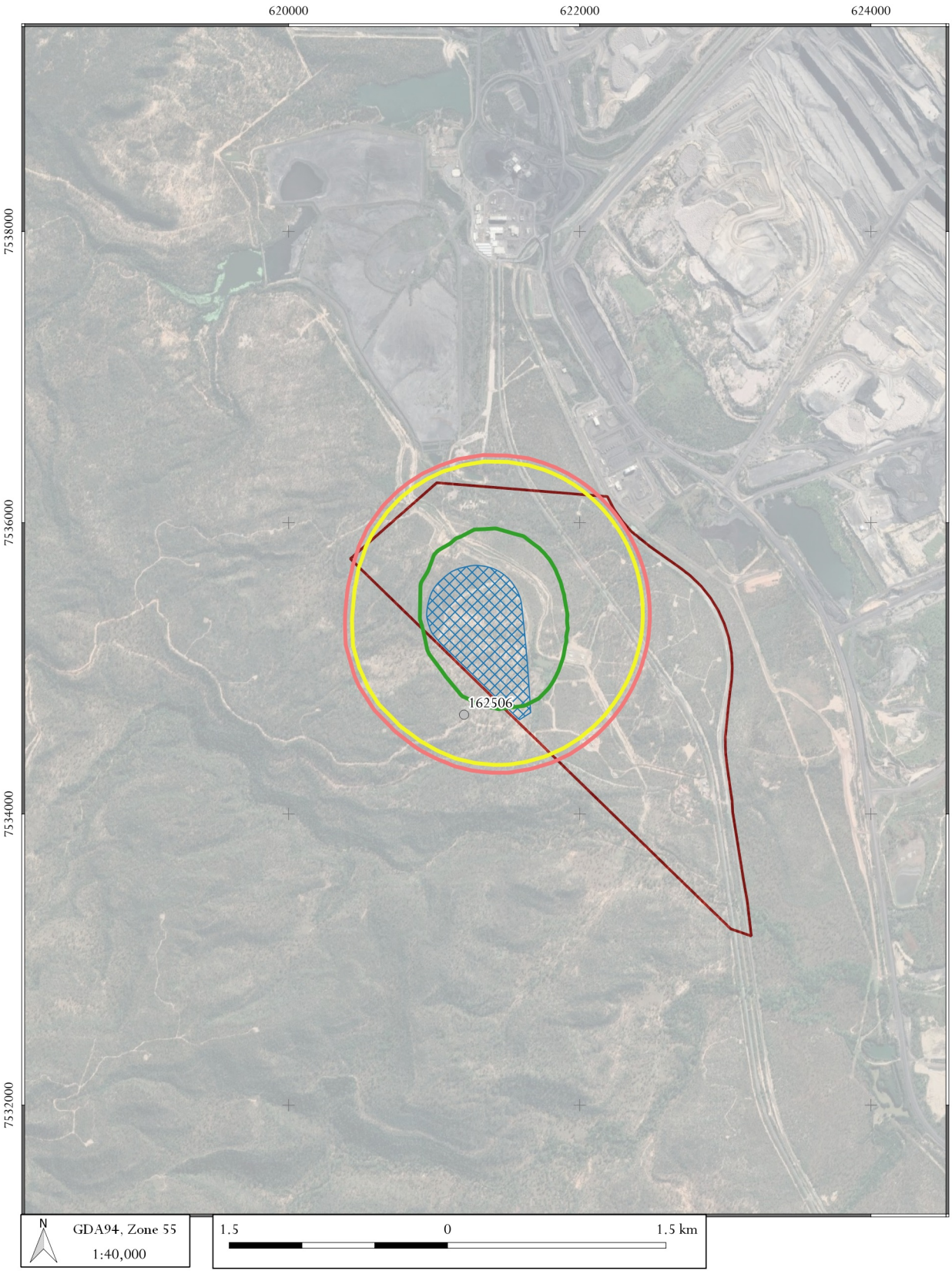
Sensitivity analysis was carried out to understand the possible change of inflows and drawdown from the model by adjusting some key model parameters of the Project. Two changes were considered:

1. the horizontal hydraulic conductivity of layer 11 was increased by one order of magnitude, denoted as the 'K+'; and,
2. the specific yield and specific storage of layer 11 was decrease by one order of magnitude, denoted as the 'S-'.

Both models were run using with the 'mine' and 'no mine' scenarios. The predicted pit inflows and drawdown were then processed and compared with the 'basecase' model (with calibrated parameters) to analyse the model sensitivity.

The maximum drawdown (represented by a 1 m contour) generated from the sensitivity analyses for the MAT coal seam (layer 11) are shown in Figure 6-6 along with the 'basecase' model predictions. The K+ and S- scenarios result in comparable maximum drawdown extents. The 1 m contour for the sensitivity analyses (Figure 6-6) predicts drawdown extending up to 800 m from the Matilda pit crest.

The K+ scenario shows a higher inflow with over 13 m^3/d at the beginning of mining (Figure 6-7), while the predicted inflow in the S- scenario is around half of that in the basecase scenario.



LEGEND

- ML700060
- Matilda pit
- 1 m maximum drawdown - basecase
- 1 m maximum drawdown - K+
- 1 m maximum drawdown - S-

DATE
05/08/2022

hydrogeologist.com.au

Vulcan Coal Mine EA amendment - Groundwater Impact Assessment (4124)

Sensitivity analysis – maximum drawdown (L11)

FIGURE No.
6.6

©2022 Oasis Hydrogeology Pty Ltd - trading as hydrogeologist.com.au
Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.
Z:\4000_Projects\4124_Metserve_Matilda Pit\3_GIS\3_11_Workspaces_QGIS\06_08_4124_matilda_sensitivity max drawdown in L11.qgz

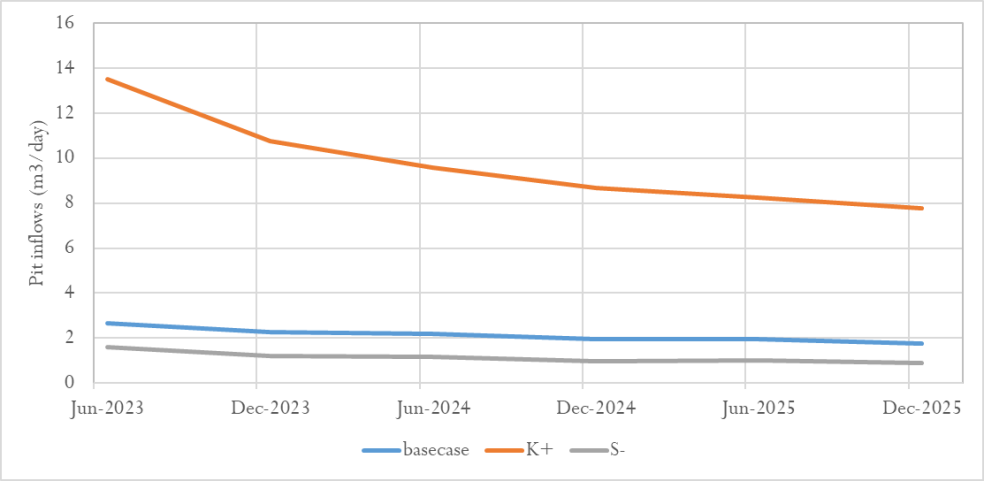


Figure 6-7 Sensitivity analyses - predicted mine inflow rates

6.3. Impacts on users

As Figure 6-5 indicates, the predicted extent of maximum drawdown in the MAT coal seam (layer 11) is limited. There are no third-party groundwater users within the predicted extent of drawdown, hence impacts on existing users are considered very unlikely. The nearest third party bore to the proposed pit is RN162506, at a distance of 100 m from the 1 m predicted drawdown contour line. However, the sensitivity analysis shows that RN 162506 falls within the 1 m extent of maximum probable drawdown (Figure 6-6) and could be impacted by the Project. Vitrinite should confirm the presence of RN 162506 with the landholder and this bore should be monitored for future impact (Section 7).

6.4. Impacts on surface drainage

In Section 5.4 (Figure 5-3), the mechanism of recharge from surface water systems in the Project area was presented. Further discussion of the surface – groundwater interaction followed in Section 5.5 and it was concluded that there was no significant surface-groundwater interaction in the Project area.

The predicted changes in modelled groundwater in- or out-flow from/to river (RIV) cells due to the Project only are generally less than 0.13 m^3/d (or 130 L/d) over the entire model domain and are therefore considered negligible. For these reasons impacts on surface waters are considered extremely unlikely.

6.5. Impacts on GDEs

Figure 6-8 shows the maximum predicted drawdown in layer 11 anytime during the modelling and the location of mapped aquatic GDEs. There are no mapped potential aquatic GDEs within the maximum predicted project drawdown.

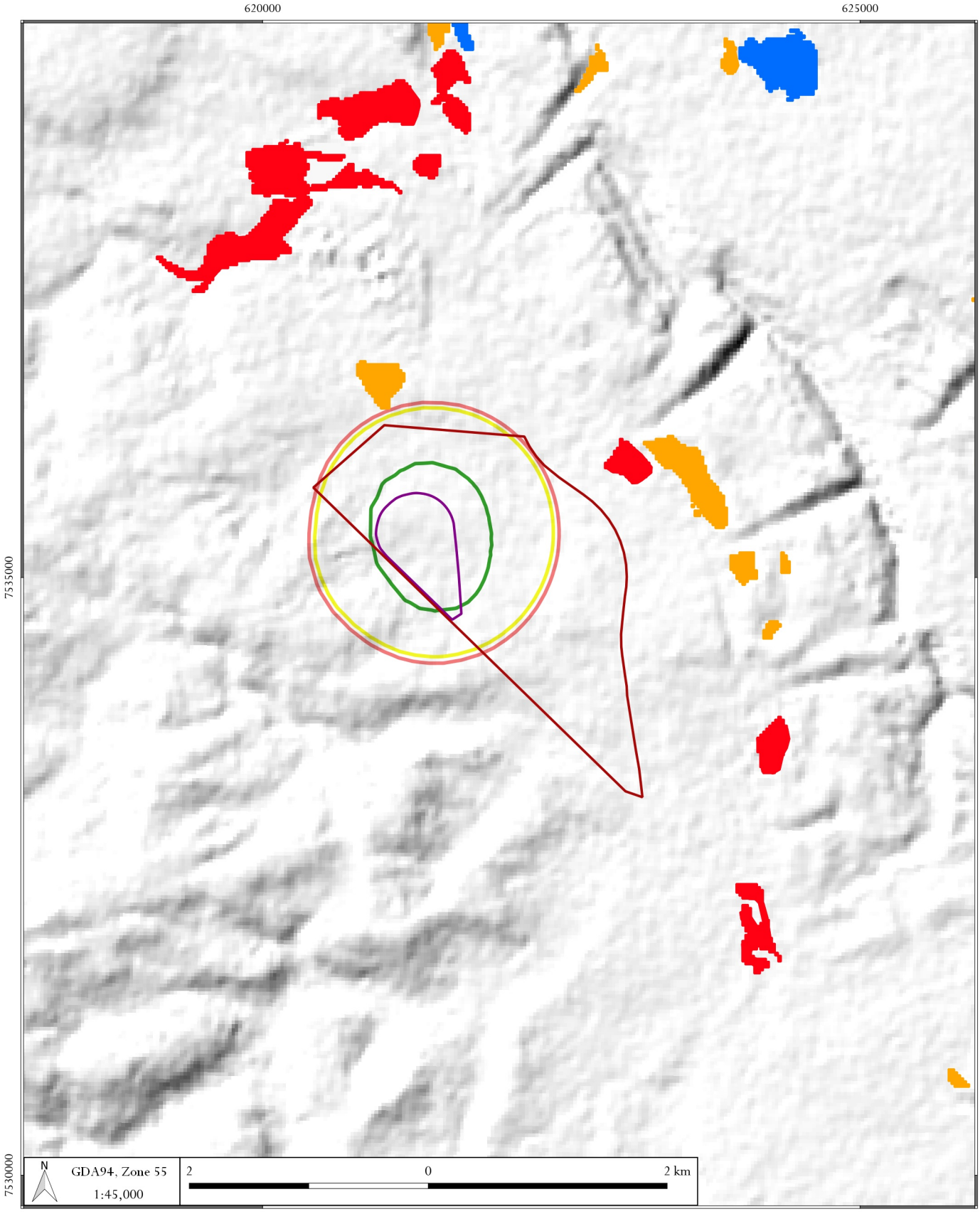
In Section 5.6.2, it was the interpretation of **hydrogeologist.com.au** that there were no valid aquatic GDEs within 3 km of the VCM. This is because aquatic GDEs with high or moderate potential for groundwater interaction are most likely to occur in areas where the seasonally high groundwater potentiometric heads are above or close to the corresponding surface water heads. This is necessary to maintain a hydraulic gradient from the groundwater to surface water, or at least have a hydraulically 'connected' system. Within or adjacent to the Project area, the surface water systems are above the groundwater table (see Section 5.5) and the surface water system is hydraulically disconnected from the groundwater system.

In addition, groundwater in the Project area is brackish to saline and therefore unsuitable for the maintenance of freshwater GDEs (see Section 5.7 for further information on groundwater quality). Further, aquatic GDEs associated with a number of separate wetlands along the Moranbah – Dysart Road, between Phillips Creek and Boomerang Creek, all appear to be manmade impoundments associated with Saraji Mine or pastoral properties.

Figure 6-9 shows maximum predicted drawdowns anytime during the modelling and the position of mapped terrestrial GDEs. Figure 6-9 indicates very small and insignificant overlaps between the drawdown affected areas and mapped terrestrial GDEs adjacent to the proposed Matilda pit.

As stated in Section 5.6.2, it is the experience of **hydrogeologist.com.au** that terrestrial GDEs with high or moderate potential for groundwater interaction are most likely to occur in areas where depth to groundwater is less than 10 m. Analysis of the depth to groundwater data surrounding the Project area identified that groundwater was typically recorded at levels deeper than 15 m (Figure 5-9) and likely to be outside of the accessible reach of Eucalypt vegetation. The nearest areas with depth to groundwater less than 10 m (red or orange colours that are not associated with the artefact of gridding near Saraji Mine) are approximately 3 km to the south-west of the proposed pits and even these areas are associated with aquatic features (Hughes Creek) not terrestrial ones.

For the reasons stated above, **hydrogeologist.com.au** interprets that there is no valid aquatic or terrestrial GDEs within the maximum drawdown zones and impacts on GDEs are considered highly unlikely. The reader is directed to the Vulcan Coal Mine – Ecological Impact Assessment report for further information regarding the presence of aquatic or terrestrial GDEs.



LEGEND

- ML700060
- Matilda pit
- 1 m maximum drawdown - basecase
- 1 m maximum drawdown - K+
- 1 m maximum drawdown - S-

Aquatic groundwater dependent ecosystem

- High potential GDE - from national assessment
- High potential GDE - from regional studies
- Moderate potential GDE - from national assessment
- Low potential GDE - from national assessment

DATE
05/08/2022

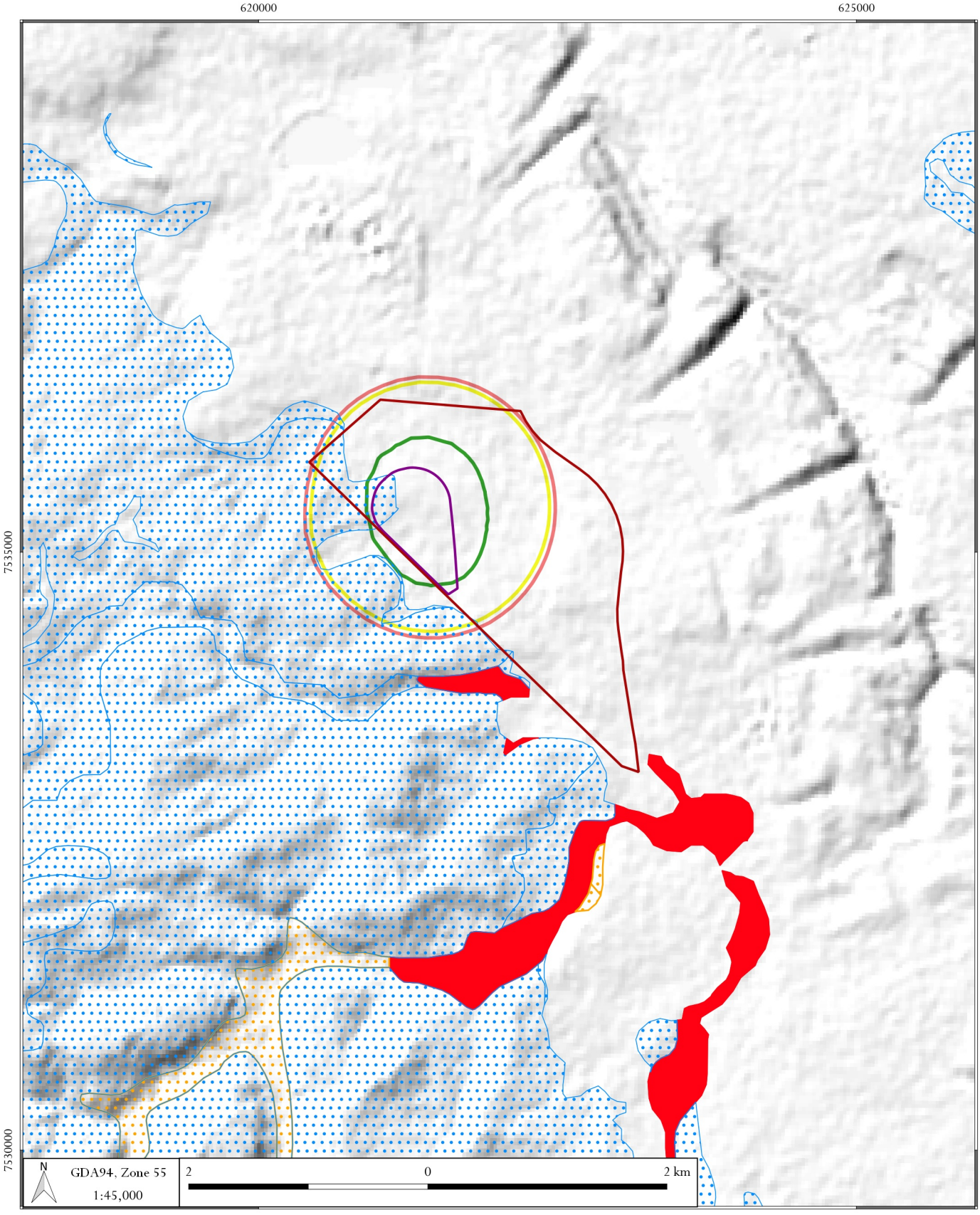
hydrogeologist.com.au

Vulcan Coal Mine EA amendment - Groundwater Impact Assessment (4124)

Maximum drawdown and aquatic GDEs

FIGURE No.
6.8

©2022 Oasis Hydrogeology Pty Ltd - trading as hydrogeologist.com.au
Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.
Z:\4000_Projects\4124_Metserve_Matilda Pit\3_GIS\3_11_Workspaces_QGIS\05_08_4124_Matilda_Vulcan South_Aquatic GDEs.qgz



LEGEND

- ML700060
- Matilda pit
- 1 m maximum drawdown - basecase
- 1 m maximum drawdown - K+
- 1 m maximum drawdown - S-

Terrestrial groundwater dependent ecosystem

- High potential GDE - from national assessment
- Moderate potential GDE - from national assessment
- Moderate potential GDE - from regional studies
- Low potential GDE - from national assessment

DATE
05/08/2022

hydrogeologist .com.au

Vulcan Coal Mine EA amendment - Groundwater Impact Assessment (4124)

Maximum drawdown and terrestrial GDEs

FIGURE No.
6.9

©2022 Oasis Hydrogeology Pty Ltd - trading as hydrogeologist.com.au

Source: 1 second SRTM Derived DEM-S - © Commonwealth of Australia (Geoscience Australia) 2011.; GEODATA TOPO 250K Series 3 - © Commonwealth of Australia (Geoscience Australia) 2006.
Z:\4000_Projects\4124_Metserve_Matilda Pit\3_GIS\3_11_Workspaces_QGIS\05_09_4124_Matilda_Vulcan South_Terrestrial GDEs.qgz

6.6. Impacts on groundwater quality

During mining, the proposed Matilda pit, VCM and the Saraji Mine pits will act as sinks for surrounding groundwater. Any local contamination of groundwater will report to the mine pit and be contained during operations. The ex-pit and in-pit waste rock emplacement areas will be progressively rehabilitated during mine development and therefore no final voids or evaporative sinks will remain in the Project area. Groundwater is predicted to recover towards the pre-mining groundwater levels, subject to mining plans that include the adjacent Saraji and Peak Downs Mines. It is assumed that the pit voids at Saraji Mine and Peak Downs Mine will likely remain into perpetuity and will behave as regional evaporative sinks on the groundwater system, hence minimising any eastward migration of potential contaminants.

The evaluation of groundwater EV in the Project area (Section 5.7.2) indicated that groundwater is of no, or limited value for most uses because of the high salinity. Local groundwater was found to be brackish to highly saline and even an unprecedented 50% increase in salinity would not impact on the beneficial uses identified (livestock beef cattle watering (limited); and industrial purposes, limited to dust suppression in mining). This is because the salinity of local groundwater is well in excess of the WQOs for aquatic ecosystems and drinking water suitability.

All mine infrastructure areas such as workshops, fuel and chemical storage areas will be developed in accordance with current Australian Standards, including adequate bunding and spill kits. These engineering and administrative controls will assist in preventing groundwater contamination. Impacts on groundwater quality, associated with local contamination from mine activities are considered highly unlikely.

6.7. Cumulative impacts

Cumulative impacts have been assessed by representing historical and proposed mining for Saraji Mine, Peak Downs Mine and VCM. The Saraji Mine and Peak Downs Mine have been active since the 1970s. The VCM has been in operation since 2021. The impacts of these approved mines (Saraji Mine, Peak Downs Mine and the VCM) have been predicted in isolation of the Project and in a cumulative sense through the development of the 'mine' vs 'no mine' model scenarios. For the purposes of this assessment, the cumulative impact on groundwater is represented in Figure 6-10.

The graph shows the long-term model predicted inflows (on a log scale) to the Saraji Mine and Peak Downs Mine with recent and proposed average annual inflow rates in the order of 3,000 m^3/day to 5,000 m^3/day. The proposed mining inflow rates at the Saraji Mine and Peak Downs Mine correlate with AECOM (2016). The model predicted inflows to the approved VCM are also shown in Figure 6-10 with predicted inflows between 0.9 m^3/day and 40 m^3/day. The minimal inflow rates predicted for the Project (maximum inflow rate of 2.65 m^3/d) represent less than a 0.1% increase in groundwater seepage within the model domain.

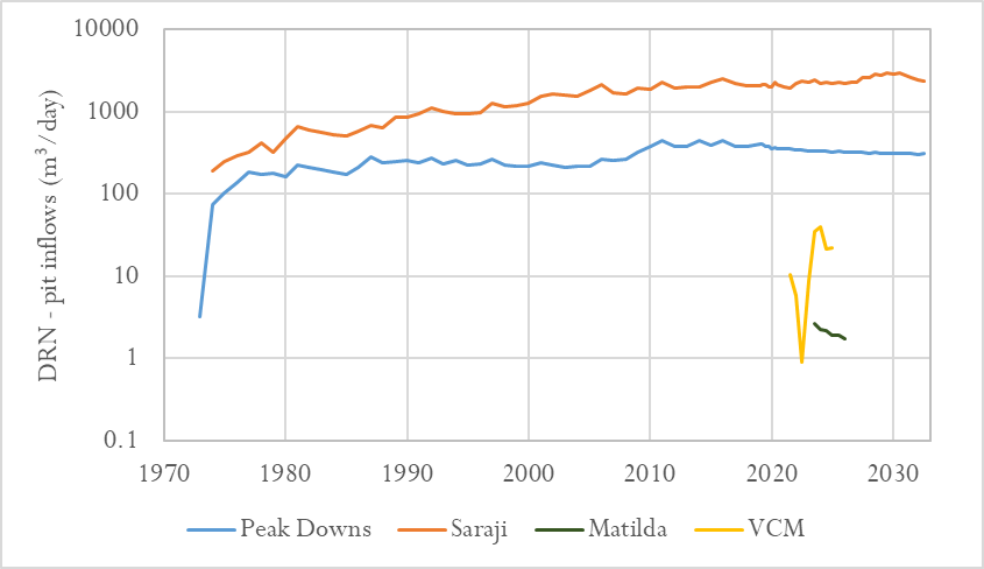


Figure 6-10 Predicted inflow rates – Saraji Mine, Peak Downs Mine and Matilda pit

7. Management and mitigation

7.1. Licensing

The proposed pit will intercept groundwater from Groundwater Unit 2 (sub-artesian aquifers) under the Water Plan (Fitzroy Basin) 2011. The predicted take of groundwater, based on the numerical model (Section 6.2.1) and the life of the Project, will involve allocation of up to 0.9 ML/year from Groundwater Unit 2. This annual inflow rate was calculated as the product of the maximum daily inflow, 2.65 m^3/d (Table 6-3) over an annual period.

The predicted take of groundwater for the approved VCM, involves up to 14.6 ML/year from Groundwater Unit 2 (based on the maximum predicted daily inflow of 40 m^3/d). Combined, the predicted take of groundwater from the VCM will be 15.5 ML/year from Groundwater Unit 2.

Post mining, there will be no requirement for a perpetual water licence as the pit will be progressively backfilled. No final void will remain in the Project area and therefore no evaporative sink will act on the groundwater regime. Groundwater is predicted to recover towards the pre-mining groundwater levels, subject to on-going mining that may occur at Saraji Mine and Peak Downs Mine.

7.2. Adaptive management strategy

The following section summarises the proposed framework for the on-going Groundwater Management Strategy to be developed to assist with the management and mitigation of drawdown and potential water quality impacts. An adaptive management strategy is proposed to assist with the management and mitigation of drawdown and potential water quality impacts. The framework of the adaptive management strategy includes the following components which will be defined in the EA.

7.2.1. Drawdown

The predicted drawdown resulting from the Project is shown in Figure 6-5 and Figure 6-6. Section 6.2.2 discusses and summarises the extent and magnitude of drawdown, and Section 6.2.3 through to Section 6.7 discuss the resulting impacts of this predicted drawdown on the surrounding environment.

The current groundwater monitoring network (Section 5.2) implemented at the VCM is considered fit for purpose for this assessment and will form the basis for ongoing drawdown monitoring and management through the life of the Project. The groundwater monitoring network may be regularly amended to ensure it remains representative of groundwater conditions and fit for purpose.

Monitoring of groundwater levels from the groundwater monitoring network will enable natural groundwater level fluctuations (such as responses to rainfall recharge) to be distinguished from potential groundwater level impacts (drawdown) due to dewatering/depressurisation resulting from proposed mining activities. Automatic data loggers are currently installed in the groundwater monitoring network and they will continue to be used to enable daily measurements. These data loggers should be downloaded regularly to coincide with groundwater quality sampling.

Some of the site-specific monitoring bores are situated adjacent to the predicted drawdown zone. Groundwater level data from all monitoring bores within the groundwater monitoring network will be assessed in a biennial comparison between actual and modelled drawdowns. This annual comparison and assessment will be completed in consideration of the DSITI (2017) guidelines for *using monitoring data to assess groundwater quality and potential environmental impacts*. This assessment will allow for verification of the numerical model predictions.

Private water supply bore RN 162506 is the nearest third party bore. The bore is located 100 m from the predicted extent of drawdown. Pending agreement to access the bore, quarterly groundwater level monitoring of this bore would provide benefit in understanding the regional behaviour of the groundwater regime in relation to mining. Any Project related impacts at RN 162506 would be mitigated through Make Good Provisions under the Water Act (see Section 2.1.1).

There is merit in a groundwater data sharing arrangement between Vitrinite and BHP. Routine groundwater level and quality monitoring from Saraji Mine and Peak Downs Mine would provide Vitrinite with a greater understanding of the hydrogeological system responses during mining.

Given the low pit inflow predictions, limited extent of drawdown and unlikely impacts on the groundwater regime, regular updates to the numerical model are not likely to be required. However, it will be important to compare and assess on a biennial basis the groundwater level observations against the modelled predictions to verify that observations are consistent with model outputs.

Every three years, consideration will be given for the redevelopment and or recalibration of the numerical groundwater model. Any such redevelopment or recalibration of the numerical groundwater model may require an iterative review of the conceptual hydrogeological model. This may result from measuring hydraulic responses that are inconsistent with the conceptual understanding or model predictions, changes to the mine plan, or modification of potential contamination sources.

The reporting obligations proposed as part of on-going Groundwater Management Strategy will be defined as conditions in the EA.

7.2.2. Groundwater quality

Groundwater quality monitoring and sampling of the groundwater monitoring network will continue in order to comply with EA conditions and to collect further information on the groundwater system. Groundwater quality parameters monitored at the VCM will continue to comply with the parameters specified in the EA. The monitoring and sampling will be carried out in consideration of DES (2018a).

Interim groundwater quality limits have been developed from site-specific data collected to date and are conditions in the EA. If site-specific data is not available, default guidelines have been implemented until data allows for site-specific limits to be developed. Following further data collection, current groundwater quality limits are required to be updated in April 2023 to better reflect the site-specific water quality at each monitoring bore conditioned in the EA.

7.3. Mitigation measures

No mitigation measures are currently proposed or required as part of the Project. There are no impacts predicted for third party groundwater users and surface water systems. Impacts to GDEs are considered highly unlikely as are impacts on groundwater quality and EV. Should monitoring and subsequent assessment determine potential impacts, mitigation strategies would be considered commensurate with the level and risk of environmental impact.

8. Conclusions

hydrogeologist.com.au has prepared a groundwater impact assessment to support the EA amendment for the Vulcan Coal Mine. The EA amendment involves the open cut mining of coal from the MAT coal seam of the Permian Back Creek Group from a single pit (the Matilda pit).

The main hydro-stratigraphic units occurring at the Project area include the Tertiary sediments or weathered zone (regolith) and the Permian coal measures. There is no Quaternary alluvium present within the Project area. The Permian MAT coal seam is partially / variably saturated over the Project area and the Matilda pit will intersect the regional groundwater table which has been historically depressurised by mining at Saraji Mine and Peak Downs Mine. A portion of mining will occur above the regional groundwater table.

Groundwater quality within the mined coal seam (and within other hydro-stratigraphic units) is generally brackish to saline and this is consistent with other mine sites in the region. The groundwater quality within the Project area has limited or no environmental value and potentially may be used for livestock beef cattle watering and / or industrial purposes (such as dust suppression for mining operations).

The groundwater quality is considered too saline to support aquatic GDEs and the depth to groundwater is considered too deep to support terrestrial GDEs. There are limited third party groundwater users in the region and Vitrinite has developed a clear understanding of where these third-party groundwater bores are located.

A numerical groundwater flow model has been modified to support the groundwater impact assessment and has been undertaken in accordance with relevant Australian guidelines. The model is assessed to be a reliable and acceptable simulator of historical mining activities and of groundwater level behaviour in and surrounding the Project area. Future predictions have been made by representing proposed mining at Saraji Mine and Peak Downs Mine, and the proposed mining schedule for the VCM.

The model predictions show limited pit inflows (less than 3 m^3/day) to the Matilda pit and it is likely that most of the predicted inflows would be lost through evaporation on the pit face or as entrained moisture within the mined coal. Hence, seepage to the pit is unlikely to be observed during the Project's life. The drawdown predicted from the Project is limited in extent (maximum up to 300 m) and magnitude (up to 20 m in the deepest part of the proposed pit).

The extent of predicted drawdown does not encroach on any of the third-party groundwater users in the region and therefore impacts in this regard are considered very unlikely. Impacts on surface waters and are considered very unlikely. It is the assessment of **hydrogeologist.com.au** that there is no recorded aquatic or terrestrial GDEs within the maximum drawdown zones and impacts on GDEs are considered very unlikely. Furthermore, impacts on groundwater quality are assessed to be very unlikely and there would need to be an unprecedented change in salinity to affect the current beneficial use and environmental values of the groundwater regime.

An adaptive management strategy is proposed for the Project to assist with the management and mitigation of drawdown and potential water quality impacts. The framework of the strategy includes iterative components which will be defined as conditions in the EA.

9. References

AECOM (2016). Groundwater Technical Report, Saraji Open Cut Extension Project prepared for BM Alliance Coal Operations Pty Ltd.

Arrow Energy (2012). 2012 Bowen Basin 2D Seismic Survey Report ATP1103 & ATP1031.

Arrow Energy (2016). Underground Water Impact Report for PL 191, 196, 223, 224 and Authority to Prospect 1103, 742, 831 and 1031. August 2016.

Arrow Energy (2019). Underground Water Impact Report for PL 191, 196, 223, 224 and Authority to Prospect 742, 1031 and 1103. 4 April 2019.

Australasian Groundwater and Environmental Consultants Pty Ltd, 2007. Report on Hydrogeological Regime and Impact Assessment Saraji Mine, Project No. G1387, December 2007

Australasian Groundwater and Environmental Consultants Pty Ltd, 2011. Report on Saraji East Project Groundwater Impact Assessment, Project No. G1549, December 2011

Australasian Groundwater and Environmental Consultants Pty Ltd, 2012a. Australian Groundwater & Environmental Consultants Memorandum – Predicted Inflows and Drawdown Extents – Saraji East Underground Mine, ref. G1549, dated 24 February 2012

Australian and New Zealand Guidelines for Fresh and Marine Water Quality (AWQG, October 2000), prepared by the Australian and New Zealand Environment and Conservation Council (ANZECC) and the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ).

Australian and New Zealand Guidelines for Fresh and Marine Water Quality (AWQG, 2018), prepared by the Australian and New Zealand Environment and Conservation Council (ANZECC) and the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ). https://www.waterquality.gov.au/guidelines/anz-fresh-marine

Barnett B, Townley LR, Post V, Evans RE, Hunt RJ, Peeters L, Richardson S, Werner AD, Knapton A and Boronkay A. (2012) Australian groundwater modelling guidelines, Waterlines report, National Water Commission, Canberra.

Bureau of Meteorology. 2016. "Australian Climate Averages - Climate Classifications." November 2016. http://www.bom.gov.au/jsp/ncc/climate_averages/climate-classifications/index.jsp.

CDM Smith (2013). Westside Corporation, Underground Water Impact Report ATP688. https://environment.des.qld.gov.au/management/non-mining/documents/westside-report

CSIRO (2002). Acarp Project C9021. Exploration and Mining Report 976c. Bowen Basin Supermodel 2000. Open report, August 2002, CSIRO Exploration and Mining Report.

Department of Environment and Heritage Protection (2009). Queensland Water Quality Guidelines, Version 3, ISBN 978-0-9806986-0-2.

Department of Environment and Heritage Protection (2011). Environmental Protection (Water) Policy 2009 Isaac River Sub-basin Environmental Values and Water Quality Objectives Basin No. 130 (part), including all waters of the Isaac River Sub-basin (including Connors River). September 2011.

Department of Environment and Science, (2016), "Guideline – Environmental protection Act 1994 – Requirement for site specific and amendment applications – underground water rights", ESR/2016/3275, Version 1.00, Effective: 06 Dec 2016.

Department of Environment and Science (2017). Guideline. Environmental Protection (Water) Policy 2009. Model mining conditions, March 2017, version 6.02.

Department of Environment and Science (2018a). Environmental Protection (Water) Policy 2009. Monitoring and Sampling Manual, June 2018, version 2.

Department of Environment and Science (2022). Guideline. Environmental Protection (Water) Policy 2009. Deciding aquatic ecosystem indicators and local water quality guidelines, December 2018.

Department of Science, Information Technology and Innovation (DSITI) (2017). Using monitoring data to assess groundwater quality and potential environmental impacts. Version 1. Queensland Government, Brisbane. March 2017.

Doherty, J., 2012. Windows BEOPEST.

Doherty, J., 2019a. Groundwater Data Utilities; Part C: Programs Written for Unstructured Grid Models.

Doherty, J., 2019b. PEST - Model-Independent Parameter Estimation; user manual Part I: PEST, SENSAN and Global Optimisers.

Doherty, J., 2019c. PEST - Model-Independent Parameter Estimation; User manual Part II: PEST Utility Support Software.

Geoscience Australia (2019). Bowen Basin https://www.ga.gov.au/scientific-topics/energy/province-sedimentary-basin-geology/petroleum/onshore-australia/bowen-basin visited on 1 August 2019.

Hvorslev, M.J., 1951, Time lag and soil permeability in ground water observations, U.S. Army Corps of Engineers Waterway Experimentation Station, Bulletin 36.

hydrogeologist.com.au (2019). Hydrogeological Drilling Report – Vulcan Complex Project. Prepared for Vitrinite Pty Ltd.

hydrogeologist.com.au (2022). Groundwater Monitoring Plan – Vulcan Coal Mine – Vulcan Coal Mine. Prepared for Vitrinite Pty Ltd.

HydroSimulations (2018). Olive Downs Coking Coal Project Groundwater Assessment for Pembroke Olive Downs Pty Ltd

Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development, Information Guidelines for Independent Expert Scientific Committee advice on coal seam gas and large coal mining development proposals. http://www.iesc.environment.gov.au/system/files/pages/a55d4199-0218-4f91-a012-8613f62f9056/files/iesc-information-guidelines-consultation-draft.pdf

Jeffrey, Stephen J., John O. Carter, Keith B. Moodie, and Alan R. Beswick. 2001. "Using Spatial Interpolation to Construct a Comprehensive Archive of Australian Climate Data." Environmental Modelling & Software 16 (4): 309–30. https://doi.org/10.1016/S1364-8152(01)00008-1.

Mayer, XM, Ruprecht, JK & Bari, MA (2005). Stream salinity status and trends in south-west Western Australia, Department of Environment, Salinity and land use impacts series, Report No. SLUI 38.

Office of Groundwater Impact Assessment (OGIA), (2016). Groundwater modelling report for the Surat Cumulative Management Area. State of Queensland. September 2016.

Panday, S., Langevin, C.D., Niswonger, R.G., Ibaraki, M., Hughes, J.D., 2015. MODFLOW-USG. U.S. Geological Survey. https://doi.org/10.5066/f7r20zfj

Panday, S., Langevin, C.D., Niswonger, R.G., Ibaraki, M., Hughes, J.D., 2013. MODFLOW–USG version 1: An unstructured grid version of MODFLOW for simulating groundwater flow and tightly coupled processes using a control volume finite-difference formulation (No. Chapter 45 of Section A, Groundwater Book 6, Modeling Techniques), Techniques and Methods 6-A45. U.S. Geological Survey, Reston, Virginia, USA.

Pearce, Bruce R, and Hansen, James W. L. & Action Salinity & Water Australia & Queensland. Department of Natural Resources, Mines and Water. (2006). Hydrogeological investigation of the Fitzroy River sub-catchment, Central Queensland, Australia, Dept. of Natural Resources, Mines and Water, Brisbane.

Queensland Government (2019) LongPaddock - SILO Point climate data; Queensland Government 2020. https://longpaddock.qld.gov.au/silo/point-data/.

Raymond, M. A. A. and V. H. McNeil. (2011). Regional Chemistry of the Fitzroy Basin Groundwater. Brisbane: Department of Environment and Resource Management, Queensland Government.

RGS. (2020). Waste Rock Disposal Plan, Vulcan Bulk Sample Project, report for Vitrinite Pty Ltd. https://vitrinite.com.au/wp-content/uploads/2021/10/Waste-Rock-Disposal-Plan.pdf.

URS (2009). Caval Ridge Groundwater Impact Assessment, prepared for BM Alliance Coal Operations Pty Ltd.

URS, (2012). Groundwater Impact Assessment, Bowen Gas Project. Prepared for Arrow Energy Pty Ltd. Available: http://www.arrowenergy.com.au/__data/assets/pdf_file/0008/3869/Appendix- L_Groundwater-and-Geology-Technical-Report.pdf

URS (2014). Dysart East Coal project. Environmental Assessment Report, Groundwater Technical Report, for Bengal Coal Pty Ltd.

Xu, Y, and Gj Van Tonder. 2001. “Estimation of Recharge Using a Revised CRD Method.” Water SA 27 (3): 341–43. https://doi.org/10.4314/wsa.v27i3.4977.

Zolfaghar, S, Villalobos-Vega, R, Cleverly, J, Zeppel, M, Rumman, R & Eamus, D 2014, 'The influence of depth-to-groundwater on structure and productivity of Eucalyptus woodlands', Australian Journal of Botany, vol. 62, no. 5, pp. 428-437.

Appendix C- Soil and Land Suitability Assessment Report

VULCAN COMPLEX PROJECT
SOIL AND LAND SUITABILITY ASSESSMENT

PREPARED FOR

METSERVE PTY LTD

APRIL 2021



BRISBANE OFFICE
Suite 5, 1 Swann Road
Taringa, QLD 4068
P +61 7 3217 8772

CAIRNS OFFICE
PO Box 4887
Cairns, QLD 4879
P +61 7 4057 9402

E info@aarc.net.au
AARC.NET.AU

ACN. 620 818 920
ABN. 71 620 818 920

AARC Environmental Solutions Pty Ltd

Document History and Status

Issue	Rev.	Issued To	Qty	Date	Reviewed	Approved
Draft	1	METServe	1	26/09/19	SR	GB
Draft	2	METServe	1	17/10/19	SR	GB
Final	3	METServe	1	31/10/19	SR	SR
Final	4	METServe	1	28/11/19	SR	SR
Final	5	METServe	1	18/03/20	SR	SR
Final	6	METServe	1	25/03/20	SR	SR
Final	7	METServe	1	09/07/20	SR	SR
Final	8	METServe	1	25/08/20	SR	SR
Final	9	METServe	1	06/04/2021	SR	SR

Author:	Meghan Barnard
Project Manager:	Stuart Ritchie
Name of Client:	METServe Pty Ltd
Name of Project:	Vulcan Complex Project
Title of Document:	Soil and Land Suitability Assessment
Document Version:	Final

This controlled document is the property of AARC Environmental Solutions Pty Ltd and all rights are reserved in respect of it. This document may not be reproduced or disclosed in any manner whatsoever, in whole or in part, without the prior written consent of AARC Environmental Solutions Pty Ltd. AARC Environmental Solutions Pty Ltd expressly disclaims any responsibility for or liability arising from the use of this document by any third party.

Opinions and judgements expressed herein, which are based on our understanding and interpretation of current regulatory standards, should not be construed as legal opinions. Information obtained from interviews and contained in the documentation has been assumed to be correct and complete. AARC Environmental Solutions Pty Ltd does not accept any liability for misrepresentation of information or for items not visible, accessible nor able to be inspected at the sites at the time of the site visits.

INDEX

1.0 INTRODUCTION 9
1.1 OBJECTIVES 9
2.0 PROJECT BACKGROUND 10
2.1 LOCAL TOPOGRAPHY AND LANDFORM 10
2.2 REGIONAL GEOLOGY 11
2.3 REGIONAL CLIMATE 11
2.4 CURRENT LAND USE 12
2.5 STRATEGIC CROPPING LAND 12
2.6 LAND SYSTEMS 12
2.6.1 Carborough Land System 12
2.6.2 Connors Land System 13
2.6.3 Cotherstone Land System 13
2.6.4 Monteagle Land System 13
3.0 SOIL SURVEY METHODOLOGY 14
3.1 DESKTOP ANALYSIS 14
3.2 SURVEY DESIGN 14
3.3 FIELD INVESTIGATIONS 15
3.4 LABORATORY ANALYSIS 15
3.5 CHARACTERISATION OF SOIL MANAGEMENT UNITS 16
3.6 INTERPRETATION OF CHEMICAL DATA 16
3.6.1 pH 17
3.6.2 Electrical Conductivity 17
3.6.3 Chloride 18
3.6.4 Cation Exchange Capacity and Exchangeable Cations 18
3.6.5 Exchangeable Sodium Percentage 19
3.6.6 Organic Matter 19
3.6.7 Particle Size Analysis 20
3.6.8 Extractable trace elements/metals 20
3.6.9 Nitrate 20
3.6.10 Sulphate 21
3.6.11 Phosphorous and Potassium 21

3.6.12 Emerson Class 22

4.0 SOIL SURVEY RESULTS 23

4.1 CROCODILE SOIL MANAGEMENT UNIT 25

4.2 FISH MANAGEMENT UNIT 29

4.3 KEI MANAGEMENT UNIT 33

4.4 KOMATI MANAGEMENT UNIT 37

4.5 LIMPOPO MANAGEMENT UNIT 41

4.6 ORANGE MANAGEMENT UNIT 45

4.7 SABIE MANAGEMENT UNIT 49

4.8 ZAMBEZI MANAGEMENT UNIT 53

5.0 STRATEGIC CROPPING LAND ASSESSMENT 57

6.0 LAND SUITABILITY ASSESSMENT 58

6.1 CATTLE GRAZING 59

6.1.1 Water Availability 60

6.1.2 Nutrient Deficiency 61

6.1.3 Soil Physical Factors 62

6.1.4 Salinity 63

6.1.5 Rockiness 63

6.1.6 Microrelief 63

6.1.7 pH 64

6.1.8 Exchangeable Sodium Percentage (ESP) 65

6.1.9 Wetness 65

6.1.10 Water Erosion 66

6.1.11 Flooding 66

6.1.12 Vegetation Regrowth (management limitation) 67

6.1.13 Summary of Land suitability for Cattle Grazing 68

6.2 RAINFED BROADACRE CROPPING 71

6.2.1 Water Availability 71

6.2.2 Nutrient Deficiency 72

6.2.3 Soil Physical Factors 73

6.2.4 Soil Workability 73

6.2.5 Salinity 74

6.2.6 Rockiness 74

6.2.7 Microrelief 75

6.2.8 Wetness 75

6.2.9 Topography 76

6.2.10 Water Erosion 77

6.2.11 Flooding 77

6.2.12 Summary of Land suitability for Rainfed Broadacre Cropping 78

7.0 AGRICULTURAL LAND ASSESSMENT 81

8.0 SOIL HANDLING RECOMMENDATIONS 82

8.1 TOPSOIL SUITABILITY AND STRIPPING 82

8.2 TOPSOIL STOCKPILING 84

8.3 TOPSOIL PLACEMENT 85

8.3.1 Topsoil amelioration 85

8.3.1.1 Organic matter application 85

8.3.1.2 Fertiliser application 86

8.3.2 Cover crops 86

8.3.3 Hydromulching 87

8.4 SUBSOIL MANAGEMENT 89

8.4.1 Subsoil amelioration 89

9.0 POTENTIAL IMPACTS AND MANAGEMENT 90

9.1 LAND SUITABILITY 90

9.2 EROSION 91

9.3 TOPSOIL ERODIBILITY AND EROSION RISK 91

9.3.1 Pre-mining erosion prediction 93

9.3.2 Post-mining erosion prediction 94

9.3.3 Assessment outcome 97

9.4 EROSION OF REHABILITED LANDFORMS 97

9.5 SOIL DEGRADATION 98

9.6 EROSION MONITORING ON REHABILITATED LANDFORMS 99

9.6.1 Field Assessment Methodologies 99

9.6.2 Remote Sensing Methodologies 100

10.0 REFERENCES 101

LIST OF FIGURES

Figure 1 Project Location 10

Figure 2 Climate statistics (Clermont Post Office) 12

Figure 3 Distribution of Soil Management Units (1:85,000) 24

Figure 4 Cattle Grazing Land Suitability Classes 70

Figure 5 Rainfed Broadacre Cropping Land Suitability Classes 80

Figure 6 VCP Project Disturbance 88

LIST OF TABLES

Table 1 Survey Site Numbers for SLSA 2019 15
Table 2 Electrical Conductivity Ratings after *Interpreting Soil Test Results* (2016) 17
Table 3 Soil Salinity Ratings (based on EC values in dS/m) 17
Table 4 Chloride concentration ratings 18
Table 5 Soil CEC ratings 18
Table 6 Ratings for Extractable Cations (cmol(+)/kg) 19
Table 7 Soil ESP Ratings 19
Table 8 Soil Organic Matter Ratings 19
Table 9 Ideal Concentration Ranges for Trace Elements/Metals 20
Table 10 Soil Nitrate Ratings 20
Table 11 Soil Sulphate Ratings 21
Table 12 Soil Phosphorous Ratings 21
Table 13 Soil Potassium Ratings 21
Table 14 Emerson Class Numbers 22
Table 15 Soil Management Units – Study Area 23
Table 16 Soil Management Units – Project Area 23
Table 17 Key Crocodile SMU Parameters 25
Table 18 Chemical Properties of the Crocodile SMU 27
Table 19 Surface Soil (0-10 cm) Properties of the Crocodile SMU 28
Table 20 Key Fish SMU Parameters 29
Table 21 Chemical Properties of the Fish SMU 31
Table 22 Surface Soil (0-10 cm) Properties of the Fish SMU 32
Table 23 Key Kei SMU Parameters 33
Table 24 Chemical Properties of the Kei SMU 35
Table 25 Surface Soil (0 - 10 cm) Properties of the Kei SMU 36
Table 26 Key Komati SMU Parameters 37
Table 27 Chemical Properties of the Komati SMU 39
Table 28 Surface Soil (0-10 cm) Properties of the Komati SMU 40
Table 29 Key Limpopo SMU Parameters 41
Table 30 Chemical Properties of the Limpopo SMU 43
Table 31 Surface Soil (0-10 cm) Properties of the Limpopo SMU 44
Table 32 Key Orange SMU Parameters 45
Table 33 Chemical Properties of the Orange SMU 47
Table 34 Surface Soil (0-10cm) Properties of the Orange SMU 48
Table 35 Key Sabie SMU Parameters 49
Table 36 Chemical Properties of the Sabie SMU 51

Table 37 Surface Soil (0-10cm) Properties of the Sabie SMU 52
Table 38 Key Zambezi SMU Parameters 53
Table 39 Chemical Properties of the Zambezi SMU 55
Table 40 Surface Soil (0-10cm) Properties of the Zambezi SMU....56
Table 41 Agricultural and Conservation Land Classes....59
Table 42 Land Suitability for Cattle Grazing based on PAWC 61
Table 43 Land Suitability for Cattle Grazing based on Nutrient Status 62
Table 44 Land Suitability for Cattle Grazing based on Soil Physical Factors....62
Table 45 Land Suitability for Cattle Grazing based on Salinity....63
Table 46 Land Suitability Cattle Grazing based on Rockiness....64
Table 47 Land Suitability for Cattle Grazing based on Microrelief....64
Table 48 Land Suitability for Cattle Grazing based on pH....65
Table 49 Land Suitability for Cattle Grazing based on ESP 65
Table 50 Land Suitability for Cattle Grazing based on Wetness 66
Table 51 Land Suitability for Cattle Grazing based on Water Erosion 66
Table 52 Land Suitability for Cattle Grazing based on Flooding 66
Table 53 Land Suitability for Cattle Grazing based on Vegetation 67
Table 54 Summary of Land Suitability Limitations for Cattle Grazing 69
Table 55 Land Suitability for Rainfed Broadacre Cropping based on PAWC....72
Table 56 Land Suitability for Rainfed Broadacre Cropping based on Nutrient Status....72
Table 57 Land Suitability for Rainfed Broadacre Cropping based on Soil Physical Factors....73
Table 58 Land Suitability for Rainfed Broadacre Cropping based on Soil Workability....73
Table 59 Land Suitability for Rainfed Broadacre Cropping based on Salinity....74
Table 60 Land Suitability for Rainfed Broadacre Cropping based on Rockiness....74
Table 61 Land Suitability for Rainfed Broadacre Cropping based on Microrelief....75
Table 62 Land Suitability for Rainfed Broadacre Cropping based on Wetness 76
Table 63 Land Suitability for Rainfed Broadacre Cropping based on Topography 76
Table 64 Land Suitability for Rainfed Broadacre Cropping based on Water Erosion....77
Table 65 Land Suitability for Rainfed Broadacre Cropping based on Flooding....77
Table 66 Summary of Land Suitability Limitations for Rainfed Broadacre Cropping....79
Table 67 Description of Agricultural Land Classes....81
Table 68 Summary of Agricultural Land Classes....81
Table 69 Maximum Topsoil Stripping Depths for all Soil Management Units....82
Table 70 Estimated Soil Volumes – Project Disturbance Area....85
Table 71 Summary of the Size and Suitability Classes for Project Area SMUs 90
Table 72 Soil RUSLE K factors....93
Table 73 Predicted soil loss per slope characteristics of the pre-mining landform....94
Table 74 Predicted soil loss as a factor of slope and management practice 95
Table 75 Erosion classifications 100

LIST OF PHOTO PLATES

Photo Plate 1 Crocodile SMU Vegetation 25
Photo Plate 2 Fish SMU Vegetation 29
Photo Plate 3 Kei SMU Vegetation 33
Photo Plate 4 Komati SMU Vegetation 37
Photo Plate 5 Limpopo SMU Vegetation 41
Photo Plate 6 Orange SMU Vegetation 45
Photo Plate 7 Sabie SMU Vegetation 49
Photo Plate 8 Zambezi SMU Vegetation 53

LIST OF APPENDICES

Appendix A Lab Results ..... A
Appendix B Soil Profile Data ..... B
Appendix C Soil Observation Data C
Appendix D Sampling Site Locations ..... D

LIST OF ABBREVIATIONS

AARC	-	AARC Environmental Solutions Pty Ltd
Ca/Mg	-	Calcium/Magnesium Ratio
CEC	-	Cation Exchange Capacity
EC	-	Electrical Conductivity
ESP	-	Exchangeable Sodium Percentage
MLA	-	Mining Lease Application
NATA	-	National Association of Testing Authorities
PAWC	-	Plant Available Water Capacity
ROM	-	Run-of-mine
SCL	-	Strategic Cropping Land
SLSA	-	Soil and Land Suitability Assessment
SMU	-	Soil Management Unit
VCP	-	Vulcan Complex Project

1.0 INTRODUCTION

AARC Environmental Solutions Pty Ltd (AARC) was commissioned by Mining and Energy Technical Services Pty Ltd (METServe), on behalf of Vitrinite Pty. Ltd., owner of Qld Coal Aust No.1 Pty. Ltd. and Queensland Coking Coal Pty. Ltd. (Vitrinite), to conduct a Soil and Land Suitability Assessment (SLSA) for the proposed Vulcan Complex Project (VCP, the Project). The Project is located north of Dysart and approximately 33 km south of Moranbah in Queensland's Bowen Basin (Figure 1). The Project lies to the immediate west of several established mining operations including BHP's Peak Downs and Saraji mines. The closest major town to the site is Emerald, approximately 125 km south of the Project site.

As part of the Project planning and feasibility assessment, the proponent nominated a considerably larger area (the study area) than the proposed Project Mining Lease Application (MLA) area. The baseline data collected within this larger study area has been used in the assessment of the Project, and for context, as required. Subject to further project planning, the proponent may, in future, utilise this baseline information to assess the potential impacts of additional project development opportunities with the study area.

This SLSA documents the nature and distribution of major soil types in the study area and assesses their suitability for the land uses of both cattle grazing and dryland cropping. This assessment establishes baseline environmental characteristics and values relating to land use and suitability and provides recommendations for the management of soil resources within the Project area.

1.1 OBJECTIVES

The objectives of the SLSA are to:

- Describe the agricultural use(s) of the Project site and the surrounding area, including any crop rotations;
- Describe, map and illustrate soil types and profiles according to the *Australian Soil and Land Survey Field Handbook* (National Committee on Soil and Terrain 2009), *Guidelines for Surveying Soil and Land Resources* (McKenzie *et. al.* 2008) and *Australian Soil Classification* (Isbell 2002);
- Identify soils that would require specialised management due to wetness, erosivity, depth, acidity, salinity or other features;
- Identify soils from representative samples down the soil profile, based on their physical and chemical properties that are likely to, or have potential to be subject to erosion from storm water runoff. Similarly, soils proposed to be used for rehabilitation, and particularly where agriculture is the final land use, will be assessed for their suitability for this use;
- Describe and map land suitability classes of the study area in accordance with the *Guidelines for Agricultural Land Evaluation in Queensland – Second Edition (Draft)* (State of Queensland 2012), and the *Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland – Land suitability Assessment Techniques* (DME 1995);
- Assess the potential impacts of the Project on the soil and land use values of the area and provide recommended mitigation measures to minimise negative impacts; and
- Include the findings in a stand-alone report suitable for inclusion in an environmental impact statement.

2.0 PROJECT BACKGROUND

The Project is situated in the Bowen Basin, central Queensland, approximately 30 km north-east of the township of Dysart, 125 km north of Emerald, and 270 km north-west of Rockhampton (Figure 1). The Project is to the immediate west of several established mining operations including Peak Downs, Saraji, Norwich Park and Caval Ridge.

The Project will operate for approximately four years and will extract approximately 6 Mt of ROM hard coking coal with a thermal by-product at a rate of up to 1.95 Mtpa. Truck and shovel mining operations will be employed to develop the pit. ROM coal will be trucked off site for toll washing at a nearby facility between Moranbah and Coppabella on the Peak Downs Highway.

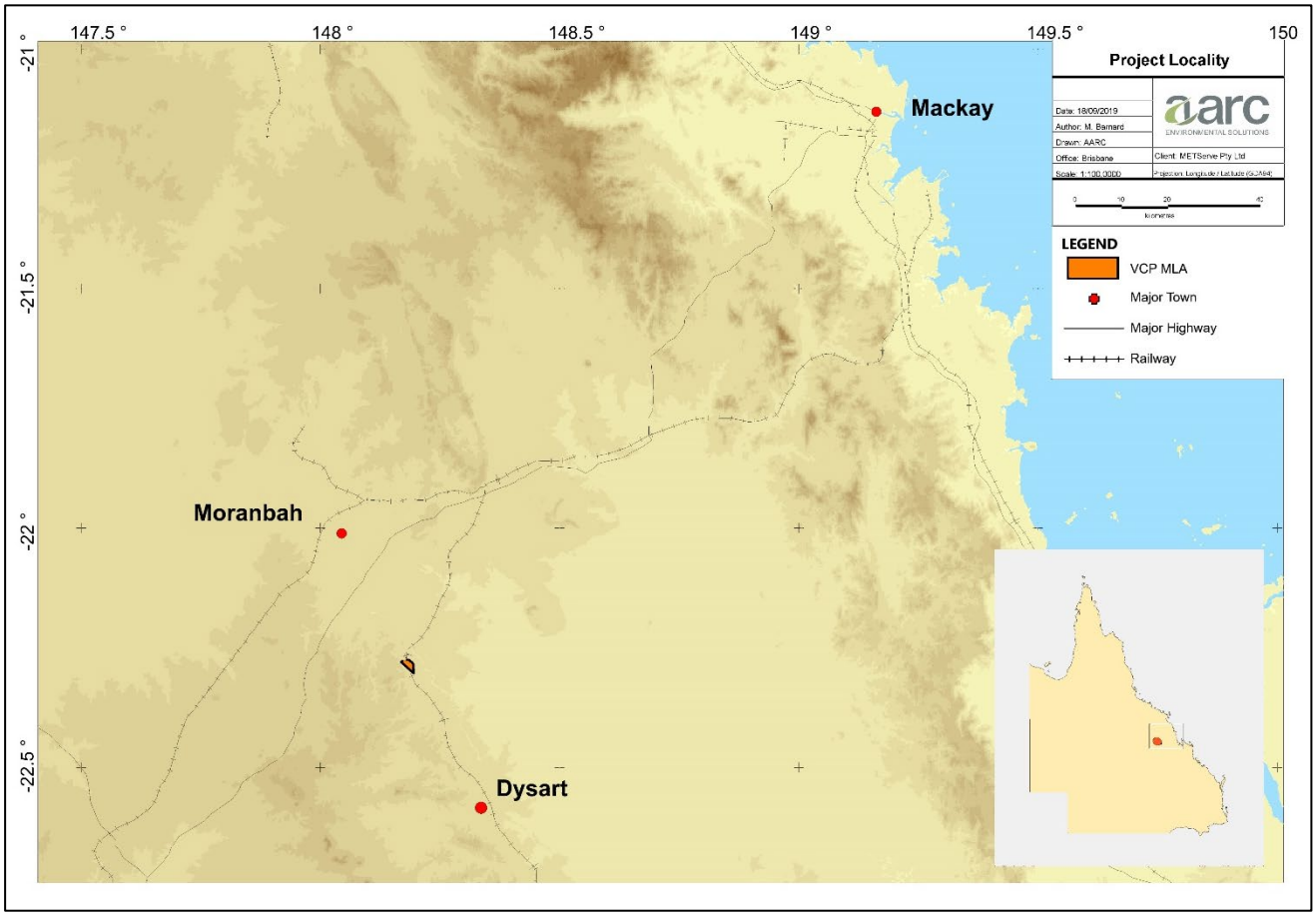


Figure 1 Project Location

2.1 LOCAL TOPOGRAPHY AND LANDFORM

The Project lies within the Fitzroy River Basin. This basin encompasses an area of 142,545 km^2, and contains the Comet, Dawson, Fitzroy, Isaac, Mackenzie and Nogoa Rivers, which make up six sub-catchment areas (Department of Environment and Science, 2019).

The Project exists within the Isaac River sub-catchment, which is situated in the northern region of the Fitzroy River Basin and has a total area of 22,364 km^2. The major water bodies associated with the site are the Boomerang and Hughes Creeks. Boomerang Creek dissects the study area in a north-easterly direction and flows just to the south of the Project area. Hughes Creek flows in an easterly direction across the southern region of the study area. Both creeks form within approximately 10 km beyond the western boundary of the study area, flowing east to north-east. Boomerang Creek joins Hughes Creek

near the south-eastern boundary of the study area before its confluence with the Isaac River and finally the Fitzroy River; eventually flowing to the Pacific Ocean approximately 46 km north of Gladstone.

The topography within the study area varies from hilly, rocky terrain to the north to flat plains and undulating hills to the south, with elevation ranging between 200 m to 400 m above sea level. Vegetation in the region includes grassy plains, riparian vegetation and woodlands.

2.2 REGIONAL GEOLOGY

The geology of the area is influenced by its position within the Bowen Basin, one of Queensland's largest depositional zones, forming through a period of rifting and subsidence lasting from the Early Permian to the Mid-Triassic. The area surrounding the Project is dominated by clastic sedimentary rocks of marine and lacustrine origin, including sandstones, mudstones, siltstones and coal (Geoscience Australia 2019).

The coal seams found in the east-central part of the Bowen Basin are of Permian age and contain higher quality coking coal deposits, with the rank falling below the coking range farther south and west (Hutton, 2009), (Mutton, 2003).

The solid geology of the region is described as including:

- Moranbah Coal Measures – Permian comprising of coal and interseam material composed of sandstone, shale, siltstone with minor clay stone; and
- Back Creek Group – Early to Late Permian comprising of quartzose to lithic sandstone, conglomerate, siltstone, carbonaceous shale and coal.

While surface geology includes the following:

- Qr – Qr - (QLD) (Qr) – Quaternary clay, silt, sand, gravel and soil with colluvial and residual deposits; and
- TQa – QLD (TQa) – Late Tertiary to Quaternary poorly consolidated sand, silt, clay, minor gravel and high-level alluvial deposits.

2.3 REGIONAL CLIMATE

The regional climate is classified as semi-arid, with characteristic hot summers and mild to warm winters. Climate statistics have been sourced from the Bureau of Meteorology for the Clermont Post Office, located approximately 77km south-west of the Project. The data indicates average rainfall for the region to be approximately 665 mm with a characteristic wet season between November and March. Long term temperature statistics demonstrate that the average maximum daily temperature in summer is 34ºC with overnight minimum temperatures averaging at 21ºC. In winter, the average maximum temperature is 24ºC with an average minimum temperature of 8ºC (Bureau of Meterology, 2019).

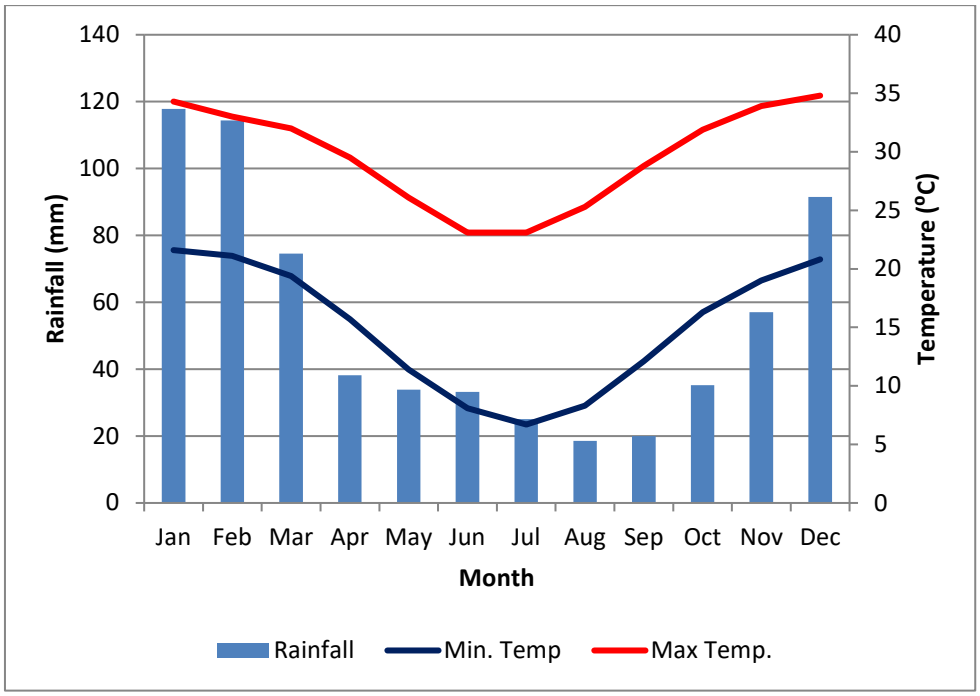


Figure 2 Climate statistics (Clermont Post Office)

2.4 CURRENT LAND USE

The land within the Project boundary is currently used for low intensity cattle grazing, and small commercial operations with few significant disturbances apart from small farm dams and dirt tracks.

2.5 STRATEGIC CROPPING LAND

The *Regional Planning Interests Act 2014* (RPI Act) is administered by the Department of State Development, Manufacturing, Infrastructure and Planning and regulates impacts from resource and other regulated activities on identified areas of regional interest. This includes the strategic cropping area which consists of areas shown on the strategic cropping land (SCL) trigger map as SCL. SCL is land that is, or is likely to be, highly suitable for cropping because of a combination of the land's soil, climate and landscape features.

The Department of Natural Resources, Mines and Energy makes and certifies the SCL trigger map. None of the lands within the study area are included within the SCL trigger map.

2.6 LAND SYSTEMS

The Report on Lands of The Isaac-Comet Area (Story *et al.* 1967) mapped at a scale of 1:500,000 indicates the study area contains the land system units described in the following sections.

2.6.1 Carborough Land System

The Carborough Land System is characterised by mountains and hills with broken and dissected local relief ranging between 30 m to 400 m. Structural benches and cliffs are common landforms with severe weathering occurring in some areas. This mountainous land system has formed shallow coarse-textured rocky soils with species such as bloodwood (*Corymbia erythrophloia*), lancewood (*Acacia shirleyi*) and narrow-leaved ironbark (*Eucalyptus crebra*) populating the area. A small area of the Carborough Land System is also characterised by lower slopes and hills and alluvial flats with a local relief between 10 m

to 60 m. Texture-contrast soils have formed in these areas and possess a thick sandy topsoil. Savannah woodland dominated by narrow-leaved iron bark (*Eucalyptus crebra*) is established in this area.

Geology in this land system is comprised of partly weathered quartz sandstone.

2.6.2 Connors Land System

The Connors Land System is characterised by alluvial plains composed of terraces and levees up to 3 km wide. Texture-contrast soils have developed in this area and are characterised by a thick sandy topsoil and neutral to strongly alkaline subsoil. Vegetation consists of savannah woodlands dominated by Poplar box (*Eucalyptus populnea*) and mixed shrub woodland.

2.6.3 Cotherstone Land System

The Cotherstone Land System is characterised by hills and prominent strike ridges as well as gentler undulating terrain associated with low indefinite strike ridges and colluvial foot slopes. The more prominent strike ridges possess a local relief varying between 10 m to 30 m and have developed shallow course-textured to rocky soils that support savannah woodland consisting mostly of narrow-leaved iron bark (*Eucalyptus crebra*) and lancewood (*Acacia shirleyi*). The gentler undulating terrain has a local relief of less than 15 m and is associated with texture-contrast soils with a sandy upper-horizon. Depending on the steepness of terrain either narrow-leaved iron bark dominated savannah woodland (slopes of <10%) or mixed shrub woodland (slopes of <5%) have been established.

The geology in this land system is weathered Permian sandstone and shale.

2.6.4 Monteagle Land System

The Monteagle Land System is predominantly characterised by low-lying plains and colluvial foot slopes with local relief generally below 6 m. This land system is associated with texture-contrast soils composed of a thick sandy topsoil and neutral to strongly alkaline subsoils. Savannah woodlands consisting largely of Poplar box (*Eucalyptus populnea*) and some narrow-leaved iron bark (*Eucalyptus crebra*) dominate the area.

Geology in this land system is comprised of undissected Tertiary sandstones and clays.

3.0 SOIL SURVEY METHODOLOGY

3.1 DESKTOP ANALYSIS

A desktop analysis was conducted prior to field sampling. This analysis was comprised of background research and evaluation of available information for the study area. Resources used included:

- The Digital Atlas of Australian Soils (Bureau of Rural Science, 1991). Australian soils were mapped at a scale of 1:2,000,000. Although this scale is broad it provided a good foundation for understanding the soils that may be present in the study area region.

- Government maps featuring regional topography, geology, contour data and watercourse locations were used to help refine mapping boundaries, particularly where soil types are a function of gradient.

- Reference information for land systems: *Land Systems of the Isaac-Comet Area, Queensland* (Story *et al.,* 1967).

- Reference Information for regional geology: *Geology of the Bowen Basin, Queensland* (Dickins and Malone, 1973).

- Reference information for land management: *Understanding and Managing Soils in the Central Highlands* (Bourne and Tuck, 1993).

3.2 SURVEY DESIGN

Methodologies employed throughout this study followed procedures detailed in the *Australian Soil and Land Survey Field Handbook* (National Committee on Soil and Terrain, 2009) and the *Guidelines for Surveying Soil and Land Resources* (McKenzie *et al.*, 2008). The soil survey was based on a free-survey technique with soil profile and observation sites located to best represent all soil types present in the study area.

As part of the Project planning and feasibility assessment, the proponent commissioned environmental assessments of a considerably larger study area than the proposed MLA Project area. As a result, the SLSA study area surveyed comprises a significantly larger area of 10,120 ha which incorporates the Project area as well as lands lying predominantly to the west and south of the Project area.

Mapping scales for the study area were selected in order to satisfy the requirements of an environmental impact statement taking into consideration available resources, land access and soil complexity. For the study area, a scale between 1:25,000 to 1:100,000 was deemed most appropriate. This scale was selected based on information contained within the *Guidelines for Surveying Soil and Land Resources* (McKenzie *et al.*, 2008). The final mapping scale of 1:85,000 for the study area fell within the specified range.

To achieve a mapping scale of 1:25,000 to 1:100,000, McKenzie *et al.* (2008) suggest a minimum recommended sampling density of one site per 25 hectares (ha) with data collection comprising detailed soil profile descriptions (15 to 35% of sites), representative profile sampling for lab analysis (1 to 5%) and mapping observations sites (55 to 83%).

The number of sites surveyed for the SLSA (refer Table 1) exceeded these minimum requirements.

Table 1 Survey Site Numbers for SLSA 2019

Survey Site	Scale	Detailed Soil Profiles	Representative Profiles for Analysis	Mapping Observations	Total
Study Area (10,120 ha)	1:100,000	42	12	66	121

3.3 FIELD INVESTIGATIONS

AARC undertook field sampling at the Project from 19 to 26 July 2019, consisting of both primary sampling sites (profiles) and secondary visual assessments (observations).

Sampling site locations were determined based on the desktop analysis, land management units, landform and vehicle access. Visual assessments were conducted continually while traversing the landscape to confirm major soil types and boundaries between soil units. The GPS coordinates of each location were recorded.

Detailed soil profiles were undertaken at 42 sites within the Project boundaries. A jackhammer-operated soil corer was used to excavate cores to a maximum depth of 120 cm. Soil samples were collected from profiles at standard depths of 0-10 cm, 20-30 cm, 50-60 cm, 80-90 cm and 110-120 cm where possible. Samples were sealed in clean, plastic zip-lock bags and labelled with the site number, date, depth of sampling and the initials of the sampler.

Parameters recorded included micro relief, permeability, drainage, substrate, site disturbance, landform (slope percentage, relief, elevation, morphological type, landform element and landform pattern), runoff, erosion, surface coarse fragments, rock outcrops, surface condition and dominant vegetation type. Soil profile morphology was described in the field in terms of horizon type, horizon depth, boundary, colour, mottles, texture, coarse fragments, structure, segregations, consistency and field pH.

3.4 LABORATORY ANALYSIS

Samples from a total of 12 representative sites were chosen for analysis through Australian Laboratory Services for NATA approved physical and chemical analyses. Samples from all standard depths at the chosen sites were analysed to:

- Confirm the classification of the described soil profile;
- Assist in the description of soil characteristics;
- Assist in the determination of land suitability classes;
- Assist in the determination of topsoil and subsoil as a suitable topdressing media; and
- Assist in the identification of soils that would require specialised management.

Physical and chemical parameters analysed for all samples included:

- pH;
- Electrical conductivity (EC);

- Moisture content;
- Chloride (soluble);
- Exchangeable cations (Ca, Mg, Na, K);
- Cation Exchange Capacity (CEC); and
- Exchangeable Sodium Percentage (ESP).

Additional physical and chemical parameters analysed for topsoil samples included:

- Organic matter (%);
- Particle Size Analysis (PSA);
- Extractable trace elements/metals (Fe, Cu, Zn, Mn);
- Boron ($CaCl_2$ extractable);
- N as nitrate;
- SO_4 (water soluble S as sulphate);
- Phosphorus and potassium (Colwell); and
- Emerson Class.

3.5 CHARACTERISATION OF SOIL MANAGEMENT UNITS

Soil classification was undertaken using the methodologies specified in *The Australian Soil Classification* (Isbell 1996). Soil Management Units (SMUs) were then defined based on grouping soils of like soil morphology, parent material, and land attributes in accordance with the *Guidelines for Surveying Soil and Land Resources* (McKenzie *et al.* 2008). Each SMU has been described in terms of its soil profile class with the attributes and limitations of the soil interpreted using the *Guidelines for Agricultural Land Evaluation in Queensland – Second Edition* (DSITI and DNRM 2015) to determine their suitability for cattle grazing and broadacre cropping. SMUs were mapped at a scale of 1: 85,000 across the study area.

3.6 INTERPRETATION OF CHEMICAL DATA

The characteristics and chemical data for each SMU have been described in Section 4.0. The following guidelines were used to assist in interpretation of the SMU physical and chemical properties and to determine ratings and categories of the assessed soil parameters.

- *Interpreting Soil Test Results* (Hazelton and Murphy 2016);
- *Soil Chemical Methods of Australasia* (Rayment GE and Lyons D 2011); and
- *Standard Soil Test Methods and Guidelines for Interpretation of Soil Results* (Government of South Australia 2013).

Broad descriptions for each soil parameter have been provided below and where applicable, a summary of the rating system used.

3.6.1 pH

Soil pH influences the availability of plant available nutrients and toxic elements by controlling the solubility of these elements. At extreme pH, the availability of essential plant nutrients can be severely reduced while toxic elements can become mobile within the soil solution. The soil pH ratings used are shown in Table 2. In general, a suitable soil pH ranges from 5.5 – 9.0 as at this pH all essential nutrients are available to some degree.

Table 2 Electrical Conductivity Ratings after *Interpreting Soil Test Results* (2016)

pH_{water}	Rating	Soil Chemistry Indications
< 4.0	Very strongly acid	Typical of disturbed acid sulphate soils
4.0 to < 5.0	Strongly acid	Acidified soils
5.0 to < 6.0	Moderately acid	Range most suitable for plant growth
6.0 to < 7.0	Slightly acid	
7.0	Neutral	
> 7.0 to < 8.0	Slightly alkaline	
8.0 to < 9.0	Moderately alkaline	
9.0 to 10.0	Strongly alkaline	Some nutrients becoming unavailable, indication of sodicity
> 10.0	Very strongly alkaline	Extreme pH, high sodicity and carbonates

3.6.2 Electrical Conductivity

EC provides an indication of the presence of soluble salts in the soil profile. High levels of soluble salts can interfere with the osmotic capacity of plants. This compromises the plants ability to take up water as needed resulting in water stress regardless of the water content in the soil. The texture of soil needs to be considered when interpreting EC as the clay content determines the amount of salt present that will affect plant growth. Table 3 provides soil salinity ratings sourced from Rayment GE and Lyons D (2011).

Table 3 Soil Salinity Ratings (based on EC values in dS/m)

Soil Salinity Rating	10 - 20% Clay	20 - 40% Clay
Very Low	< 0.07	< 0.09
Low	0.07 - 0.15	0.09 - 0.19
Medium	0.15 - 0.34	0.19 - 0.45
High	0.34 - 0.63	0.45 - 0.76
Very High	0.63 - 0.93	0.75 - 1.21
Extreme	> 0.93	> 1.21

3.6.3 Chloride

Chloride is associated with EC as soluble salts contain chloride, thus the presence of soluble salts in soils is directly proportional to chloride in soil. A high chloride concentration can induce chloride toxicity and interfere with the osmotic capacity of plants. Table 4 below provides chloride ratings (Rayment and Bruce, 1984).

Table 4 Chloride concentration ratings

Chloride Rating	Cl Concentration (mg/kg)
Very Low	< 100
Low	100 - 300
Medium	300 - 600
High	600 - 2,000
Very High	> 2,000

3.6.4 Cation Exchange Capacity and Exchangeable Cations

CEC is an indication of the soil's capacity to adsorb cationic nutrients to the surface of soil particles. This process of adsorption prevents nutrients leaching from the soil and buffers the concentration of plant available nutrients in the soil solution. A high CEC of the soil contributes to larger quantities of exchangeable cations (Ca, K, Mg, Na) available. The ratio of cations on the exchange is also an important consideration as cations that dominate the exchange can interfere with the availability of other cations. Table 5 and Table 6 provide ratings for soil CEC and extractable cations sourced from the guide *Interpreting Soil Test Results* (2016).

Table 5 Soil CEC ratings

CEC Rating	CEC (cmol(+)/kg)
Very Low	< 6
Low	6 - 12
Medium	12 - 25
High	25 - 40
Very High	> 40

Table 6 Ratings for Extractable Cations (cmol(+)/kg)

Cation	Very Low	Low	Moderate	High	Very High	Ideal range (% of CEC)
Ca	0 - 2	2 - 5	5 - 10	10 - 20	> 20	65 - 80
K	0 - 0.2	0.2 - 0.3	0.3 - 0.7	0.7 - 2	> 2	1 - 5
Mg	0 - 0.3	0.3 - 1	1 - 3	3 - 8	> 8	10 - 15
Na	0 - 0.1	0.1 - 0.3	0.3 - 0.7	0.7 - 2	> 2	< 1

3.6.5 Exchangeable Sodium Percentage

ESP is defined as the amount of exchangeable sodium as a percentage of the total CEC of the soil. It provides a measure of how much of the CEC of the soil is dominated by sodium. Due to the chemical characteristics of sodium ions, an increasing ESP indicates increasing sodicity thus increasing the risk of dispersion. Table 7 provides ESP ratings sourced from the guide *Interpreting Soil Test Results* (2016).

Table 7 Soil ESP Ratings

ESP (%)	ESP Rating
< 6	Non-sodic
6 - 15	Sodic
> 15	Strongly sodic

3.6.6 Organic Matter

Organic matter is an essential constituent of soil. It is an important component of microbial processes and nutrient cycling. Furthermore, it contributes to the ability of a soil to buffer changes to pH and nutrient content and supports the aggregation of soils thereby improving the structural stability of the soil. Table 8 provides soil organic matter ratings sourced from the guide *Interpreting Soil Test Results* (2016).

Table 8 Soil Organic Matter Ratings

Organic Matter Rating	Organic Matter Content (g/100 g)
Extremely low	< 0.7
Very low	0.7 - 1
Low	1 - 1.7
Moderate	1.7 - 3
High	3 - 5.15
Very High	> 5.15

3.6.7 Particle Size Analysis

Particle size analysis determines the percentage composition of sand, silt and clay sized particles which controls the soil texture. Soil texture influences the structural stability and water holding characteristics of a soil as the particle size distribution influences the porosity and permeability of soil.

3.6.8 Extractable trace elements/metals

Trace elements such as copper, iron, manganese, zinc and boron are essential nutrients required for plant growth, although needed in much smaller quantities than exchangeable cations. Table 9 provides trace element/metal ratings sourced from the guide *Standard Soil Test Methods and Guidelines for Interpretation of Soil Results* (2013).

Table 9 Ideal Concentration Ranges for Trace Elements/Metals

Trace Element/Metal	Rating	Concentration
Boron	Low	< 0.5
	High	> 15
Copper	Low	< 0.3
	High	> 1
Iron	Low	< 10
	High	> 70
Manganese	Low	< 1
	High	> 10
Zinc	Low	< 0.5
	High	> 1

3.6.9 Nitrate

Nitrate is a plant-available form of nitrogen. It is an essential nutrient and is often the most limiting to plant growth. It is also susceptible to nitrification and leaching which reduces nitrate concentration in soil. Table 10 provides soil nitrate ratings sourced from the guide *Interpreting Soil Test Results* (2016).

Table 10 Soil Nitrate Ratings

Rating	Nitrate Concentration (mg/kg)
Very low	0 - 6
Low	7 - 15
Moderate	16 - 22
High	23 - 30
Very High	> 30

3.6.10 Sulphate

Sulphate is another essential plant nutrient and has a similar behaviour to nitrate in that it is susceptible to leaching and is important in microbial processes. Table 11 provides soil sulphate ratings sourced from Government of South Australia (2013).

Table 11 Soil Sulphate Ratings

Rating	Sulphate Concentration (mg/kg)
Low	< 5
Marginal	5 - 10
High	> 10

3.6.11 Phosphorous and Potassium

Both phosphorous and potassium are the next most essential nutrients after nitrogen and sulphate. Phosphorous and potassium are involved in several chemically- and microbially-driven processes within the soil with most forms of these nutrients being unavailable for plant uptake. Table 12 and Table 13 provide ratings for soil phosphorous and potassium levels sourced from the guide *Interpreting Soil Test Results* (2016).

Table 12 Soil Phosphorous Ratings

Rating	Phosphorous Concentration (mg/kg)
Very low	< 5
Low	5 - 10
Moderate	10 - 17
High	17 - 25
Very High	> 25

Table 13 Soil Potassium Ratings

Soil Texture	Critical Concentration (mg/kg)*
Sand	126
Sandy loam	129
Sandy clay loam	143
Clay loam	161

* Critical concentration is that concentration where 95% of maximum yield is achieved

3.6.12 Emerson Class

Emerson class is a class assigned to soil that is determined on the stability of dry aggregates in water. The Emerson Class Number of a soil is assigned as an indication of the dispersion and slaking ability of a soil. Table 14 below describes the Emerson Dispersion Class (Emerson 1967).

Table 14 Emerson Class Numbers

Emerson Aggregate Class	Level of Dispersion
1	Slaking and complete dispersion
2	Slaking and some dispersion
3	Slaking and no dispersion
4	$CaCO_3$/$CaSO_4$ present. No dispersion at field capacity
5	No $CaCO_3$/$CaSO_4$ present. No dispersion at field capacity, however, dispersion in an aggregate-water suspension
6	No $CaCO_3$/$CaSO_4$ present. No dispersion at field capacity, however, flocculation in an aggregate-water suspension
7	No slaking and swelling
8	No slaking and no swelling

4.0 SOIL SURVEY RESULTS

Eight SMUs have been described within the study area. Table 15 provides an overview of each SMU and its extent within the study area and Table 16 lists the SMUs present within the Project area. The spatial distribution of the SMUs has been mapped at a scale of 1:85,000 and is illustrated in Figure 3. The coordinates for each sampling site have been provided in Appendix D.

Table 15 Soil Management Units – Study Area

SMU	Surface Area (ha)	Per cent of Study Area (%)
Crocodile	2,524	24.9
Fish	77	0.8
Kei	140	1.4
Komati	263	2.6
Limpopo	3,328	32.9
Orange	474	4.7
Sabie	1,869	18.5
Zambezi	1,445	14.3
Total Area	**10,120**	**100**

Table 16 Soil Management Units – Project Area

SMU	Surface Area (ha)	Per cent of Project Area (%)
Limpopo	392	96
Zambezi	16	4
Total Area	**408**	**100**

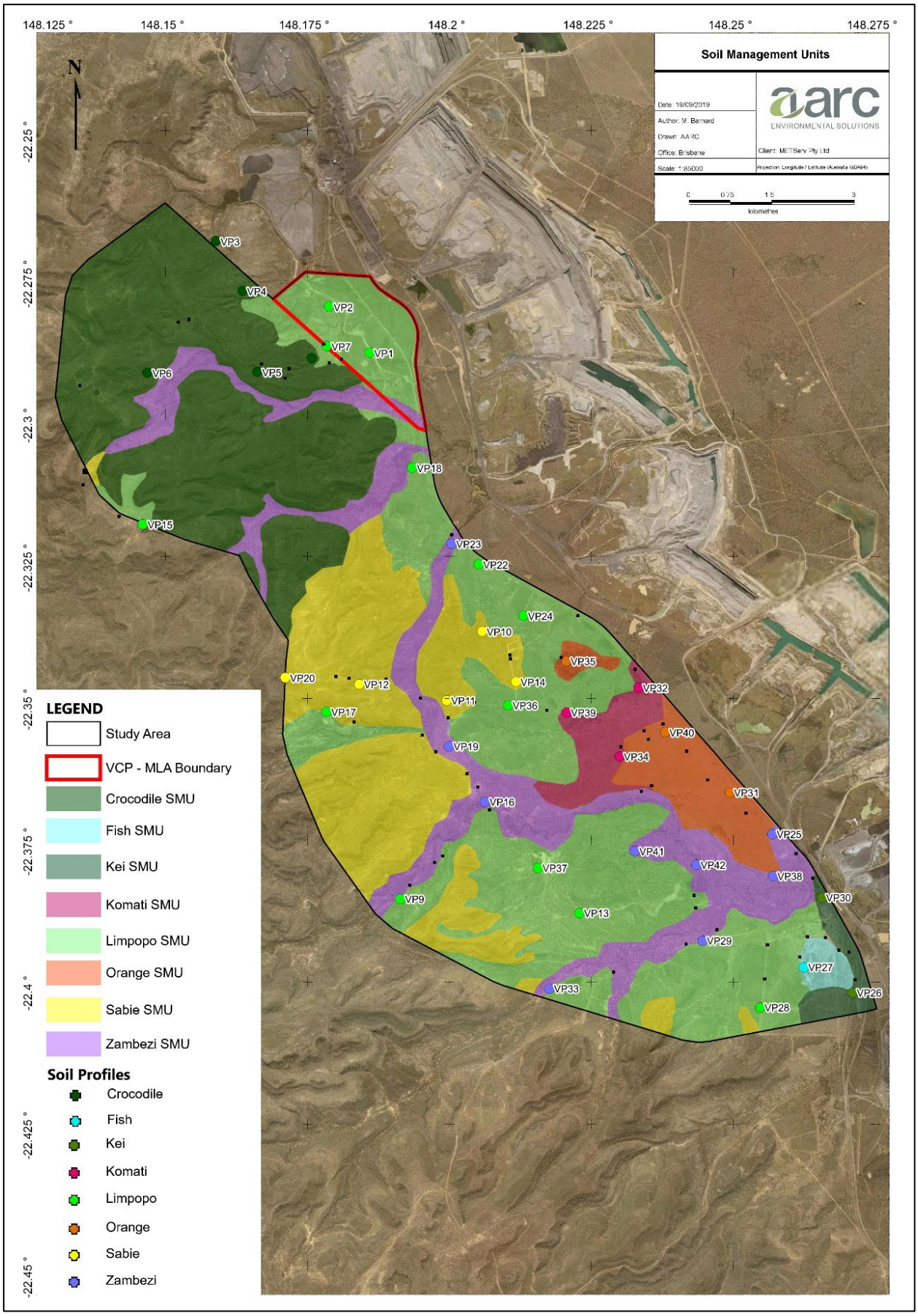


Figure 3 Distribution of Soil Management Units (1:85,000)

4.1 CROCODILE SOIL MANAGEMENT UNIT

Soil Unit Description

A shallow rocky soil unit associated with hill slopes and plateaus. Soil textures grade from loam at the surface, to loamy sands with depth; often containing rock material with little to no pedologic development throughout the solum. Vegetation associated with this unit includes *Eucalyptus crebra* and Bloodwood *Corymbia erythrophloia.*



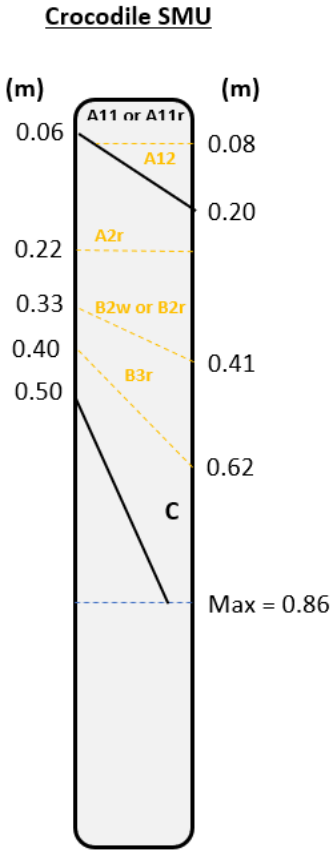
Photo Plate 1 Crocodile SMU Vegetation

Table 17 Key Crocodile SMU Parameters

Parameter	Soil Unit Description
Profile Site Numbers	VP3, VP4, VP5, VP6, VP8
Observation Site Numbers	OP1, OP3, OP6, OP8, OP10, OP14, OP15, OP16
Landform	Rises and Plateaus
Australian Soil Classification	Arenic Rudosol
Land System	Carborough Land System
Slope	1 to 10%
Geology	Back Creek Group
Vegetation	Narrow-leaved ironbark (*Eucalyptus crebra*), Bloodwood (*Corymbia erythrophloia*)
Runoff	Moderate
Permeability	Low to moderately permeable
Drainage	Moderate to rapidly drained

Profile Description – Representative Sites VP5 and VP8





The **surface soil** (A11/A11r/A12) is a black to very dark greyish brown (10YR2/1, 10YR3/2) sand to sandy loam with loose to weak polyhedral structure with some profiles containing moderately strong to strong sub-angular rock material. The soil unit has a field pH of 4.5 - 5.5, demonstrating an abrupt to clear change to;

The **lower surface soil** (A2r) is not a common horizon observed for this SMU. It is a dark brown (10YR3/3) loamy sand with an abundance (comprising 50 - 90% of this horizon) of moderately strong coarse fragments approximately 2 - 6 cm in diameter. It has loose structure and a field pH of 5.5 to 5.0. Gradual change to;

The **subsoil** (B2w/B2r) is a dark greyish to reddish brown (10YR3/2, 2.5YR2.5/4) loamy sand to clay loam with weak to moderate polyhedral structure. It can contain rounded to angular course fragments which make up < 10% of the horizon. This horizon has a field pH of 4.5 to 5.5, with a gradual change to;

The **lower profile** (C) contains either consolidated or unconsolidated partly weathered rock material that appear to have originated from underlying sandstone and siltstone with some profiles possessing an overlying transitionary horizon (B3r). Depending on the rock material present, this horizon can range from dark red to light yellow-brown colour.

Chemical and Physical Analysis

Table 18 Chemical Properties of the Crocodile SMU

Representative site: VP5								
Depth	**pH**		**EC**		**Cl**	**ESP%**		**Moisture**
(m)	**#**	**Rating**	**dS/m**	**Rating**	**(mg/kg)**	**%**	**Rating**	**(%)**
0 - 0.1	5.4	Strongly Acid	0.014	Low	< 10	1.5	Non-sodic	2.9
0.2 - 0.3	5.4	Strongly Acid	0.007	Very low	< 10	1.3	Non-sodic	2.6
0.5 - 0.6	5.6	Moderately Acid	0.006	Very low	< 10	1.5	Non-sodic	1.9
Depth	**CEC**		**Exchangeable Cations (meq/100g)**					**Emerson Class No.**
(m)	**meq / 100g**	**Rating**	**Ca**	**Mg**	**K**	**Na**	**Ca/Mg Ratio**	
0 - 0.1	7.3	Low	3.1	1.5	0.8	0.1	2.1	8
0.2 - 0.3	3.1	Very Low	0.1	1	0.2	< 0.1	< 0.1	7
0.5 - 0.6	2.4	Very Low	< 0.1	1	0.1	< 0.1	< 0.1	7
Nutrient Distribution in Topsoil (%)			42.5%	20.6%	10.9%	1.4%		

The Crocodile SMU is strongly acidic throughout the solum with only a minor increase in pH at depth. In the upper part of the profile (to an approximate depth of 0.3 m), this has the potential to limit the availability of essential nutrients and increase the risk of aluminium toxicity. Throughout the profile, both EC and chloride concentration remain very low with EC ranging between 0.014 dS/m in the topsoil to 0.006 dS/m at depth and chloride concentration remaining below 10 mg/kg. This indicates this SMU is not affected by issues associated with salinity and toxic chloride concentrations (Rayment and Lyons 2011).

CEC levels for this SMU are considered low (7.3 meq/100g) and decrease to 2.4 meq/100g with depth. All extractable cations except sodium (Na) fall below suitable plant concentrations according to (Hazelton and Murphy, 2016) These low CEC values can be attributed to the predominantly sandy texture of this SMU. The distribution of exchangeable cations within the topsoil indicate a misbalance between nutrients with the proportion of K on the exchange lower than ideal while all other cations are higher (Hazelton and Murphy, 2016). However, this is not likely to have a negative effect on soil quality due to low ESP values and Emerson class numbers.

The calcium to magnesium ratio (Ca/Mg) indicates that, relative to Mg, soil Ca concentration is considered low to deficient. This is not expected to affect plant growth in the topsoil; however, Ca concentration decreases below 0.5 meq/100g in the subsoil which may have potential to impact growth. Although the Ca:Mg ratio in the subsoil indicates that it has the potential to enhance sodicity (Ca/Mg <1), ESP values fall below 4% thus the risk of dispersion is extremely low. This is supported by the Emerson Class Number.

Table 19 Surface Soil (0-10 cm) Properties of the Crocodile SMU

Particle Size Analysis %					Soil Particle Density (g/cm^3)		Organic Matter (%)	
Clay	Silt	Sand	Gravel					
8	10	52	30		1.88		3.5	
Extractable Nutrients (mg/kg)				Extractable Metals (mg/kg)				
Phosphorous	Potassium	Sulphate	Nitrate	B	Cu	Fe	Mn	Zn
8	617	< 10	22	< 0.2	< 1	89.6	9.81	< 1

The topsoil is dominated by sand (52%) and gravel (30%) with 10% silt and 8% clay. This particle size distribution could limit the ability of the soil to hold and store plant available water. Organic matter content is considered as high providing a buffering capacity to pH changes, as well as imparting good structural stability and enhancing the capacity of the soil to retain nutrients and water. Regardless, the sandy composition of the surface horizon is a key limitation to the water holding capacity of a soil.

According to guidelines (Hazelton and Murphy, 2016), extractable nutrients measured in the SMU, with the exception of potassium (617 mg/kg), indicate poor growing conditions with phosphorous (8 mg/kg), nitrate (2.2 mg/kg) and sulphate (<10 mg/kg) considered to be outside the ideal range for plant life. In terms of extractable metals, iron (Fe) and manganese (Mn) fall within an acceptable range for plant growth with copper (Cu) and zinc (Zn) considered below plant suitable levels (Government of South Australia, 2013).

4.2 FISH MANAGEMENT UNIT

Soil Unit Description

Predominantly sandy soil unit occurring on the flats of the south-eastern end of the study area. Soil textures grade from loamy sand at the surface, to clay and silty sands with depth. Vegetation associated with this unit includes largely *Acacia excelsa* and *Eucalyptus populnea*.



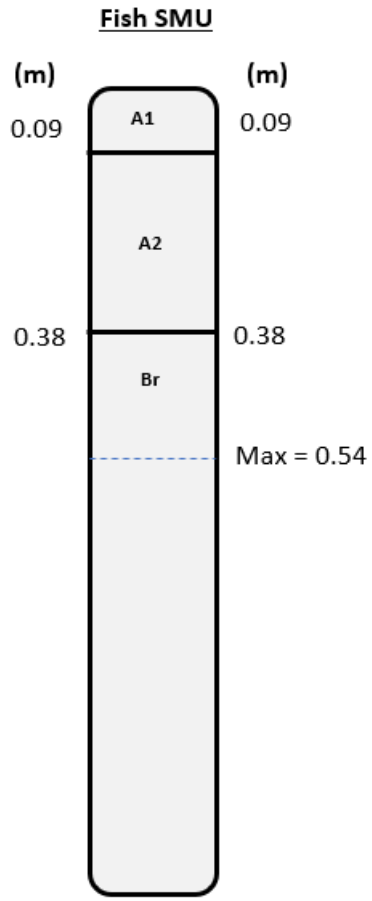
Photo Plate 2 Fish SMU Vegetation

Table 20 Key Fish SMU Parameters

Parameter	Soil Unit Description
Profile Site Numbers	VP27
Observation Site Numbers	OP46, OP50, OP51, OP52
Landform	Plains
Australian Soil Classification	Grey Kurosol
Land System	Cotherstone Land System
Slope	0%
Geology	Back Creek Group
Vegetation	Rosewood (*Acacia excelsa*), Poplar Box (*Eucalyptus populnea*)
Runoff	Slow to moderate
Permeability	Moderately permeable
Drainage	Moderate to well drained

Profile Description – Representative Sites VP27





The **surface soil** (A1) is a dark grey (10YR4/1) loamy sand with weak platy structure with the deeper horizons of the profile exhibiting diffuse red to orange mottling. It has a field pH of 5.5 to 6, demonstrating a clear change to;

The **lower surface soil** (A2) is a grey (10YR5/1) clayey loam sand. This horizon has a weak polyhedral structure and a field pH of 5.5. Abrupt change to;

The **subsoil** (Br) is a grey (10YR5/1) silty clay loam with moderate polyhedral structure. This horizon has minor occurrence of indistinct red and orange mottle with diameters of <1.5cm. This horizon has a field pH of 4.5 to 5.5.

Chemical and Physical Analysis

Table 21 Chemical Properties of the Fish SMU

Representative site: VP27								
Depth	**pH**		**EC**		**Cl**	**ESP%**		**Moisture**
(m)	**#**	**Rating**	**dS/m**	**Rating**	**(mg/kg)**	**%**	**Rating**	**(%)**
0 - 0.1	5.5	Moderately Acid	0.046	Very low	40	5.2	Non-sodic	1
0.2 - 0.3	5.2	Strongly Acid	0.042	Very low	50	8.2	Sodic	4.3
0.5 - 0.6	5.3	Strongly Acid	0.059	Very low	110	8.9	Sodic	5.3
Depth	**CEC**		**Exchangeable Cations (meq/100g)**					**Emerson Class No.**
(m)	**meq / 100g**	**Rating**	**Ca**	**Mg**	**K**	**Na**	**Ca/Mg Ratio**	
0 - 0.1	2.5	Very Low	1.3	1	0.1	0.1	1.3	3
0.2 - 0.3	4.2	Very Low	0.6	2.4	< 0.1	0.3	0.2	3
0.5 - 0.6	4.9	Very Low	0.6	3.5	< 0.1	0.4	0.2	3
Nutrient Distribution in Topsoil (%)			52.0%	40.0%	4.0%	4.0%		

The pH of the Fish SMU is considered strongly acidic throughout the profile, becoming more severe with depth to the point of introducing a risk of aluminium toxicity (pH less than 5.5). All EC values are very low which indicate the soil will not be at risk to issues associated with salinity. Chloride values are also very low and are not expected to compromise the plant environment (Rayment and Lyons, 2011).

The CEC of this soil indicates low availability of plant nutrients with all values considered below suitable levels according to guidelines (Hazelton and Murphy, 2016). There is a slight increase in CEC with depth which is likely attributed to the slight increase in clay content in deeper horizons. Of the exchangeable cations, both potassium and calcium rate as very low with manganese and sodium content considered moderate in the topsoil but increasing to high levels at depth. Nutrient distribution in topsoil indicates magnesium occupies a large proportion of the exchange capacity of the soil, contributing to the low Ca/Mg ratio.

Soil ESP values increase to what is considered sodic with depth. The very low Ca/Mg ratio in conjunction with an Emerson Class Number of 3 indicate that the subsoil of this unit is at risk of dispersion.

Table 22 Surface Soil (0-10 cm) Properties of the Fish SMU

Particle Size Analysis %					Soil Particle Density (g/cm^3)		Organic Matter (%)	
Clay	Silt	Sand	Gravel					
15	23	60	2		2.37		2.5	
Extractable Nutrients (mg/kg)				Extractable Metals (mg/kg)				
Phosphorous	Potassium	Sulphate	Nitrate	B	Cu	Fe	Mn	Zn
< 5	< 100	30	0.3	< 0.2	< 1	163	5.16	< 1

The surface soil is dominated by sand (60%) and silt (23%) with 15% clay and 2% gravel. Moderate organic matter content offers adequate structural stability while ESP and the Ca/Mg ratio indicate that the topsoil is at risk of becoming dispersive if physically disturbed.

All extractable nutrients in this SMU are deficient with phosphorous, potassium and nitrate expected to be severely limiting to plant growth. The extractable metals iron, zinc and manganese are deemed adequate for plant growth, however, both copper and boron are considered deficient (Government of South Australia, 2013)

4.3 KEI MANAGEMENT UNIT

Soil Unit Description

Brown coloured soil unit occurring on the flats of the south-eastern end of the study area. Soil textures grade from clayey to loamy sands at the surface, to medium clay with depth and orange to yellow mottles present in the deeper horizons. Vegetation associated with this unit largely includes *Eucalyptus populnea*.



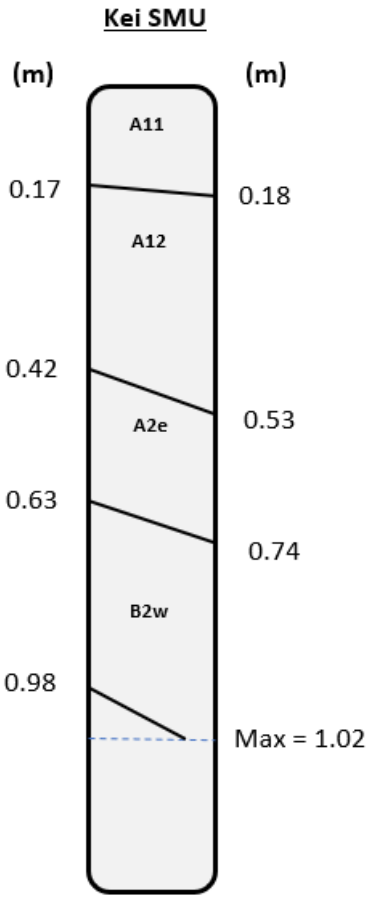
Photo Plate 3 Kei SMU Vegetation

Table 23 Key Kei SMU Parameters

Parameter	Soil Unit Description
Profile Site Numbers	VP26, VP30
Observation Site Numbers	OP30, OP52, OP58
Landform	Plains
Australian Soil Classification	Brown chromosol
Land System	Cotherstone Land System
Slope	0%
Geology	TQa – Tqa - QLD
Vegetation	Poplar Box (*Eucalyptus populnea*)
Runoff	Slow to moderate
Permeability	Moderately permeable
Drainage	Moderately well drained

Profile Description – Representative Sites VP26 and VP30





The **surface soil** (A11/A12) is a very dark greyish brown to dark yellowish brown (7.5YR3/2, 7.5YR3/4) clayey sand to sandy loam with a loose to weak platy structure. It has a field pH of 6 to 7, demonstrating a gradual to diffuse change to;

The **lower surface soil** (A2e) is a bleached brown (10YR4/4) loamy sand. This horizon has a loose structure and a field pH of 7-7.5. Clear to gradual change to;

The **subsoil** (B2w) is a dark greyish brown (10YR4/2) silty clay loam to medium clay with moderate strength polyhedral structure. This horizon has occurrence of faint yellow and orange mottles with diameters of <1.5cm. This horizon has a field pH of 7 to 7.5.

Chemical and Physical Analysis

Table 24 Chemical Properties of the Kei SMU

Representative site: VP30								
Depth	**pH**		**EC**		**Cl**	**ESP%**		**Moisture**
(m)	**#**	**Rating**	**dS/m**	**Rating**	**(mg/kg)**	**%**	**Rating**	**(%)**
0 - 0.1	6.4	Slightly Acid	0.013	Very low	< 10	1	Non-sodic	1.5
0.2 - 0.3	7	Neutral	0.014	Very low	< 10	1.4	Non-sodic	2.4
0.5 - 0.6	7.4	Slightly Alkaline	0.009	Very low	< 10	< 0.2	Non-sodic	1.7
0.8 - 0.9	8.6	Moderately Alkaline	0.101	Low	20	< 0.2	Non-sodic	8
Depth	**CEC**		**Exchangeable Cations (meq/100g)**					**Emerson Class No.**
(m)	**meq / 100g**	**Rating**	**Ca**	**Mg**	**K**	**Na**	**Ca/Mg Ratio**	
0 - 0.1	4.5	Very Low	2.9	1.1	0.5	0.1	2.6	3
0.2 - 0.3	4.4	Very Low	2.8	1.1	0.5	< 0.1	2.5	3
0.5 - 0.6	1.5	Very Low	1.5	< 0.2	< 0.2	< 0.2	< 7.5	3
0.8 - 0.9	9.4	Low	8.4	0.6	0.4	< 0.2	12.9	4
Nutrient Distribution in Topsoil (%)			64.4%	24.4%	11.1%	2.2%		

The Kei SMU has a neutral to slightly acidic pH in the upper horizons with an increase in alkalinity with depth. The pH in the upper 0.6 m is not considered plant limiting, however, in the deeper horizons of the profile this has potential to reduce plant available nutrients. This soil unit is not likely to be affected by issues associated with salinity and chloride toxicity with EC and chloride well within appropriate bounds (Rayment and Lyons 2011). ESP values in conjunction with the Ca/Mg ratio indicate a very low risk of dispersion throughout the entire profile.

CEC values in the upper 0.6 m of the profile are all very low (CEC less than 6) indicating that the soil has a poor ability to retain nutrients (Hazelton and Murphy, 2016). The CEC of soil is considered low with calcium, manganese and potassium below levels ideal for plant growth. Nutrient holding capacity and exchangeable cation content increase below this depth. The distribution of nutrients in the topsoil reflects an adequate balance of nutrients on the soil exchange with only potassium above the ideal proportion. This is not anticipated to influence the risk of dispersion of the soil (Hazelton and Murphy, 2016).

Table 25 Surface Soil (0 - 10 cm) Properties of the Kei SMU

Particle Size Analysis %					Soil Particle Density (g/cm^3)		Organic Matter (%)	
Clay	Silt	Sand	Gravel					
12	25	62	1		2.31		2.4	
Extractable Nutrients (mg/kg)				Extractable Metals (mg/kg)				
Phosphorous	Potassium	Sulphate	Nitrate	B	Cu	Fe	Mn	Zn
< 5	477	< 10	0.7	< 0.2	< 1	30.6	13.8	1.52

The surface soil of this unit is predominantly comprised of sand-sized particles (62%) with 25% silt, 12% clay and 1% gravel which is a contributing factor of the very low CEC. The topsoil is non-sodic with a Ca/Mg ratio above 2. This, along with the moderate organic matter content of 2.4%, indicates this soil is not likely to disperse.

The low phosphorous and nitrate concentration of the soil suggest deficiency in these nutrients which may be limiting to plant growth (Hazelton and Murphy 2016). Both potassium and sulphate content are within acceptable bounds for plant growth. Excluding manganese and boron, all extractable metals are sufficiently concentrated in the soil with boron likely deficient (<0.5 mg/kg) and manganese content rated high (>10 mg/kg) which has potential to induce manganese toxicity in plants (Government of South Australia, 2013).

4.4 KOMATI MANAGEMENT UNIT

Soil Unit Description

Dark brown coloured soil unit displaying vertic properties. Soil textures predominantly grade from light to medium clays with calcareous segregations occurring within the deeper horizons. Vegetation associated with this unit includes *Eucalyptus papuana* and open grassland.



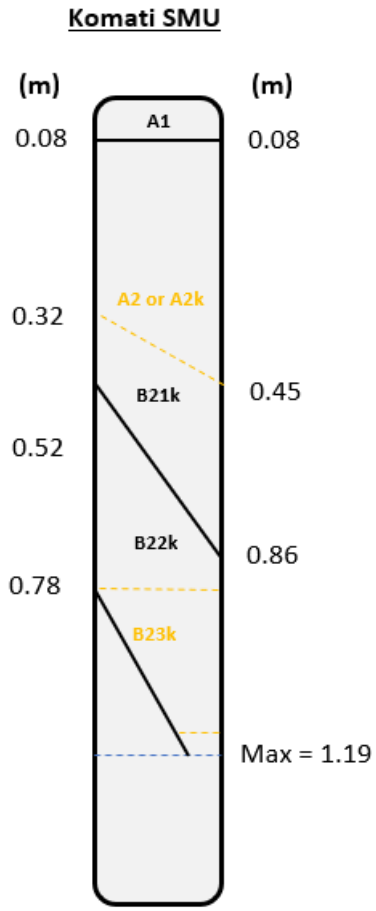
Photo Plate 4 Komati SMU Vegetation

Table 26 Key Komati SMU Parameters

Parameter	Soil Unit Description
Profile Site Numbers	VP32, VP34, VP39
Observation Site Numbers	OP23, OP24, OP25, OP42, OP43, OP65
Landform	Plains
Australian Soil Classification	Brown Vertosol
Land System	Monteagle Land System
Slope	0%
Geology	Qr - Qr - QLD
Vegetation	Dallachy's ghost gum (*Eucalyptus papuana*), grasses and shrubs
Runoff	Slow
Permeability	Slowly permeable
Drainage	Imperfectly to moderately well drained

Profile Description – Representative Sites VP32 and VP39





The **surface soil** (A1) is black to a very dark brown (7.5YR2.5/1, 7.5YR3/3) sandy clay loam to light medium clay with a polyhedral structure of moderate strength. It has a field pH of 7 to 8.5, demonstrating a clear to abrupt change to;

The **lower surface soil** (A2 or A2k) this horizon was not observed in all profiles of this SMU. It is a brown to very dark brown (7.5YR4/4, 10YR2/2) light medium to medium clay with a moderately strong polyhedral structure and a field pH of 8 - 8.5. Some profiles display a minor occurrence (< 10%) of calcareous segregations. Clear to gradual change to;

The **subsoil** (B21k, B22k, B23k) is separated into several B2 horizons depending on colour, however, all contain an abundance of calcareous segregations (20 - 50% of the horizon). Colours range from strong browns (7.5YR4/6, 7.5YR5/6) to browns and light browns 7.5YR4/4, 7.5YR6/4). Textures grade as medium clay with moderate strength lenticular to polyhedral structure. This horizon has a field pH of 8.5 to 9.

Chemical and Physical Analysis

Table 27 Chemical Properties of the Komati SMU

Representative site: VP32								
Depth	**pH**		**EC**		**Cl**	**ESP%**		**Moisture**
(m)	**#**	**Rating**	**dS/m**	**Rating**	**(mg/kg)**	**%**	**Rating**	**(%)**
0 - 0.1	6.8	Neutral	0.011	Very low	< 10	2.4	Non-sodic	2.4
0.2 - 0.3	8.5	Moderately Alkaline	0.142	Low	80	13	Sodic	7.8
0.5 - 0.6	9.5	Strongly Alkaline	0.582	High	620	18.2	Strongly Sodic	8
0.8 - 0.9	9.5	Strongly Alkaline	0.641	High	730	21.6	Strongly Sodic	7.6
Depth	**CEC**		**Exchangeable Cations (meq/100g)**					**Emerson Class No.**
(m)	**meq / 100g**	**Rating**	**Ca**	**Mg**	**K**	**Na**	**Ca/Mg Ratio**	
0 - 0.1	7	Low	3.7	3	0.2	0.2	1.2	3
0.2 - 0.3	16.4	Moderate	4.3	10	< 0.2	2.1	0.4	3
0.5 - 0.6	15.3	Moderate	3	9.5	< 0.2	2.8	0.3	4
0.8 - 0.9	14.9	Moderate	2.1	9.6	< 0.2	3.2	0.2	4
Nutrient Distribution in Topsoil (%)			52.9%	42.9%	2.9%	2.9%		

The Komati SMU is predominantly a strongly alkaline unit with pH ranging from 6.8 (neutral) at the surface to 9.5 (very strongly alkaline) in the subsoil. The higher pH has the potential to severely reduce the availability of essential plant nutrients such as nitrogen and phosphorous (Hazelton and Murphy 2016). EC values indicate that salinity is low in the upper 0.3 m the profile. Below this depth EC increases to 0.582-0.641 dS/m which is considered high. Chloride concentration increases from an acceptable concentration in the topsoil (<80 mg/kg) to 730 mg/kg in the subsoil (Rayment and Lyons 2011). This increase in EC and chloride has the potential to induce chloride toxicity which can interfere with the osmotic capacity of plants.

CEC is regarded low in the surface soil (7 meq/100g) and increases to moderate levels (approximately 15 meq/100g) in deeper horizons (Hazelton and Murphy 2016). Only magnesium (>1.6 meq/100g) is present on the soil exchange at a suitable concentration. However, and particularly in the subsoil, magnesium concentration is disproportionately large relative to other cations. This contributes to a very low Ca/Mg ratio which increases the risk of dispersion of the soil. Both calcium (<5 meq/100g) and potassium (<0.5 meq/100g) are below ideal levels throughout the profile. The distribution of nutrients within the topsoil again, reflects the imbalance between calcium and magnesium while the presence of potassium and sodium on the exchange is considered appropriate and high respectively (Hazelton and Murphy 2016).

ESP values increase rapidly with depth indicating a high risk of dispersion from as shallow as 0.2 m below the surface. This risk of dispersion is further exacerbated by the very low Ca/Mg ratio discussed

above. However, below the depth of 0.5 m, the Emerson class numbers indicate that the soil is not dispersive due to the presence of carbonate ($CaCO_3$) at this depth (Emerson, 1967).

Table 28 Surface Soil (0-10 cm) Properties of the Komati SMU

Particle Size Analysis %					Soil Particle Density (g/cm^3)		Organic Matter (%)	
Clay	Silt	Sand	Gravel					
32	11	55	2		2.24		2.7	
Extractable Nutrients (mg/kg)				Extractable Metals (mg/kg)				
Phosphorous	Potassium	Sulphate	Nitrate	B	Cu	Fe	Mn	Zn
< 5	146	< 10	0.2	< 0.2	< 1	26.6	6.8	< 1

The surface soil of the Komati SMU is composed of a moderately high clay content (32%), with 55% sand, 11% silt and 2% gravel. It has a moderate polyhedral structure with cracking occurring at the surface. The topsoil is non-sodic, however, the Emerson Class Number (3) in conjunction with a Ca/Mg ratio of 1.2 indicate that disturbance may give rise to dispersion. The particle size distribution and organic matter content (2.7%) suggest good stability of the surface horizon.

Extractable nutrient content for the surface soil is considered poor with nitrate (0.2 mg/kg), potassium (146 mg/kg) and phosphorous (<5 mg/kg) all below suitable levels for plant life and sulphate (<10 mg/kg) considered marginal (Hazelton and Murphy 2016). Of the extractable metals detected, only manganese (6.8 mg/kg) and iron (26.6 mg/kg) are present at adequate levels for plant life. Copper (<1 mg/kg), zinc (<1 mg/kg) and boron (<0.2 mg/kg) are all below concentrations suitable for plant growth (Government of South Australia, 2013).

4.5 LIMPOPO MANAGEMENT UNIT

Soil Unit Description

The Limpopo unit is a brown texture-contrast soil. Soil textures predominantly grade from sands to clay sands in the surface soils to light clays in deeper horizons. Vegetation associated with this unit includes *Eucalyptus populnea* and *Eucalyptus crebra*.



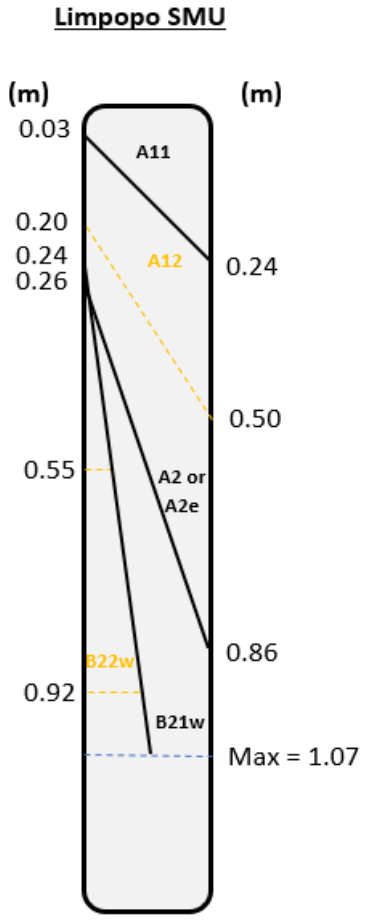
Photo Plate 5 Limpopo SMU Vegetation

Table 29 Key Limpopo SMU Parameters

Parameter	Soil Unit Description
Profile Site Numbers	VP1, VP2, VP7, VP9, VP13, VP15, VP17, VP18, VP22, VP24, VP28, VP36, VP37
Observation Site Numbers	OP6, OP8, OP10, OP11, OP18, OP19, OP22, OP23, OP26, OP32, OP33, OP39, OP41, OP45, OP46, OP47, OP48, OP49, OP55, OP56, OP57
Landform	Low rises to plains
Australian Soil Classification	Brown Sodosol
Land System	Cotherstone Land System
Slope	< 3%
Geology	Back Creek Group
Vegetation	Poplar box (*Eucalyptus populnea*), narrow-leaved ironbark (*Eucalyptus crebra*),
Runoff	Slow
Permeability	Slow to moderately permeable
Drainage	Well drained

Profile Description – Representative Sites VP7, VP15, VP17, VP18, VP22





The **surface soil** (A11, A12) is brown to a dark brown (7.5YR4/4, 7.5YR3/3) sand to loamy sand with a loose structure. It has a field pH that ranges between 5 and 6, demonstrating a clear to gradual change to;

The **lower surface soil** (A2 or A2e) is a brown to greyish brown (7.5YR4/4, 10YR5/2) with some profiles within this soil unit displaying bleaching in this horizon (A2e). Predominant textures observed in this horizon range from sandy loams to sandy clay loams with a loose to weak polyhedral structure and a field pH of 6. Clear to gradual change to;

The **subsoil** (B21w, B22w) includes dark yellowish brown to a dark greyish brown (10YR4/4, 10YR4/2) clayey or sandy loams and light clays clay with weak to moderate strength polyhedral structure. Mottling was often observed in this horizon with colours ranging between red, orange and yellow. This horizon has a field pH of 5.5 to 7.

Chemical and Physical Analysis

Table 30 Chemical Properties of the Limpopo SMU

Representative site: VP17								
Depth	**pH**		**EC**		**Cl**	**ESP%**		**Moisture**
(m)	**#**	**Rating**	**dS/m**	**Rating**	**(mg/kg)**	**%**	**Rating**	**(%)**
0 - 0.1	5.5	Moderately Acid	0.004	Very low	< 10	1	Non-sodic	1.6
0.2 - 0.3	5.5	Moderately Acid	0.005	Very low	< 10	2.6	Non-sodic	2.4
0.5 - 0.6	5.8	Moderately Acid	0.035	Very low	50	12.1	Sodic	3.8
0.8 - 0.9	5.6	Moderately Acid	0.154	Low	110	21.5	Strongly Sodic	8.6
Depth	**CEC**		**Exchangeable Cations (meq/100g)**					**Emerson Class No.**
(m)	**meq / 100g**	**Rating**	**Ca**	**Mg**	**K**	**Na**	**Ca/Mg Ratio**	
0 - 0.1	2.3	Very Low	0.8	0.5	0.4	0.1	1.6	3
0.2 - 0.3	1.8	Very Low	0.1	0.6	0.3	< 0.1	0.2	4
0.5 - 0.6	2.7	Very Low	< 0.1	1.8	0.2	0.3	< 0.1	4
0.8 - 0.9	7.3	Low	< 0.1	5.4	0.2	1.5	< 0.1	4
Nutrient Distribution in Topsoil (%)			34.78%	21.74%	17.39%	4.35%		

The upper 0.3 m of the Limpopo SMU is strongly acidic with a pH of 5.5, increasing only slightly beyond this depth. This pH is not within the bounds best suited to plant growth (Hazelton and Murphy 2016). EC and chloride concentration across the profile indicate salinity is very low with EC values ranging from 0.004 dS/m in the topsoil to 0.154 dS/m in the subsoil. Chloride concentration reflects this ranging from <10 mg/kg in the topsoil and increasing to 110 mg/kg in the subsoil which is below the limits of toxicity (Rayment and Lyons 2011).

CEC is considered very low (CEC < 6 meq/100g) across the majority of the profile increasing only slightly with depth (Hazelton and Murphy 2016). This is likely attributed to the sandy texture of the upper horizons. Potassium and calcium are present at very low concentrations throughout the soil profile with potassium consistently below 0.5 meq/100g and calcium consistently below 5 meq/100g). Although not as severe, manganese concentration is also regarded as low in the topsoil increasing to a more appropriate range in the subsoil. The Ca/Mg ratio reflects this with the ratio ranging from 1.6 in the topsoil to <0.1 in the subsoil; indicating calcium is deficient (Hazelton and Murphy 2016).

ESP values that range between 1% to 2.6% indicate the topsoil is not likely to be at risk of dispersion; however, ESP increases with depth to 21.5% in the subsoil indicating the subsoil is susceptible to dispersion. This is further supported by the very low Ca/Mg ratio discussed above although Emerson class numbers do not support this.

Table 31 Surface Soil (0-10 cm) Properties of the Limpopo SMU

Particle Size Analysis %					Soil Particle Density (g/cm^3)		Organic Matter (%)	
Clay	Silt	Sand	Gravel					
10	8	79	3		2.48		1.8	
Extractable Nutrients (mg/kg)				Extractable Metals (mg/kg)				
Phosphorous	Potassium	Sulphate	Nitrate	B	Cu	Fe	Mn	Zn
< 5	335	< 10	0.2	< 0.2	< 1	82.1	4.64	< 1

The particle size distribution reveals the A11 horizon of this SMU is strongly dominated by sand (79%) with silt and clay size particles comprising 8% and 10% of this horizon respectively. Organic matter content is regarded as moderate, contributing to average structural stability and low cohesiveness and suggesting the soil unit may be at a greater risk of erosion-induced movement.

Extractable nutrients are considered poorly balanced with both phosphorus (<5 mg/kg) and nitrate (0.2 mg/kg) concentration well below appropriate bounds for plant growth (Hazelton and Murphy, 2016). Sulphate (<10 mg/kg) presence in the topsoil is considered marginal and only potassium (335 mg/kg) content is considered suitable. Extractable metals were mostly found below suitable concentrations with copper and zinc detected at <1 mg/kg and boron at <0.2 mg/kg. Only iron (82.1 mg/kg) and manganese (4.64 mg/kg) were present at suitable concentrations (Hazelton and Murphy, 2016).

4.6 ORANGE MANAGEMENT UNIT

Soil Unit Description

Dark cracking clays associated with the flat grassy plains of the mid-eastern edge of the study area. The predominant textures of soils within this unit range from light clays in surface soils to light medium clays in deeper horizons. Vegetation associated with this unit is predominantly open grassland.



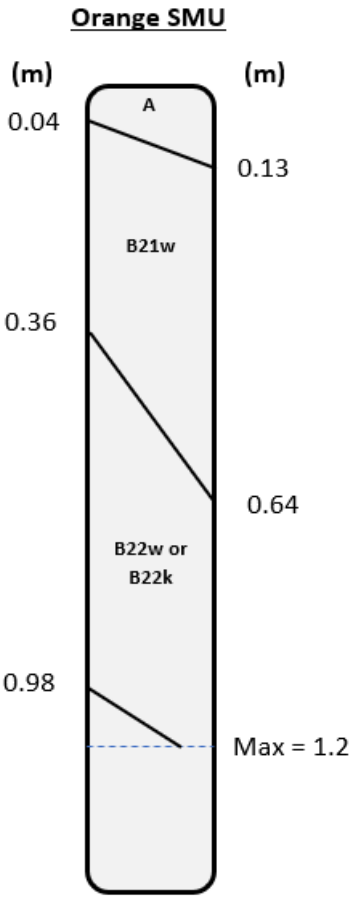
Photo Plate 6 Orange SMU Vegetation

Table 32 Key Orange SMU Parameters

Parameter	Soil Unit Description
Profile Site Numbers	VP31, VP35, VP40
Observation Site Numbers	OP21, OP24, OP25, OP44, OP60, OP61, OP62, OP65,
Landform	Plains
Australian Soil Classification	Grey Vertosol
Land System	Monteagle Land System
Slope	0%
Geology	Qr – Qr - QLD
Vegetation	Open grassland
Runoff	Slow
Permeability	Slowly permeable
Drainage	Imperfectly to moderately well drained

Profile Description – Representative Sites VP31, VP35, VP40





The **surface soil** (A) is black (10YR2/1, 2.5Y2.5/1) light clay with moderate lenticular structure. It has a field pH of 6 - 7, demonstrating an abrupt change to;

The **upper subsoil** (B21w) is a black to a very dark grey (10YR2.5/1, 2.5Y3/1) light medium clay with strong lenticular structure and a field pH of 7.5 - 8.5. Clear to diffuse change to;

The **lower subsoil** (B22w/B22k) is a very dark grey (10YR3/1, 2.5Y3/1) light medium to medium clay with strong lenticular structure. This horizon has a field pH of 8.5 – 9.

Chemical and Physical Analysis

Table 33 Chemical Properties of the Orange SMU

Representative site: VP31								
Depth	**pH**		**EC**		**Cl**	**ESP%**		**Moisture**
(m)	**#**	**Rating**	**dS/m**	**Rating**	**(mg/kg)**	**%**	**Rating**	**(%)**
0 - 0.1	8.1	Moderately Alkaline	0.135	Low	10	1.4	Non-sodic	5.5
0.2 - 0.3	8.4	Moderately Alkaline	0.054	Very low	40	7	Sodic	12.2
0.5 - 0.6	9.5	Strongly Alkaline	0.321	Medium	180	16.9	Strongly Sodic	13.1
0.8 - 0.9	9.6	Strongly Alkaline	0.575	High	540	20.8	Strongly Sodic	12.9
Depth	**CEC**		**Exchangeable Cations (meq/100g)**					**Emerson Class No.**
(m)	**meq / 100g**	**Rating**	**Ca**	**Mg**	**K**	**Na**	**Ca/Mg Ratio**	
0 - 0.1	15.5	Moderate	8.8	6.2	0.3	0.2	1.4	4
0.2 - 0.3	21	Moderate	9.4	10.1	<0.2	1.5	0.9	3
0.5 - 0.6	26.6	High	5.7	16.4	<0.2	4.5	0.3	3
0.8 - 0.9	27.7	High	4.3	17.7	<0.2	5.8	0.2	4
Nutrient Distribution in Topsoil (%)			56.8%	40.0%	1.9%	1.3%		

The Orange SMU is characterised by high pH ranging from 8.1 in the topsoil to 9.6 in the subsoil, this is beyond the pH range at which all plant nutrients are available and thus not ideal for plant growth. EC values indicate low salinity in the upper 0.3 m of the profile and increases from what is considered medium to high at depth. This has potential to compromise the health of sensitive and moderately tolerant plant species. Chloride concentrations increase from 10 mg/kg in the topsoil to 540 mg/kg in the subsoil which is considered within acceptable limits (Rayment and Lyons, 2011).

CEC increases with depth, ranging from moderate (15.5 meq/100g) in the topsoil, to high (27.7 meq/100g) in the subsoil layer. Calcium is present in the topsoil layer at a concentration of 8.8 meq/100g and decreases to 4.3 meq/100g. Magnesium concentration increases with depth from 6.2 meq/100g at the surface to 17.7 meq/100g. While the absolute concentration of calcium and magnesium are at suitable levels for plant growth, magnesium concentration is considered disproportionately high relative to calcium. This is reflected in the Ca/Mg ratio that decreases from 1.4 (calcium low) in the topsoil to 0.2 (calcium deficient) in the subsoil. In the topsoil potassium content is below the ideal concentration (0.3 meq/100mg), this decreases further with depth to <0.2 meq/100g in the subsoil. The distribution of nutrients within the topsoil shows magnesium occupying a large proportion of the exchange while the proportion of calcium on the exchange is considered lower than ideal. Both potassium and sodium are at appropriate levels (Hazelton and Murphy, 2016).

ESP values indicate the upper 0.1 m is non-sodic (1.4%), however, ESP increases beyond this depth to 20.8% in the subsoil. These ESP values in conjunction with the Ca/Mg ratio (discussed above)

suggest that soil below 0.2 m in depth is prone to dispersion. In the deeper horizons (below 0.8 m), Emerson class numbers indicate this soil is not likely to disperse due to the presence of carbonate (Emerson, 1967).

Table 34 Surface Soil (0-10cm) Properties of the Orange SMU

Particle Size Analysis %					Soil Particle Density (g/cm^3)		Organic Matter (%)	
Clay	Silt	Sand	Gravel					
28	19	51	2		2.13		3.6	
Extractable Nutrients (mg/kg)				Extractable Metals (mg/kg)				
Phosphorous	Potassium	Sulphate	Nitrate	B	Cu	Fe	Mn	Zn
< 5	182	< 10	0.2	< 0.2	< 1	27	24.5	<1

The surface soil of the Orange SMU is composed of 51% sand, 28% clay, 19% silt and 2% gravel. It has a moderate lenticular structure with a cracking, self-mulching surface. This particle size distribution in conjunction with a high organic matter content (3.5%) will contribute to good structural stability of the topsoil. ESP values suggest the topsoil is not considered to be at risk of dispersion which is supported by the Emerson Class Number of 4.

Extractable nutrients are mostly considered to be low with phosphorous (<5 mg/kg), sulphate (<10 mg/kg) and nitrate (0.2 mg/kg) all below suitable concentrations for plant life and only potassium (182 mg/kg) above the critical concentration (Hazelton and Murphy 2016). The majority of extractable metals are present at low concentrations with boron <0.2 mg/kg and both copper and zinc at <1 mg/kg. Iron (27 mg/kg) is considered adequate, however, manganese (24.5 mg/kg) is regarded as high potentially inducing manganese toxicity in plants.

4.7 SABIE MANAGEMENT UNIT

Soil Unit Description

A dark-coloured texture-contrast soil with surface soils consisting of sands, increasing in clay content in deeper horizons. Lower horizons display red to orange mottles. Vegetation associated with this unit is dominated by *Eucalyptus crebra.*



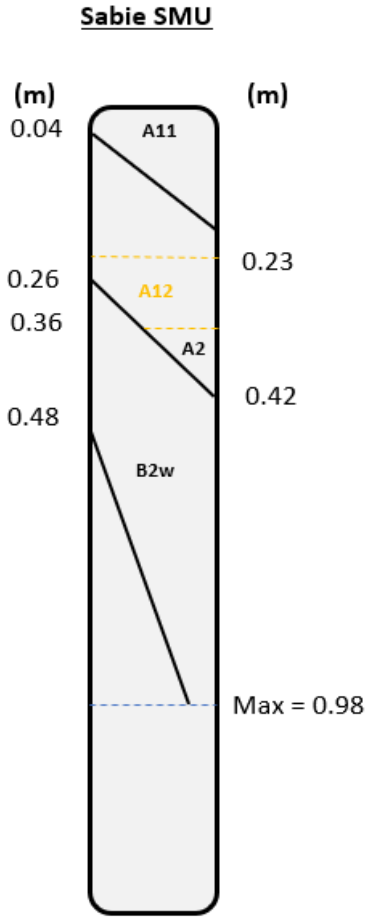
Photo Plate 7 Sabie SMU Vegetation

Table 35 Key Sabie SMU Parameters

Parameter	Soil Unit Description
Profile Site Numbers	VP10, VP11, VP12, VP14, VP20, VP21,
Observation Site Numbers	OP10, OP19, OP27, OP30, OP32, OP33, OP35, OP41
Landform	Rises and Plains
Australian Soil Classification	Red Sodosol
Land System	Carborough Land System
Slope	<10%
Geology	Back Creek Group
Vegetation	Narrow-leaved ironbark (*Eucalyptus crebra*), Bloodwood (*Corymbia erythrophloia*)
Runoff	Slow to moderate
Permeability	Moderately permeable
Drainage	Moderate to well drained

Profile Description – Representative Sites VP10, VP11, VP12, VP20





The **surface soil** (A11/A12) is black to very dark brown (2.5YR2.5/1, 7.5YR2.3/3) sand to loamy sand with loose to very weak platy structure. It has a field pH of 5 - 7, demonstrating a clear to abrupt change to;

The **lower surface soil** (A2) is a brown to a dark reddish brown (7.5YR4/4, 5YR3/3) clayey sand to sandy clay loam with loose or very weak polyhedral structure and a field pH of 5 - 6. Clear to gradual change to;

The **lower subsoil** (B2w) is a dark reddish brown to dusky red (5YR3/3, 2.5Y3/2) clayey loam to medium clay with moderate polyhedral structure. This horizon has a field pH of 5 - 6.

Chemical and Physical Analysis

Table 36 Chemical Properties of the Sabie SMU

Representative site: VP10								
Depth	**pH**		**EC**		**Cl**	**ESP%**		**Moisture**
(m)	**#**	**Rating**	**dS/m**	**Rating**	**(mg/kg)**	**%**	**Rating**	**(%)**
0 - 0.1	4.6	Strongly Acid	0.128	Low	50	3.2	Non-sodic	2
0.2 - 0.3	4.9	Strongly Acid	0.025	Very low	10	9.2	Sodic	5
0.5 - 0.6	5.9	Moderately Acid	0.02	Very low	20	8.4	Sodic	11.6
0.8 - 0.9	6	Slightly Acid	0.108	Low	140	15.4	Strongly Sodic	9.9
Depth	**CEC**		**Exchangeable Cations (meq/100g)**					**Emerson Class No.**
(m)	**meq / 100g**	**Rating**	**Ca**	**Mg**	**K**	**Na**	**Ca/Mg Ratio**	
0 - 0.1	3.7	Very Low	1.3	0.6	0.5	0.1	2.2	3
0.2 - 0.3	3.5	Very Low	0.1	0.5	0.3	0.1	0.2	3
0.5 - 0.6	8.1	Low	< 0.1	5.6	0.6	0.6	< 0.1	3
0.8 - 0.9	9.6	Low	< 0.1	7.4	0.4	1.4	< 0.1	2
Nutrient Distribution in Topsoil (%)			35.1%	16.2%	13.5%	2.7%		

The surface soil of the Sabie SMU is strongly acidic (pH < 5) to a depth of 0.3 m which has potential to reduce plant available nutrients and induce aluminium toxicity. Beyond this depth pH increases to 6 which is suitable for plant life. EC is low throughout the profile, with EC values varying between 0.02 dS/m to 0.128 dS/m with no obvious trend associated with depth. The chloride concentration reflects the low EC with chloride consistently below 300 mg/kg.

CEC values are considered very low in the topsoil (3.7 meq/100g) and increase with depth to 9.6 meq/100g in the subsoil. Throughout the profile calcium is below ideal levels and decreases from 1.3 meq/100g to <0.1 meq/100g in the subsoil. Topsoil magnesium concentration is also below ideal levels at 0.6 meq/100g, however, with depth this increases to an acceptable concentration. Overall potassium concentration is sufficient for plant life as it varies within close-proximity of the critical concentration of 0.5 meq/100g. Nutrients in the topsoil are poorly distributed with the proportion of the exchange occupied by calcium considered below ideal while both sodium and potassium in particular are considered high (Hazelton and Murphy 2016).

ESP increases from 3.2% in the topsoil to 15.4% in the subsoil. This information in conjunction with the Ca/Mg ratio indicates the risk of dispersion increases substantially below 0.2m. The Emerson class numbers of 3 and 2 support this (Emerson 1967).

Table 37 Surface Soil (0-10cm) Properties of the Sabie SMU

Particle Size Analysis %					Soil Particle Density (g/cm^3)		Organic Matter (%)	
Clay	Silt	Sand	Gravel					
12	10	75	3		2.29		4.1	
Extractable Nutrients (mg/kg)				Extractable Metals (mg/kg)				
Phosphorous	Potassium	Sulphate	Nitrate	B	Cu	Fe	Mn	Zn
< 5	446	30	35.8	0.3	< 1	226	8	< 1

The A11/A12 horizon of this SMU is dominated by sand-sized particles (75%) with 12% clay, 10% silt and 3% gravel. It has a loose single grain to weak platy structure with high organic matter content (4.1%). This information in conjunction with the ESP and Ca/Mg ratio of this topsoil layer suggest the topsoil is not prone to dispersion if undisturbed.

Apart from phosphorous (<5 mg/kg), all extractable nutrients are present in the topsoil at concentrations suitable for plant life (Hazelton and Murphy 2016). Of the extractable metals, only manganese (8 mg/kg) is detected at a suitable concentration. Both copper (<1 mg/kg) and zinc (<1 mg/kg) are low for plant growth and iron concentration is found to be very high with the capacity to induce iron toxicity in plants.

4.8 ZAMBEZI MANAGEMENT UNIT

Soil Unit Description

A predominantly grey coloured texture-contrast soil with surface soils consisting of sands, increasing in clay content in deeper horizons. Lower horizons display diffuse orange to yellow mottles. Vegetation associated with this unit is dominated by *Eucalyptus populnea.*



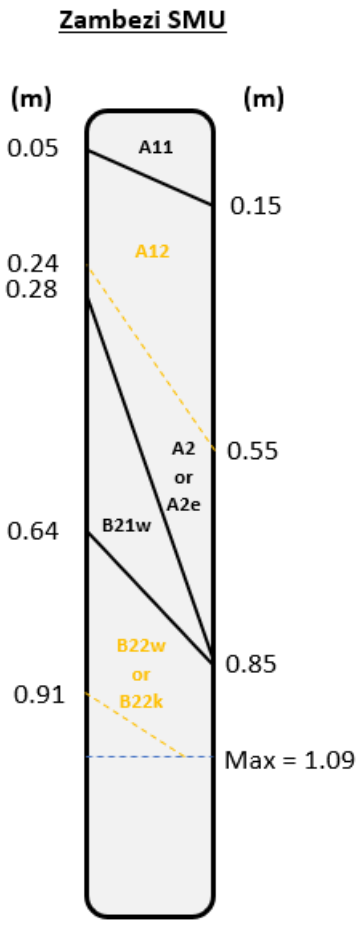
Photo Plate 8 Zambezi SMU Vegetation

Table 38 Key Zambezi SMU Parameters

Parameter	Soil Unit Description
Profile Site Numbers	VP16, VP19, VP23, VP25, VP29, VP33, VP38, VP41. VP42
Observation Site Numbers	OP18, OP28, OP29, OP32, OP34, OP35, OP37, OP39, OP40, OP41, OP43, OP45, OP47, OP55, OP56, OP57, OP58
Landform	Plains
Australian Soil Classification	Grey Sodosol
Land System	Cotherstone Land System
Slope	<3%
Geology	TQa – Tqa-QLD
Vegetation	Poplar-box (Eucalyptus populnea), Narrow-leaved ironbark (Eucalyptus crebra)
Runoff	Slow
Permeability	Moderately permeable
Drainage	Moderately well drained

Profile Description – Representative Sites VP25, VP29





The **surface soil** (A11/A12) is dark brown to a very dark greyish brown (7.5YR2.2.5/5, 10YR3/2) coarse grained loamy sand with loose to very weak platy structure. It has a field pH of 5.5 - 7, demonstrating a clear to abrupt change to;

The **lower surface soil** (A2/A2e) is a brown to greyish brown (7.5YR5/4, 10YR5/2) loamy sand with some profiles displaying this as a bleached horizon with loose single-grained structure and a field pH of 6 - 7.5. Clear to abrupt change to;

The **lower subsoil** (B2w) is a light grey to grey (10YR7/2, 7.5YR6/1) clayey loam sand to silty clay loam with moderate polyhedral structure. This horizon has a field pH of 7 - 9.

Chemical and Physical Analysis

Table 39 Chemical Properties of the Zambezi SMU

Representative site: VP25								
Depth	**pH**		**EC**		**Cl**	**ESP%**		**Moisture**
(m)	**#**	**Rating**	**dS/m**	**Rating**	**(mg/kg)**	**%**	**Rating**	**(%)**
0 -0.1	6.4	Slightly Acid	0.018	Very low	< 10	0.6	Non-sodic	1.8
0.2 - 0.3	6.7	Slightly Acid	0.005	Very low	< 10	0.1	Non-sodic	2.8
0.5 - 0.6	7.8	Slightly Alkaline	0.059	Very low	40	18.5	Strongly Sodic	7.2
0.8 - 0.9	9	Strongly Alkaline	0.174	Low	160	23.3	Strongly Sodic	9.1
Depth	**CEC**		**Exchangeable Cations (meq/100g)**					**Emerson Class No.**
(m)	**meq / 100g**	**Rating**	**Ca**	**Mg**	**K**	**Na**	**Ca/Mg Ratio**	
0 - 0.1	3.4	Very Low	2.3	0.8	0.4	0.1	2.9	3
0.2 - 0.3	1.8	Very Low	1.3	0.4	0.1	0.1	3.2	4
0.5 - 0.6	5.1	Very Low	1.1	3.1	< 0.2	0.9	0.4	2
0.8 - 0.9	10	Low	1.7	5.7	< 0.2	2.3	0.3	2
Nutrient Distribution in Topsoil (%)			67.7%	23.5%	11.8%	2.9%		

The Zambezi SMU has a slightly acidic (6.4 – 6.7) pH in the upper 0.3 m of the profile which is not considered plant limiting. However, beyond this depth pH rises to very strongly alkaline (9), which is beyond the suitable pH range for plants (Hazelton and Murphy 2016). EC values and chloride concentration are both well below appropriate limits. EC values range from 0.0018 dS/m in the topsoil to 0.174 dS/m in the subsoil. The chloride concentration is consistently below 300 mg/kg throughout the profile.

CEC is predominantly regarded as very low (<6 meq/100g) with a slight increase in the deepest observed horizon. This is reflected in the low concentrations of extractable cations with calcium and potassium consistently below 5 meq/100g and 0.5 meq/100g respectively. Topsoil magnesium concentrations are considered low (<1.6 meq/100g) but increase to concentrations suitable for plant life with depth. Within the topsoil, the proportion of the exchange occupied by calcium is considered appropriate, however the presence of magnesium, potassium and sodium on the exchange is above ideal (Hazelton and Murphy 2016).

The upper 0.3 m of the profile is non-sodic with ESP values well below 6%. Below this point ESP values increase to 23.2% indicating high potential for dispersion. This is supported by the very low Ca/Mg ratios and an Emerson Class Number of 2 in the subsoil (Emerson 1967).

Table 40 Surface Soil (0-10cm) Properties of the Zambezi SMU

Particle Size Analysis %					Soil Particle Density (g/cm^3)		Organic Matter (%)	
Clay	Silt	Coarse Sand	Gravel					
9	14	77	< 1		2.43		2	
Extractable Nutrients (mg/kg)				Extractable Metals (mg/kg)				
Phosphorous	Potassium	Sulphate	Nitrate	B	Cu	Fe	Mn	Zn
< 5	311	< 10	2.6	< 2	< 1	60.7	8.92	<1

The surface horizon (A11) of the Zambezi SMU is dominated by sand (77%) with 14% silt, 9% clay and <1% gravel and has a loose to weak platy structure. This, in conjunction with the low organic matter content (2%) suggests poor structural stability of topsoil layer. The topsoil is non-sodic with very low Ca/Mg ratio indicating the topsoil is not dispersive if undisturbed.

Nutrient levels in the topsoil layer are generally poor, with nitrate (2.6 mg/kg), sulphate (<10 mg/kg) and phosphorous (<5 mg/kg) below suitable levels and potassium (311 mg/kg) above the critical concentration indicating potassium is not deficient. Extractable metals vary in suitability with iron (60.7 mg/kg), manganese (8.92 mg/kg), and boron (<2 mg/kg) present in suitable concentrations and both copper (<1 mg/kg) and zinc (<1 mg/kg) at lower than preferred levels for plant growth (Hazelton and Murphy 2016).

5.0 STRATEGIC CROPPING LAND ASSESSMENT

The RPI Act aims to identify areas of Queensland that are of regional interest because they contribute, or are likely to contribute, to Queensland's economic, social and environmental prosperity. The RPI Act also aims to give effect to the policies about matters of State interest stated in regional plans, and to effectively manage the impact of resource activities on the areas of regional interest.

Areas of regional interest that the RPI Act aims to protect are classified as:

- living areas in regional communities (Priority Living Areas);
- high-quality agricultural areas from dislocation (Priority Agricultural Areas);
- strategic cropping areas; and
- regionally important environmental areas (Strategic Environmental Areas).

Detailed descriptions of what constitutes each type of area of regional interest are provided in Sections 8 to 11 of the RPI Act as well as the Regional Planning Interests Regulation 2014 (RPI regulation). The RPI Act and RPI Regulation seek to strike an appropriate balance between protecting priority land uses and delivering a diverse and prosperous economic future for our regions.

There are no areas of regional interest within the study area. The nearest mapped strategic cropping areas are located between 13 to 15 km to the north-west, south-west and south-east of the study area.

6.0 LAND SUITABILITY ASSESSMENT

Land suitability refers to the adequacy of land for a defined use. Land suitability assessment considers environmental factors including climate, soils, geology, geomorphology, erosion, topography and the effects of past land uses. The classification does not always represent the current land use. Rather, it indicates the potential of the land to be used for specific agricultural activities. The aim of this land suitability assessment is to evaluate the suitability of the Project area for agricultural land uses including cattle grazing and dryland cropping, prior to the development of the mine.

The assessment for land suitability (cattle grazing and rainfed broadacre cropping) has been carried out in accordance with the methodologies described in:

- DSITI and DNRM (2015). *Guidelines for Agricultural Land Evaluation in Queensland* (2nd edition). Queensland Government, Brisbane, Queensland; and
- DME (1995). *Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland – Land suitability Assessment Techniques*, Queensland Government. Brisbane, Queensland.

The five land suitability classes used for assessing land are defined in Table 41. Land is considered less suitable as the severity of limitations for a land use increase. The land suitability class reflects the score of the most limiting attribute for a given SMU. An increase in limitations may reflect either:

- reduced potential for production;
- increased inputs to achieve an acceptable level of production;
- increased inputs to prepare the land for successful production; and/or
- increased inputs required to prevent land degradation.

Table 41 Agricultural and Conservation Land Classes

Class	Agricultural description	Conservation description
Class 1	**Suitable land with negligible limitations.** This is highly productive land requiring only simple management practices to maintain economic production.	Areas well suited for conservation uses must possess significant conservation benefits in the pre-mining environment and be capable of being returned to that use post-mining.
Class 2	**Suitable land with minor limitations** which either reduce production or require more than the simple management practices of class 1 land to maintain economic production.	Areas suited to conservation use in that a significant component of the pre-mining conservation values can be restored post-mining. There will however be some loss in conservation values where soil terrain or hydrological post-mining conditions may inhibit the full replication of the pre-mining values.
Class 3	**Suitable land with moderate limitations** which either further lower production or require more than those management practices of class 2 land to maintain economic production.	These lands contain significant conservation values pre-mining, however restoration of all of these values may not be feasible. These areas could, however be restored to a form of conservation use which provides alternative conservation benefits.
Class 4	**Marginal land**, which is presently considered unsuitable due to severe limitations. The long-term significance of these limitations on the proposed land use is unknown or not quantified. The use of this land is dependent upon undertaking additional studies to determine whether the effect of the limitation(s) can be reduced to achieve sustained economic production.	These lands contain limited conservation value pre-mining and/ or are incapable of being effectively restored post-mining to any alternative conservation use which provides similar benefits. The area could however be restored to provide a stable form of use which does not impact on surrounding conservation values.
Class 5	**Unsuitable land** with extreme limitations that preclude its use.	These lands contain no significant conservation values.

6.1 CATTLE GRAZING

Limitations for the assessment of grazing land suitability on improved pastures as outlined in the Land Suitability Assessment Technique (QDME, 1995) Guidelines (Table 2.2) are:

- Water availability;
- Nutrient deficiency;
- Soil physical factors;
- Salinity;
- Rockiness;
- Micro relief;
- pH;
- ESP;
- Wetness;
- Topography;
- Water erosion;
- Flooding; and
- Vegetation.

Numerous parameters outlined in this assessment require determination of the ‘rootzone’. The rootzone is the depth to hard or weathered rock, or the depth to a significant salt bulge within the soil profile. Where these limitations are not encountered within the sampling depth, a value of 0.6 m can be assumed as the rootzone as described in the QDME guidelines (1995).

For cattle grazing, **Class 1** and **Class 2** land is considered suitable for grazing improved pastures with maximum grazing productivity achieved in most seasons. **Class 3** land is considered suitable for grazing improved pastures however, it is less productive than **Classes 1** and **2**. **Class 4** land is categorised as marginal for grazing improved pastures although it is largely considered suitable for grazing native pastures of variable quality. **Class 5** land is unsuitable for any form of pasture improvement and is limited to low productivity grazing of native pastures. Due to the poor soil quality **Class 5** land may require destocking in poor seasons.

Each of the limitations listed above is assessed in the following subsections on the basis of Table 2.2 of the QDME guidelines (1995).

6.1.1 Water Availability

The availability of water in soils is vital for both plants and soil organisms as they require water to survive. The PAWC cut-off levels for each of the land suitability classes for beef cattle grazing are as follows:

Class 1: > 125 mm

Class 2: 100 - 125 mm

Class 3: 75 - 100 mm

Class 4: 50 - 75 mm

Class 5: < 50 mm

These cut-off levels are not based on a specific species of pasture, but on pasture as a general land use. The soils are assessed on the depth to weathered rock, or other root inhibiting factors such as a salt bulge or significant sodicity. Table 42 provides the outcomes of the land suitability class assessment on the basis of plant available water capacity.

Table 42 Land Suitability for Cattle Grazing based on PAWC

Soil Management Unit	Limiting Features	PAWC (mm)	Land Suitability Class
Crocodile	Shallow sands and sandy loams ⩽ 45 cm deep	⩽ 50 mm	5
Fish	Sands and sandy loams 45 - 90 cm deep	50 - 75 mm	4
Kei	Sands and sandy loams > 90 cm deep	75 - 100 mm	3
Komati	Cracking clays: alkaline to neutral pH throughout and 60- 90 cm depth to ESP ⩾ 15	100 - 125 mm	2
Limpopo[1]	Duplex soils with subsoil becoming sodic (ESP 6 - 14) within 60 cm of the surface but not strongly sodic (ESP ⩾ 15) within 90 cm	75 - 100 mm	3
Orange	Cracking clays: alkaline to neutral pH throughout and 60 - 90 cm depth to ESP ⩾ 15	100 - 125 mm	2
Sabie	Duplex soils with subsoil becoming sodic (ESP 6 - 14) within 60 cm of the surface but not strongly sodic (ESP ⩾ 15) within 90 cm	75 - 100 mm	3
Zambezi[1]	Duplex soils with a sodic subsoil (ESP 6 - 14) becoming strongly sodic (ESP ⩾ 15) within 60 cm of surface	50 - 75 mm	4

Notes: 1 SMUs present within the Project area

6.1.2 Nutrient Deficiency

The nutrient status of each SMU identified has been assessed and the results are presented in Table 43. Note that bicarbonate phosphorus was only analysed within the topsoil layer (0 - 10 cm). Soil nutrients are vital for plant and animal growth and metabolism.

Table 43 Land Suitability for Cattle Grazing based on Nutrient Status

Soil Management Unit	Limiting Features	Land Suitability Class
Crocodile	Sands and loams at least 75 cm deep or overlying rock at shallow depth, with bicarbonate P 5 - 10 ppm,	4
Fish	Sands and loams at least 75 cm deep or overlying rock at shallow depth, with bicarbonate P ⩽ 4 ppm	4
Kei	Sands and loams at least 75 cm deep or overlying rock at shallow depth, with bicarbonate P ⩽ 4 ppm	4
Komati	Other soils with bicarbonate P 5 - 10 ppm	3
Limpopo[1]	Sands and loams at least 75 cm deep or overlying rock at shallow depth, with bicarbonate P ⩽ 4 ppm	4
Orange	Other soils with bicarbonate P 5 - 10 ppm	3
Sabie	Sands and loams at least 75 cm deep or overlying rock at shallow depth, with bicarbonate P ⩽ 4 ppm	4
Zambezi[1]	Sands and loams at least 75 cm deep or overlying rock at shallow depth, with bicarbonate P ⩽ 4 ppm	4

Notes: 1 SMUs present within the Project area

6.1.3 Soil Physical Factors

Soil physical factors for each SMU identified have been assessed with results presented in Table 44. The physical condition of soils plays a direct role with seed germination and emergence. Adverse conditions such as hard-setting or crusting of surface soils reduces plant establishment through creating a barrier, reducing seed soil contact.

Table 44 Land Suitability for Cattle Grazing based on Soil Physical Factors

Soil Management Unit	Limiting Features	Land Suitability Class
Crocodile	Rigid soils with a loose, soft or firm surface when dry	1
Fish	Rigid soils with a loose, soft or firm surface when dry	1
Kei	Rigid soils with a loose, soft or firm surface when dry	1
Komati	Cracking clays with fine self-mulch (peds 2-10 mm)	2
Limpopo[1]	Rigid soils with a loose, soft or firm surface when dry	1
Orange	Cracking clays with fine self-mulch (peds 2-10 mm)	2
Sabie	Rigid soils with a hard-setting surface when dry	3
Zambezi[1]	Rigid soils with a loose, soft or firm surface when dry	1

Notes: 1 SMUs present within the Project area

6.1.4 Salinity

Land suitability class for each SMU based on salinity has been assessed with the results provided in Table 45. Given salinity can inhibit plant growth, the highest EC recorded is considered the most limiting factor and dictates the rating given to each SMU. Significant levels of salinity present in the rootzone can negatively impact plant growth and production.

Table 45 Land Suitability for Cattle Grazing based on Salinity

Soil Management Unit	Limiting Features	Land Suitability Class
Crocodile	Rootzone EC < 0.15 mS/cm	1
Fish	Rootzone EC < 0.15 mS/cm	1
Kei	Rootzone EC < 0.15 mS/cm	1
Komati	Rootzone EC 0.3 - 0.9 mS/cm	3
Limpopo[1]	Rootzone EC < 0.15 mS/cm	1
Orange	Rootzone EC 0.15 - 0.3 mS/cm[2]	2
Sabie	Rootzone EC < 0.15 mS/cm	1
Zambezi[1]	Rootzone EC < 0.15 mS/cm	1

Notes: 1 SMUs present within the Project area
2 The 0.5–0.6 Orange horizon marginally exceeds the 0.3 threshold but given the EC values for adjacent upper horizons it is considered sufficiently close to the threshold to warrant the classification provided.

6.1.5 Rockiness

The land suitability for each SMU based on rockiness was assessed with results presented in Table 46. The impacts of rockiness are more extreme for cropping than for grazing. With respect to grazing, rock outcrops reduce the area available to grow pasture, indirectly impacting the carrying capacity of the land.

6.1.6 Microrelief

The microrelief for each SMU identified has been assessed with results presented in Table 47. Microrelief refers to local relief (up to several metres) around the plane of the land (National Committee on Soil and Terrain, 2009). Impacts of microrelief on the suitability of land for cattle grazing are only experienced when soil is severely melonholed. Ponding of water in the depressions can reduce pasture yield, indirectly impacting the land's carrying capacity.

Table 46 Land Suitability Cattle Grazing based on Rockiness

Soil Management Unit	Limiting Features	Land Suitability Class
Crocodile	20 - 50% surface cobble (6 - 20 cm diameter) and rock outcrop	3
Fish	< 10 course surface gravel (> 6 cm diameter)	1
Kei	< 10 course surface gravel (> 6 cm diameter)	1
Komati	< 10 course surface gravel (> 6 cm diameter)	1
Limpopo[1]	< 10 course surface gravel (> 6 cm diameter)	1
Orange	< 10 course surface gravel (> 6 cm diameter)	1
Sabie	< 10 course surface gravel (> 6 cm diameter)	1
Zambezi[1]	< 10 course surface gravel (> 6 cm diameter)	1

Notes: 1 SMUs present within the Project area

Table 47 Land Suitability for Cattle Grazing based on Microrelief

Soil Management Unit	Limiting Features	Land Suitability Class
Crocodile	Melonholes cover <20% surface area	1
Fish	Melonholes cover <20% surface area	1
Kei	Melonholes cover <20% surface area	1
Komati	Melonholes cover <20% surface area	1
Limpopo[1]	Melonholes cover <20% surface area	1
Orange	Melonholes cover <20% surface area	1
Sabie	Melonholes cover <20% surface area	1
Zambezi[1]	Melonholes cover <20% surface area	1

Notes: 1 SMUs present within the Project area

6.1.7 pH

The land suitability class for pH has been assessed with results presented in Table 48. Soil pH determines the availability of nutrients for plant intake. Where a soil material is strongly acidic, aluminium and manganese toxicity may limit root growth and plant productivity. Were an improved pasture post-mining land use to be targeted, there may be a need to for ameliorants to correct soil pH and increase nutrient availability.

Table 48 Land Suitability for Cattle Grazing based on pH

Soil Management Unit	Limiting Features	Land Suitability Class
Crocodile	pH 5.0 - 5.6	2
Fish	pH 5.0 - 5.6	2
Kei	pH 6.6 - 8.0	2
Komati	pH 6.6 - 8.0	2
Limpopo[1]	pH 5.0 - 5.6	2
Orange	pH 8.0 - 9.0	3
Sabie	pH 4.5 - 5.0	3
Zambezi[1]	pH 6.6 - 8.0	2

Notes: 1 SMUs present within the Project area

6.1.8 Exchangeable Sodium Percentage (ESP)

The ESP of each SMU identified has been assessed with results presented in Table 49. ESP is used to determine the erosion potential of soils. The land suitability class identified for each SMU based on ESP in the upper 100 mm of soil.

Table 49 Land Suitability for Cattle Grazing based on ESP

Soil Management Unit	Limiting Features	Land Suitability Class
Crocodile	ESP < 5%	1
Fish	ESP 5 - 10%	2
Kei	ESP < 5%	1
Komati	ESP < 5%	1
Limpopo[1]	ESP < 5%	1
Orange	ESP < 5%	1
Sabie	ESP < 5%	1
Zambezi[1]	ESP < 5%	1

Notes: 1 SMUs present within the Project area

6.1.9 Wetness

The land suitability class identified for each SMU based on wetness has been assessed with results presented in Table 50. The wetness limitation refers to any excess water both in and on the soil profile. The adverse effects of excess water include reducing plant growth, impeding oxygen supply to plant roots (possibly leading to denitrification) and increased risk of plant disease.

Table 50 Land Suitability for Cattle Grazing based on Wetness

Soil Management Unit	Limiting Features	Land Suitability Class
Crocodile	Undulating terrain or elevated plains	1
Fish	Non-sodic rigid soils with coarse pale grey and yellow mottles within 50 cm of the surface	2
Kei	Low-lying level plains	2
Komati	Rigid soils with strongly sodic subsoil (ESP⩾15) within 60 cm of the surface	2
Limpopo[1]	Non-sodic rigid soils with coarse pale grey and yellow mottles within 50 cm of the surface	2
Orange	Low-lying level plains	2
Sabie	Undulating terrain or elevated plains	1
Zambezi[1]	Rigid soils with strongly sodic subsoil (ESP⩾15) within 60 cm of the surface	2

Notes: 1 SMUs present within the Project area

6.1.10 Water Erosion

The land suitability class identified for each SMU based on water erosion has been assessed with the results presented in Table 51. Erosion of topsoil reduces the productivity of the land through the loss of key nutrients in the soil's upper horizons.

Table 51 Land Suitability for Cattle Grazing based on Water Erosion

Soil Management Unit	Limiting Features	Land Suitability Class
Crocodile	Slopes 3 - 12% on non-sodic rigid soils	2
Fish	Slopes < 3% on non-sodic soils	1
Kei	Slopes < 3% on non-sodic soils	1
Komati	Slopes < 3% on non-sodic soils	1
Limpopo[1]	Slopes < 3% on non-sodic soils	1
Orange	Slopes < 3% on non-sodic soils	1
Sabie	Slopes < 3% on non-sodic soils	1
Zambezi[1]	Slopes < 3% on non-sodic soils	1

Notes: 1 SMUs present within the Project area

6.1.11 Flooding

The land suitability class identified for each SMU based on flooding risk has been assessed with results presented in Table 52. Flooding may result in plant death or reduced growth. In severe cases where land is inundated for a prolonged period stock loss and loss of grazing production may also occur.

Table 52 Land Suitability for Cattle Grazing based on Flooding

Soil Management Unit	Limiting Features	Land Suitability Class
Crocodile	No flooding	1
Fish	No flooding	1
Kei	No flooding	1
Komati	Periodic flooding	2
Limpopo[1]	No flooding	1
Orange	Periodic flooding	2
Sabie	No flooding	1
Zambezi[1]	Periodic flooding	2

Notes: 1 SMUs present within the Project area

6.1.12 Vegetation Regrowth (management limitation)

The land suitability class identified for each SMU based on vegetation regrowth has been assessed with results presented in Table 53. Vegetation communities may contain poisonous species or woody weeds that will limit the productivity of grazing pastures to varying degrees and increase the need for land management. The density of tree species and presence of a woody shrub layer may also limit the carrying capacity of the land.

Table 53 Land Suitability for Cattle Grazing based on Vegetation

Soil Management Unit	Limiting Features	Land Suitability Class
Crocodile	Bloodwood and ironbark open woodland	1
Fish	Acacia scrub without melonholes	1
Kei	Acacia scrub without melonholes	1
Komati	Box woodlands without wattle understorey	2
Limpopo[1]	Box and ironbark woodlands without wattle understorey	2
Orange	Grasslands	1
Sabie	Bloodwood and ironbark open woodlands	1
Zambezi[1]	Box and ironbark woodlands without wattle understorey	2

Notes: 1 SMUs present within the Project area

6.1.13 Summary of Land suitability for Cattle Grazing

Table 54 provides a summary of the assessed land suitability limitations for a beef cattle grazing land use.

In the study area, the suitability of land for cattle grazing is mostly limited by pH controlled nutrient deficiency and water availability.

Unsuitable pH conditions can greatly reduce nutrient levels in the soil. This has potential to impact livestock production through a reduction in pasture growth and nutrient value of pasture species. Additionally, water availability can also compromise pasture growth by inducing water stress in pasture species and preventing the mobilisation of nutrients in the root zone

While no Class 1 or Class 2 land was identified for the study area, examination of the land suitability limitations for cattle grazing (Table 54) indicates that 737 ha is suitable for cattle grazing with moderate limitations (Class 3). The majority of the study area (6,859 ha) is considered marginal land with the remaining area (2,524 ha) comprised of Class 5 land.

All land within the Project area comprises Class 4 land.

It is important to note that although the two SMUs present in the Project area are classified as Class 4 (marginally suitable); given this is the current land use of the area, the land is considered suitable for grazing. The land suitability framework is used as a guide to determine potential land suitability and should be considered alongside historical land use. One of the two limiting factors which produced a land suitability class of 4 is limited soil phosphorous (< 10 mg/kg), which is able to be overcome with the addition of phosphorous to topsoil before re-spreading.

Figure 4 shows the distribution of land suitability classes for cattle grazing across the study area.

Table 54 Summary of Land Suitability Limitations for Cattle Grazing

Limitation	Crocodile	Fish	Kei	Komati	Limpopo[1]	Orange	Sabie	Zambezi[1]
Water availability	5	4	3	2	3	2	3	4
Nutrient deficiency	4	4	4	3	4	3	4	4
Soil physical factors	1	1	1	2	1	2	3	1
Salinity	1	1	1	3	1	2	1	1
Rockiness	3	1	1	1	1	1	1	1
Microrelief	1	1	1	1	1	1	1	1
pH	2	2	2	2	2	3	3	2
ESP (10cm) %	1	2	1	1	1	1	1	1
Wetness	1	2	2	2	2	2	1	2
Water erosion	2	1	1	1	1	1	1	1
Flooding	1	1	1	2	1	2	1	2
Vegetation Regrowth	1	1	1	2	2	1	1	2
Overall Suitability Rating	**5**	**4**	**4**	**3**	**4**	**3**	**4**	**4**

Notes: 1 SMUs present within the Project area. Green shading = suitable, red shading = unsuitable.

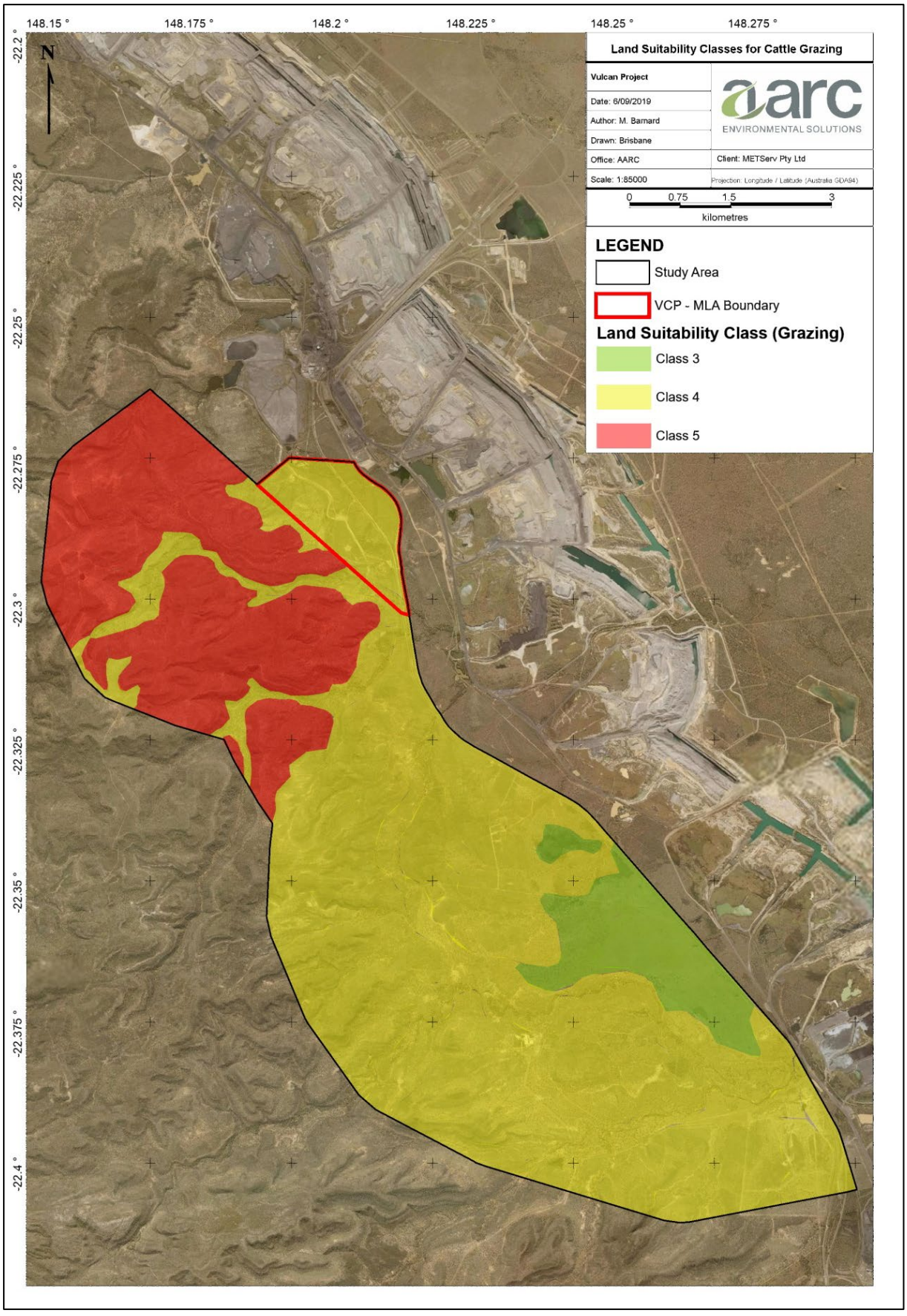


Figure 4 Cattle Grazing Land Suitability Classes

6.2 RAINFED BROADACRE CROPPING

Limitations for the assessment of rainfed broadacre cropping as outlined in the Land Suitability Assessment Technique (QDME 1995) Guidelines (Table 2.1) are:

- Water availability;
- Nutrient deficiency;
- Soil physical factors;
- Soil workability
- Salinity;
- Rockiness;
- Micro relief;
- Wetness;
- Topography;
- Water erosion; and
- Flooding.

Numerous parameters outlined in this assessment require determination of the 'rootzone'. The rootzone is the depth to hard or weathered rock, or the depth to a significant salt bulge within the soil profile. Where these limitations are not encountered within the sampling depth, a rootzone value of 0.6 m can be assumed as described in the QDME guidelines (1995).

Class 1 and **Class 2** land is considered suitable for rainfed broadacre cropping with negligible or minor limitations and limited management requirements to sustain this use. **Class 3** land is considered suitable however, it is likely to be less productive than lands of Class **1 or 2**. **Class 4** land is categorised as marginally suitable for rainfed broadacre cropping or would require significant inputs to ensure land use sustainability. **Class 5** land is unsuitable having extreme limitations and cannot be sustainably used for the rainfed broadacre cropping.

Each of the limitations listed above are assessed below on the basis of Table 2.1 of the QDME guidelines (1995).

6.2.1 Water Availability

The PAWC cut-off levels for each of the land suitability classes are as follows:

Class 1: > 150 mm

Class 2: 125 – 150 mm

Class 3: 100 - 125 mm

Class 4: 75 – 100 mm

Class 5: < 75 mm

These cut-off levels are not based on a specific crop-type, but on rainfed broadacre cropping as a general land use. The soils are assessed on the depth to weathered rock, or other root inhibiting factors such as a salt bulge or significant sodicity. The availability of water in soils is vital for both plants and soil organisms as they require water to survive. Table 55 provides the outcomes of the land suitability class assessment on the basis of plant available water capacity.

Table 55 Land Suitability for Rainfed Broadacre Cropping based on PAWC

Soil Management Unit	Limiting Features	PAWC (mm)	Land Suitability Class
Crocodile	Shallow sands and sandy loams ≤45 cm deep	< 75 mm	5
Fish	Sands and sandy loams 45-90 cm deep	< 75 mm	5
Kei	Sands and sandy loams >90 cm deep	75 - 100 mm	4
Komati	Cracking clays: alkaline to neutral pH throughout and 60-90 cm depth to ESP ≥ 15	100 -125 mm	3
Limpopo[1]	Duplex soils with subsoil becoming sodic (ESP 6-14) within 60 cm of the surface but not strongly sodic (ESP ≥ 15) within 90 cm	75 - 100 mm	4
Orange	Cracking clays: alkaline to neutral pH throughout and 60-90 cm depth to ESP ≥ 15	100 -125 mm	3
Sabie	Duplex soils with subsoil becoming sodic (ESP 6-14) within 60 cm of the surface but not strongly sodic (ESP ≥ 15) within 90 cm	75 - 100 mm	4
Zambezi[1]	Duplex soils with a sodic subsoil (ESP 6-14) becoming strongly sodic (ESP ≥ 15) within 60 cm of surface	< 75 mm	5

Notes: 1 SMUs present within the Project area

6.2.2 Nutrient Deficiency

The nutrient status of each SMU identified has been assessed and the results are presented in Table 56. Note that bicarbonate phosphorus was only analysed within the topsoil layer (0 - 10 cm). Soil nutrients are vital for plant growth and metabolism.

Table 56 Land Suitability for Rainfed Broadacre Cropping based on Nutrient Status

Soil Management Unit	Limiting Features	Land Suitability Class
Crocodile	Bicarbonate P 5 - 10 ppm and exchangeable K ≤ 0.3 meq %	3
Fish	Bicarbonate P < 10 ppm and exchangeable K ≤ 0.3 meq % and exchangeable Ca < 3 meq %	4
Kei	Bicarbonate P < 10 ppm and exchangeable K ≤ 0.3 meq % and exchangeable Ca < 3 meq	4
Komati	Bicarbonate P < 10 ppm and exchangeable K ≤ 0.3 meq % and exchangeable Ca < 3 meq %	4
Limpopo[1]	Bicarbonate P < 10 ppm and exchangeable K ≤ 0.3 meq % and exchangeable Ca < 3 meq %	4
Orange	Bicarbonate P 5 - 10 ppm and exchangeable K ≤ 0.3 meq %	3
Sabie	pH < 5 within 30 cm of the surface	5
Zambezi[1]	Bicarbonate P < 10 ppm and exchangeable K ≤ 0.3 meq % and exchangeable Ca < 3 meq %	4

Notes: 1 SMUs present within the Project area

6.2.3 Soil Physical Factors

Soil physical factors for each SMU identified have been assessed with results presented in Table 57. The physical condition of soils plays a direct role with seed germination and emergence. Adverse conditions such as hard-setting or crusting of surface soils reduces plant establishment through creating a barrier, reducing seed soil contact.

Table 57 Land Suitability for Rainfed Broadacre Cropping based on Soil Physical Factors

Soil Management Unit	Limiting Features	Land Suitability Class
Crocodile	Rigid soils with a hard-setting surface when dry	3
Fish	Rigid soils with a loose, soft or firm surface when dry	1
Kei	Rigid soils with a loose, soft or firm surface when dry	1
Komati	Cracking clays with fine self-mulch (peds 2-10 mm)	2
Limpopo[1]	Rigid soils with a loose, soft or firm surface when dry	1
Orange	Cracking clays with fine self-mulch (peds 2-10 mm)	2
Sabie	Rigid soils with a hard-setting surface when dry	3
Zambezi[1]	Rigid soils with a loose, soft or firm surface when dry	1

Notes: 1 SMUs present within the Project area

6.2.4 Soil Workability

Soil physical factors for each SMU identified have been assessed with results presented in Table 58. The workability of soils refers to the capacity of the soil to support machinery during management practices such as tillage.

Table 58 Land Suitability for Rainfed Broadacre Cropping based on Soil Workability

Soil Management Unit	Limiting Features	Land Suitability Class
Crocodile	Rigid soils with a hard-setting surface when dry	2
Fish	Rigid soils with a loose, soft or firm surface when dry	1
Kei	Rigid soils with a loose, soft or firm surface when dry	1
Komati	Firm cracking clays	2
Limpopo[1]	Rigid soils with a loose, soft or firm surface when dry	1
Orange	Firm cracking clays	2
Sabie	Rigid soils with a loose, soft or firm surface when dry	1
Zambezi[1]	Rigid soils with a loose, soft or firm surface when dry	1

Notes: 1 SMUs present within the Project area

6.2.5 Salinity

Land suitability class for each SMU based on salinity has been assessed with the results provided in Table 59. Given salinity can inhibit plant growth, the highest EC recorded is considered the most limiting factor and dictates the rating given to each SMU. Significant levels of salinity present in the rootzone can negatively impact plant growth and production.

Table 59 Land Suitability for Rainfed Broadacre Cropping based on Salinity

Soil Management Unit	Limiting Features	Land Suitability Class
Crocodile	Rootzone EC < 0.15 mS/cm	1
Fish	Rootzone EC < 0.15 mS/cm	1
Kei	Rootzone EC < 0.15 mS/cm	1
Komati	Rootzone EC 0.3 – 0.9 mS/cm	3
Limpopo[1]	Rootzone EC < 0.15 mS/cm	1
Orange	Rootzone EC 0.3 – 0.9 mS/cm	3
Sabie	Rootzone EC < 0.15 mS/cm	1
Zambezi[1]	Rootzone EC < 0.15 mS/cm	1

Notes: 1 SMUs present within the Project area

6.2.6 Rockiness

The land suitability for each SMU based on rockiness was assessed with results presented in Table 60. The impacts of rockiness are more extreme for cropping than for grazing. In regard to cropping, rock outcrops reduce the area available to grow crops, as land cannot be easily traversed or mechanised.

Table 60 Land Suitability for Rainfed Broadacre Cropping based on Rockiness

Soil Management Unit	Limiting Features	Land Suitability Class
Crocodile	20-50% surface cobble (6-20 cm diameter) and rock outcrop	3
Fish	<10 course surface gravel (>6 cm diameter)	1
Kei	<10 course surface gravel (>6 cm diameter)	1
Komati	<10 course surface gravel (>6 cm diameter)	1
Limpopo[1]	<10 course surface gravel (>6 cm diameter)	1
Orange	<10 course surface gravel (>6 cm diameter)	1
Sabie	<10 course surface gravel (>6 cm diameter)	1
Zambezi[1]	<10 course surface gravel (>6 cm diameter)	1

Notes: 1 SMUs present within the Project area

6.2.7 Microrelief

The microrelief for each SMU identified has been assessed with results presented in Table 61. Microrelief refers to local relief (up to several metres) around the plane of the land (National Committee on Soil and Terrain 2009). Impacts of microrelief on the suitability of land for rainfed broadacre cropping are only experienced when soil is severely melonholed. Ponding of water in the depressions can compromise growing conditions directly impacting on crop growth and yield.

Table 61 Land Suitability for Rainfed Broadacre Cropping based on Microrelief

Soil Management Unit	Limiting Features	Land Suitability Class
Crocodile	No melonholes (semi-circular depressions <30 cm deep and usually surrounded by mounds)	1
Fish	No melonholes (semi-circular depressions <30 cm deep and usually surrounded by mounds)	1
Kei	No melonholes (semi-circular depressions <30 cm deep and usually surrounded by mounds)	1
Komati	Melonholes cover <20% surface area	2
Limpopo[1]	No melonholes (semi-circular depressions <30 cm deep and usually surrounded by mounds)	1
Orange	Melonholes cover <20% surface area	2
Sabie	No melonholes (semi-circular depressions <30 cm deep and usually surrounded by mounds)	1
Zambezi[1]	No melonholes (semi-circular depressions <30 cm deep and usually surrounded by mounds)	1

Notes: 1 SMUs present within the Project area

6.2.8 Wetness

The land suitability class identified for each SMU based on wetness has been assessed with results presented in Table 62. The wetness limitation refers to any excess water both in and on the soil profile. The adverse effects of excess water include reducing plant growth, impeding oxygen supply to plant roots (possibly leading to denitrification) and increased risk of plant disease.

Table 62 Land Suitability for Rainfed Broadacre Cropping based on Wetness

Soil Management Unit	Limiting Features	Land Suitability Class
Crocodile	Undulating terrain or elevated plains	1
Fish	Non-sodic rigid soils with coarse pale grey and yellow mottles within 50 cm of the surface	3
Kei	Low-lying level plains with melonholes covering <25 % surface area	2
Komati	Rigid soils with strongly sodic subsoil (ESP≥15) within 60 cm of the surface	3
Limpopo[1]	Rigid soils with sodic subsoil (ESP 6 - 14) within 60 cm of the surface	2
Orange	Rigid soils with strongly sodic subsoil (ESP≥15) within 60 cm of the surface	3
Sabie	Rigid soils with sodic subsoil (ESP 6 - 14) within 60 cm of the surface	2
Zambezi[1]	Rigid soils with strongly sodic subsoil (ESP≥15) within 60 cm of the surface	3

Notes: 1 SMUs present within the Project area

6.2.9 Topography

The land suitability class identified for each SMU based on wetness has been assessed with results presented in Table 63. The topography limitation refers to the surface features of the land. Substantial variation in slope and elevation of an area can introduce limitations for cropping by reducing the area of land on which cropping is viable.

Table 63 Land Suitability for Rainfed Broadacre Cropping based on Topography

Soil Management Unit	Limiting Features	Land Suitability Class
Crocodile	Many deep gullies make the arable areas too small to cultivate	4
Fish	No gully dissection	1
Kei	No gully dissection	1
Komati	No gully dissection	1
Limpopo[1]	No gully dissection	1
Orange	No gully dissection	1
Sabie	Occasional deep gullies impede cultivation slightly	2
Zambezi[1]	Occasional deep gullies impede cultivation slightly	2

Notes: 1 SMUs present within the Project area

6.2.10 Water Erosion

The land suitability class identified for each SMU based on water erosion has been assessed with the results presented in Table 64. Erosion of topsoil reduces the productivity of the land through the loss of key nutrients in the upper horizons of the soil.

Table 64 Land Suitability for Rainfed Broadacre Cropping based on Water Erosion

Soil Management Unit	Limiting Features	Land Suitability Class
Crocodile	Slopes >6% on non-sodic rigid soils	5
Fish	Slopes 1-2 % on non-sodic soils	2
Kei	Slopes 1-2 % on non-sodic soils	2
Komati	Slopes <1% on non-sodic rigid soils	1
Limpopo[1]	Slopes 1-2 % on non-sodic soils	2
Orange	Slopes <1% on non-sodic rigid soils	1
Sabie	Slopes 1-2 % on non-sodic soils	2
Zambezi[1]	Slopes 1-2 % on non-sodic soils	2

Notes: 1 SMUs present within the Project area

6.2.11 Flooding

The land suitability class identified for each SMU based on flooding risk has been assessed with results presented in Table 65. Flooding may result in plant death or reduced growth. In severe cases where land is inundated for a prolonged period crop failure may occur.

Table 65 Land Suitability for Rainfed Broadacre Cropping based on Flooding

Soil Management Unit	Limiting Features	Land Suitability Class
Crocodile	No flooding	1
Fish	No flooding	1
Kei	No flooding	1
Komati	Rare flooding	2
Limpopo[1]	No flooding	1
Orange	Rare flooding	2
Sabie	No flooding	1
Zambezi[1]	Infrequent flooding	3

Notes: 1 SMUs present within the Project area

6.2.12 Summary of Land suitability for Rainfed Broadacre Cropping

Table 66 provides a summary of the assessed land suitability limitations for a rainfed broadacre cropping land use.

In the study area, the suitability of land for rainfed broadacre cropping is primarily limited by nutrient deficiency and water availability.

Unsuitable poor nutrient availability in the soil has potential to impact crop health and yield. Fertiliser application is thus required to overcome this limitation, which is an additional expense to agricultural systems, subsequently reducing profitability of a farm. Additionally, water availability can also compromise crop growth by inducing water stress in crops and preventing the mobilisation of nutrients in the root zone

No Class 1, Class 2 or Class 3 land was identified within the Project area. Examination of the land suitability limitations for cattle grazing (Table 54) indicates that 392 ha of the Project area is considered marginal land (Class 4) with the remainder of the Project area (16 ha) comprised of Class 5 land.

Figure 5 shows the distribution of land suitability classes for cattle grazing across the study area.

Table 66 Summary of Land Suitability Limitations for Rainfed Broadacre Cropping

Limitation	Crocodile	Fish	Kei	Komati	Limpopo[1]	Orange	Sabie	Zambezi[1]
Water availability	5	5	4	3	4	3	4	5
Nutrient deficiency	3	4	4	4	4	3	5	4
Soil physical factors	3	1	1	2	1	2	3	1
Soil workability	2	1	1	2	1	2	1	1
Salinity	1	1	1	3	1	3	1	1
Rockiness	3	1	1	1	1	1	1	1
Microrelief	1	1	1	2	1	2	1	1
Wetness	1	3	2	3	2	3	2	3
Topography	4	1	1	1	1	1	2	2
Water erosion	5	2	2	1	2	1	2	2
Flooding	1	1	1	2	1	2	1	3
Overall Suitability Rating	**5**	**5**	**4**	**4**	**4**	**3**	**5**	**5**

Notes: 1 SMUs present within the Project area. Green shading = suitable, red shading = unsuitable.

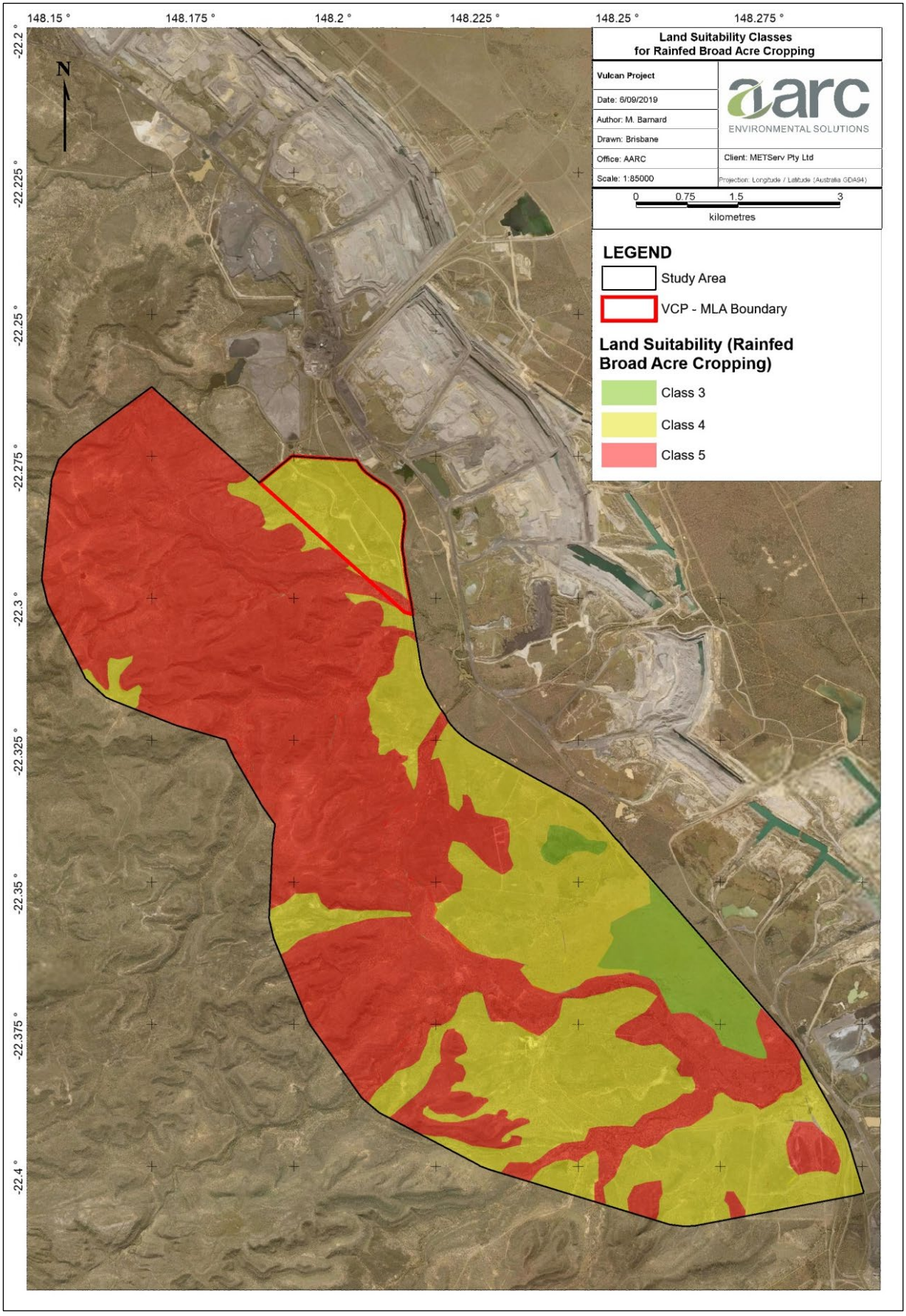


Figure 5 Rainfed Broadacre Cropping Land Suitability Classes

7.0 AGRICULTURAL LAND ASSESSMENT

Agricultural land class classification follows a hierarchical scheme in order to identify land that can be used sustainably for a particular land use to limit land degradation. There are three broad classes of agricultural land, namely Class A, Class B and Class C with one non-agricultural land class (Class D). Descriptions of agricultural land classes relevant to this agricultural assessment are provided in Table 67 below (DNRM/DSITIA, 2015).

Table 67 Description of Agricultural Land Classes

Class	Description
A	Cropping Land – Land that is suitable for a wide range of crops with nil to moderate limitations.
B	Limited Cropping Land – Land that is suitable for a narrow range of crop types.
C1	Pasture Land – Land suitable for grazing on native pastures on higher fertility soils.
C2	Pasture Land – Land suitable for grazing on native pastures on lower fertility soils.
C3	Pasture Land – Land suitable for light grazing on native pastures in accessible areas, and includes steep land.
D	Non-agricultural Land – Land not suitable for agricultural use.

Based on the outcome of the land suitability assessment, study area SMUs have been assigned the agricultural land classes as per Table 68.

Table 68 Summary of Agricultural Land Classes

Agricultural Land Class Assessment		
Soil Management Unit	**Class**	**Area (ha)**
Crocodile	C3	2,524
Fish	C3	77
Kei	C2	140
Komati	C2	263
Limpopo[1]	C2	3,328
Orange	C2	474
Sabie	C3	1,869
Zambezi[1]	C3	1,445

Notes: 1 SMUs present within the Project area

8.0 SOIL HANDLING RECOMMENDATIONS

8.1 TOPSOIL SUITABILITY AND STRIPPING

In general, fertility decreases with depth in response to the variation with depth of the various parameters impacting on soil fertility. For the study area, usable soil resources are mainly confined to the surface horizons, which contain the seedstock, micro-organisms and nutrients necessary for plant growth. This section lists the SMUs and the maximum depth to which suitable material may be stripped for stockpiling and future rehabilitation. Stripping recommendations have been determined based on the SMU characteristics detailed in Section 4.0.

Where practicable, stripping should be timed to avoid periods of excessive rain or prolonged dry periods. Where practicable, topsoil should be directly placed in prepared rehabilitation areas and used immediately rather than stockpiled for later use. Where topsoils have been identified as requiring amelioration and where practicable, the areas where they have been re-spread and/or the stockpiles where they have been stored should be delineated and recorded to ensure the appropriate treatment subsequently occurs.

Table 69 summarises the maximum depths to which each SMU should be stripped, a detailed discussion of each SMU's topsoil resource is outlined in the following sections.

Table 69 Maximum Topsoil Stripping Depths for all Soil Management Units

SMU	Topsoil Stripping Depth (m)
Crocodile	0.1
Fish	0.1
Kei	0.6
Komati	0.1
Limpopo[1]	0.3
Orange	0.1
Sabie	0.1
Zambezi[1]	0.3

Notes: 1 SMUs present within the Project area

Crocodile Soil Management Unit (Stripping Depth 0.1 m)

The Crocodile SMU is limited in its suitability as a topsoil medium where an improved pasture post-mining land use is to be implemented. The land within this SMU has uneven rocky terrain which may introduce accessibility challenges for earth-moving machinery. Given this, the total volume of topsoil able to be sourced from this SMU may be reduced. The soil is very strongly acidic at the surface (pH 5.4) remaining so with depth. pH values such as these have potential to limit soil nutrient content and thus plant growth. Furthermore, this soil unit is very shallow often containing large quantities of unweathered rock material.

The Crocodile SMU may be better suited to use where a native ecosystem post-mining land use similar to that existing on this SMU is to be re-instated. In these circumstances, this material could be stripped to 0.1 to 0.2 m depth but should be segregated to ensure its use in an appropriate post-mining land use.

Fish Soil Management Unit (Stripping Depth 0.1 m)

The topsoil to 0.1 m of the Fish SMU is suitable for rehabilitation purposes. Although acidic with a pH of 5.5, the topsoil of this unit is within the range suitable for plant growth. Due to a very low nutrient holding capacity (CEC 2.5 meq/100g), its use in an improved pasture post-mining land use would benefit from fertiliser additions. Below the depth of 0.1 m, the Fish SMU becomes sodic and thus dispersive. Therefore, a stripping depth of 0.1 m is recommended.

Kei Soil Management Unit (Stripping Depth 0.6 m)

The upper 0.6 m of the Kei SMU is suitable for most rehabilitation end-uses as this soil has suitable pH and low ESP and salinity. Below this depth, the soil becomes moderately alkaline (pH 8.6), which can affect plant productivity by reducing plant-available nutrients. The Kei SMU has low nutrient content (CEC > 4.5 meq/100g) and would therefore benefit from fertiliser addition when revegetating. A stripping depth of 0.6 m is recommended.

Komati Soil Management Unit (Stripping Depth 0.1 m)

Soil to a depth of 0.1 m in the Komati SMU is considered suitable for most rehabilitation purposes. Below this depth, the soil is severely limited by its chemical characteristics with pH increasing to 8.5 and continuing to become more alkaline with depth. This pH level will limit plant available nutrients compromising plant growth and health. Furthermore, the soil becomes more susceptible to dispersion with ESP values of 13% also increasing with depth. A stripping depth of 0.1 m is recommended.

Limpopo Soil Management Unit (Stripping Depth 0.3 m)

The Limpopo SMU is suitable for most rehabilitation end-uses in the top 0.3 m of the profile. Below this depth, sodicity increases to strongly sodic levels, increasing the risk of dispersion and susceptibility to erosion. The nutrient holding capacity of this soil is very low with CEC at 2.3 meq/100g. The addition of fertiliser would enhance revegetation success. Importantly, the topsoil associated with this SMU is predominantly composed of sand (79%) and should therefore not be placed on slopes exceeding 3% without appropriate measures to manage stability.

Orange Soil Management Unit (Stripping Depth 0.1 m)

The topsoil of the Orange SMU to 0.1 m is suitable for most rehabilitation end-uses. This soil possesses adequate plant nutrients and is not saline. However, surface soil in this unit is moderately alkaline (pH 8.1) which is towards the top of the suitable pH range for plant growth. Depending on the desired rehabilitation outcome, pH adjustment may be desirable. Below a depth of 0.1 m, pH becomes moderately to strongly alkaline and may be limiting for plant growth. In addition, ESP values increase to

7% and continue to increase with depth. Therefore, below 0.1 m this SMU is at risk of dispersion and will be limited in its potential to be used as a topsoil /growth medium.

Sabie Soil Management Unit (Stripping Depth 0.1 m)

Due to several constraining factors, the Sabie SMU is not considered suitable for rehabilitation use except where a native ecosystem outcome similar to the pre-mining situation is intended. The surface soil of this unit is very strongly acidic (pH 4.6) limiting the availability of essential plant nutrients. The risk of aluminium toxicity is also high. The additional constraint of sodicity becomes apparent below the depth of 0.1 m with ESP values of 9% which increase throughout the profile.

Zambezi Soil Management Unit (Stripping Depth 0.3 m)

The Zambezi SMU is suitable for most rehabilitation purposes to a depth of 0.3 m. This surface layer has suitable pH, low salinity and is not sodic. Below this depth, the soil becomes strongly sodic with an ESP of 18.5% and is therefore at high risk of dispersion and subsequent erosion. Stripping is therefore only recommended to a depth of 0.3 m. To assist initial revegetation success, it may be beneficial to supplement this surface soil with fertiliser to improve the inherent low nutrient value of soil. The surface soil of this unit is predominantly composed of sand-sized particles (77% sand) and it is therefore recommended that the use of this soil on rehabilitated surfaces exceeding a 3% slope should be limited.

8.2 TOPSOIL STOCKPILING

Stockpiling of topsoil for extended periods can lead to physiochemical and biological deterioration in the soil and affect the viability of the soil seed bank. Where possible, topsoil should be directly placed in prepared rehabilitation areas rather than stockpiled to assist in maintaining a viable seedbank and promote timely revegetation.

Where stockpiling of topsoil is required, the following recommendations for soil management will reduce the risk of soil degradation and improve the chances of rehabilitation success:

- Where practicable, stockpiles should be less than 2m high and be constructed and positioned in a manner that encourages water drainage and discourages erosion, and with appropriate erosion and sediment controls in place;
- If there is a risk of a grass cover not establishing voluntarily, stockpiles will need to be ripped and seeded with a quick establishment pasture. Topsoil should ideally be stockpiled for the minimum time. Studies in the Hunter Valley have shown that most deterioration occurs within the first year (Keipert *et al.*, 2005).
- Stockpiles should be monitored for erosion and weeds and control measures implemented as appropriate; and
- Where soil has been stockpiled for extended periods, soil testing is recommended before use for rehabilitation purposes. If required, fertilisers and soil ameliorants should be applied.

Table 70 shows the estimated volumes of topsoil resource per SMU within the Project disturbance area, given the stripping depths outlined in section 8.1. The proposed disturbance area for the VCP Project is shown in Figure 6.

Table 70 Estimated Soil Volumes – Project Disturbance Area

SMU	Topsoil Stripping Depth (m)	SMU Area (m^2)	Potential Soil Volume (m^3)
Limpopo*	0.3	2,766,000	829,800
Zambezi*	0.3	9,400	2,820
Total Topsoil= 832,620 m^3			

Notes: SMUs with an asterisk (*) indicate soils where amelioration measures (e.g. liming agents, fertiliser), or actions (e.g. mixing) are considered beneficial to achieve a grazing land use outcome.

8.3 TOPSOIL PLACEMENT

The proposed disturbance area (Figure 6) within the VCP Project area suggests that the topsoil resource will be sourced predominantly from the Limpopo SMU. The Limpopo SMU is characterised as having moderate organic matter content and a high sand content and may therefore be at a greater risk of erosion-induced movement (Section 4.5). For this SMU, establishing a sufficient vegetative cover to mitigate erosion risk is important, particularly as rehabilitated slopes increase. To create a favourable environment for vegetation growth, topsoil from the Limpopo SMU will require application of one or more of the amelioration measures outlined in the following sub-sections.

Where possible, placement of topsoil at a minimum thickness of 0.2m is recommended for rehabilitation areas to create a growth medium of sufficient depth to hold water and support revegetation. For all rehabilitated areas, contour ripping and/or ploughing of the landform after topsoil placement should be undertaken to key the topsoil and subsoil layers together, and to improve seed germination conditions. Placement of armour rock or mulch cover to assist in stabilising the landform and reducing topsoil loss should be considered for slopes above 10%.

8.3.1 Topsoil amelioration

8.3.1.1 Organic matter application

Sandy soils such as the Limpopo SMU, usually have poor soil structure, low moisture retention and low available nutrient concentrations. The addition of organic matter to such soils helps to bind soil aggregates together and resist physical breakdown, improving soil structure; in turn increasing soil moisture retention and re-incorporating nutrients back into the soil. Where possible, topsoil should be stripped with its existing ground cover vegetation and, if subject to stockpiling, relocated with its cover crop vegetation.

Depending on availability, additional organic matter (such as mulches, manures, or compost), could be incorporated into the topsoil. Organic materials incorporated into the topsoil will increase organic carbon levels, providing more exchange sites for necessary cations, increase water holding capacity, and ensure less organic matter is oxidised into carbon dioxide and nitrous oxide or reduced into methane (Smith *et. al*., 2018). Application rates will vary depending on mulch type. Straw mulch should be applied at a rate of 5 t/ha (NSW Government 2015). Note that fresh mulch should not be used in acidic soils. Manure should be incorporated at rates of 5-30 t/ha (depending on the type of manure) (MLA n.d.). If available, compost can be applied at 70-150 t/ha (Kelly 2006).

8.3.1.2 Fertiliser application

Fertilisers can be utilised to increase nutrient concentrations in soil. As the Limpopo SMU is moderately acidic (pH of 5.5) care must be taken when fertilising, as some fertilisers (such as ammonium-based fertilisers) can have an acidifying effect on the soil. Were this to occur, lime applications would be required to mitigate the fertiliser's acidifying effects.

A calcium nitrate-based fertiliser such as calcium ammonium nitrate (15 to 27% N) is suitable for this application as it has near neutral effect on soil pH and can be used to increase both nitrogen and calcium levels in the soil. An application rate of 25-50 kg N/ha should be sufficient for successful vegetation establishment (CRDC 2020). This could be complemented with an application of sulphate of potash (41 % K) to increase potassium levels in the soil. This fertiliser would also increase sulphur and can be drilled with seeds (unlike other potassium fertilisers such as muriate of potash which can damage seed germination). Typical application rates of potassium for pastures in light soils are of around 20 kg K/ha (Department of Primary Industries n.d.).

Alternatively, urea (46.7% N) could be applied as a nitrogen fertiliser (usually the most economical nitrogen fertiliser), but this would need to be applied in combination with lime (calcium carbonate), to overcome the acidifying effects of urea. A rate of 150 kg/ha of urea is recommended for soils in low rainfall areas where soil nitrate content is below 3 mg/kg. Limestone application rates should be around 1 t/ha of lime. It is expected that 1 t/ha of lime (incorporated in the first 10 cm of soil) can increase the pH of sandy soils by 0.57 units (Department of Primary Industries n.d.). It is important to do follow up pH testing to evaluate the need to add more lime - lime should be added initially at small doses and then at gradually increasing application rates as necessary.

Phosphorus application rates should be carefully determined, as many Australian native species are adapted to low phosphorus concentrations in the soil. Application rates of 10-20 kg P/ha have been suggested for grazing pastures (Victoria Government 2013) and mine restoration (Daws *et al.* 2013). To achieve this, single superphosphate (8.8% P) could be applied, which would also supply sulphate. (Note this fertiliser should not be blended with urea).

It is important that after application, soil ameliorants are incorporated into the soil to preferably a depth of about 0.3 m (for example by using a scarifier or ripper tynes) so they are not lost by wind or washed away by rainfall. After vegetation establishment (after 6 to 12 months since sowing), soils should be re-tested to determine if any follow-up application of ameliorants is required.

Besides using fertilisers, incorporating native leguminous forbs such as *Rhynchosia minima (*Rhynchosia) and *Glycine tabacina* (Variable Glycine) to the seed mix is a more natural method of increasing soil nitrogen levels due to the nitrogen fixing capabilities of legume species. This could establish natural nitrogen cycling within the topsoil resulting in long-term improvements in soil fertility and self-sustaining vegetation.

8.3.2 Cover crops

A fast-establishing sterile annual cover crop is recommended to be included in the seed mix. This will help to rapidly establish ground cover and minimise topsoil loss. This approach will also help to supress weeds and assist in restarting biological processes in the soil, creating a favourable micro-environment for the germination and emergence of the native seeds. Considering the sandy nature of the Limpopo topsoil, it is recommended that a cover crop is sown at a high seed density, of approximately 30 kg/ha. This should provide a rapid ground cover and assist in achieving soil stabilisation. *Echinochloa esculenta* (Japanese Millet) could be used for summer applications and *Lolium sp*. (Rye Grass) for winter applications. In the transition between cold and warm seasons, a combination of both species should be used.

8.3.3 Hydromulching

The use of hydromulching as an alternative to direct seeding is a further option that can be considered in zones at higher risk of erosion. Hydromulch consists of a semi-liquid water-based mixture composed of seed, water, mulch and other components (such as fertiliser, coir and tackifiers) which can be added depending on the site's amelioration requirements. The seed mix is included in the hydromulch slurry, which is sprayed onto the revegetation site as a thin layer (approximately 10 mm) to the soil surface, usually at a rate of approximately 50 m^3/ha for topsoil applications. The aim of using hydromulch is to cover and protect the soil, together with providing a suitable germination environment for seeds. The use of hydromulch can be effective at controlling erosion and stabilising the soil, by providing an erosion resistant layer for the period of time it takes for vegetation to become established.

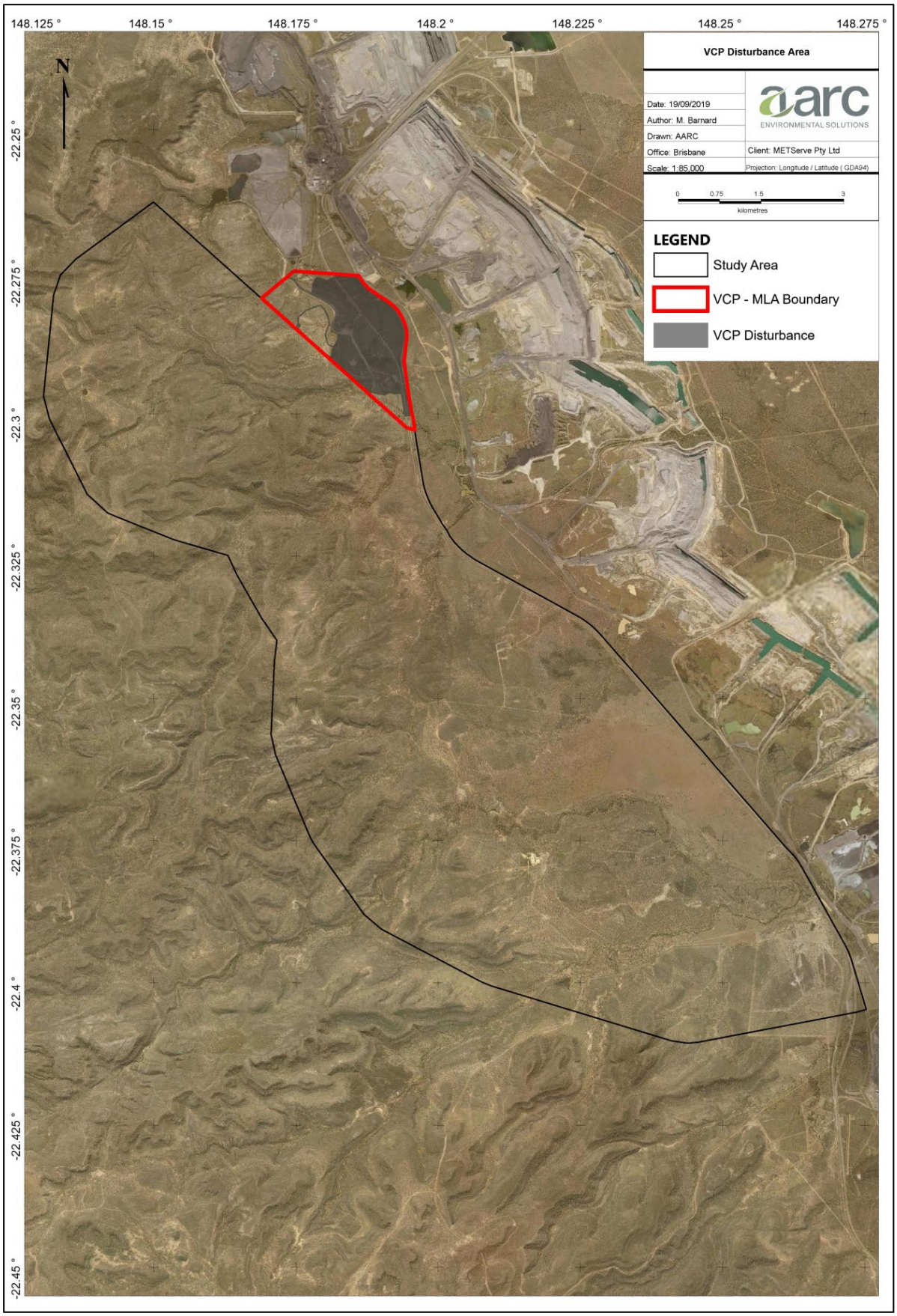


Figure 6 VCP Project Disturbance

8.4 SUBSOIL MANAGEMENT

Excluding the Crocodile and Kei units, the subsoil layers (soil located below the recommended stripping depth of each SMU) of all other SMUs are severely constrained by elevated ESP values which place these materials at a high risk of dispersion. These constraints suggest that consideration of the use of these subsoils needs to be weighed against the geochemical and physical qualities of the waste rock materials being excavated. In particular, the requirements for separate handling, storage, placement and amelioration for these subsoils, may not provide sufficient benefit over their non-use.

Outside of the Project area, the subsoil characteristics of the Crocodile and Kei units do represent an opportunity for use as a soil resource, given their non-sodic nature throughout the depth profile. If used as a soil resource, consideration should be given to incorporating ameliorants to address the pH limitations of these materials and improve their potential to support a rapid and successful rehabilitation outcome.

Sodic subsoils left exposed after topsoil stripping has occurred will represent an erosion and potential downstream sedimentation risk. Appropriate erosion and sediment control methods should be incorporated into stripping plans for these areas.

8.4.1 Subsoil amelioration

Where dispersive materials are to be used as subsoil, they should be treated with gypsum (calcium sulphate) prior to sowing/planting. Dispersive soils generally have low porosity, low air movement and therefore low oxygen availability for plants. They also have slow water infiltration which can lead to waterlogging. Gypsum application rates for moderate to severe dispersive soils usually range from 2.5 to 5 t/ha depending on site-specific characteristics (DPIRD 2020). Given the high exchangeable sodium percentage (21.5 %) and low pH present in the Limpopo subsoil, an application of 5 t/ha of gypsum is recommended. Gypsum causes soil particles to flocculate, therefore improving soil structure, increasing water and plant root penetration into the soil. Irrigation is also important; these soils should be well irrigated so that sodium is leached down the soil profile. In contrast, low amounts of water in the soil can result in sodium move up the soil profile by evaporation.

9.0 POTENTIAL IMPACTS AND MANAGEMENT

9.1 LAND SUITABILITY

The development of the Project will disturb land through the construction of infrastructure and operation of the mine. This disturbance will impact the land suitability of the Project area throughout the life of the mine and potentially after its closure. Pre-mining land suitability classes are outlined in Section 6.0 and are summarised below in Table 71.

Table 71 Summary of the Size and Suitability Classes for Project Area SMUs

SMU	Land Suitability Class (Grazing)	Land Suitability Class (Cropping)	Area (ha)
Limpopo	4*	4	392
Zambezi	4*	5	16

Note: Green = suitable, red = unsuitable. Items displayed with an asterisk (*) are considered suitable based on current land use of low intensity grazing.

Based on the pre-mining land use and the results of the SLSA, it is anticipated that most rehabilitated landforms will be able to support a post-mining land use of cattle grazing.

The economic viability of using rehabilitated land for grazing will be considered based on post-mine land suitability, as well as the total area available for cattle grazing. If developed, improved pastures will likely incorporate species such as Buffel, Rhodes and other grasses that perform well in local conditions. The areas classed as suitable for cattle grazing are extensive and are considered to offer a land use value equivalent to that existing pre-mining.

It should be noted that mining activities, including the stripping, stockpiling and handling, of soil, have the potential to impact its physical, chemical and biological properties. Therefore, the pre-mining land suitability for cattle grazing may be reduced for some rehabilitated landforms. These potential adverse impacts can be mitigated through:

- good topsoil management practices (See Section 8.0);
- the addition of fertilisers and soil ameliorants;
- timely seeding with suitable species; and
- post-establishment management of rehabilitated areas.

Where final landforms represent a relatively flat landscape (e.g. slopes less than 5%) it is envisaged that the post-mining land suitability for cattle grazing will reflect that of the pre-mining landscape.

Other areas, such as steeper outer slopes of spoil (e.g. slopes of > 10%) may be subject to increased risk of limitations such as erosion. These areas will require management to ensure they remain safe, non-polluting, stable and able to sustain an agreed post-mining land use.

9.2 EROSION

Disturbance of vegetation and the topsoil layer can lead to the mobilisation of soil through the process of erosion, particularly water erosion through heavy rainfall or overland flow. The risk of erosion at the Project will be increased by the following activities:

- Clearing of vegetation;
- Topsoil stripping and stockpiling;
- Construction of infrastructure; and
- Exposure of slopes;

Management recommendations to be considered, as required, to reduce the risk and impacts of erosion include:

- Limiting land clearing to the minimum amount of land required for safe operation of the Project;
- Diversion of overland flow/runoff around disturbed areas;
- Amelioration of sodic soils through the addition of gypsum, or addition of rock for stability if used in rehabilitation;
- Progressive rehabilitation of landforms and direct placement of topsoil to help preserve the seed bank and reduce erosion;
- Seeding of topsoil as soon as possible after placement onto rehabilitated areas, to ensure root masses assist in mitigating erosion;
- Topsoil stockpiles placed away from drainage areas, roads, machinery, transport corridors, and stock grazing areas;
- Topsoil stockpiles seeded or covered with a water-shedding lining to prevent unnecessary erosion of soil; and
- The use of sediment control structures such as retention ponds, to minimise the release of water and suspended sediments into the receiving environment.

9.3 TOPSOIL ERODIBILITY AND EROSION RISK

A soil erosion assessment was undertaken to determine potential erosion rates in the context of the use of topsoils from the three SMUs, namely Crocodile, Limpopo, and, Zambezi, on rehabilitated landforms at the VCP Project. An additional erosion assessment was conducted for the pre-mining conditions on each of the three SMUs to provide comparative baseline erosion rates to be used for assessing the predicted erosion rates of the rehabilitated landform. The output from this assessment is also able to be used to inform the topsoil management and rehabilitation strategies for the Project.

This assessment has been conducted on the Crocodile, Limpopo and Zambezi SMUs as these SMUs are either located in or adjacent to the VCP area. Topsoil sourced for use in rehabilitation is proposed to be sourced from these SMUs.

It should be noted that the outputs from this erosion analysis are a prediction of erosion rates and utilise a number of assumptions. Therefore, results should be used for comparative purposes as opposed to being considered absolute values.

The Revised Universal Soil Loss Equation (RUSLE) is a calculation used to estimate the average annual soil loss caused by hillslope and rill erosion. The equation is limited to making predictions for long-term annual soil loss. The RUSLE equation is:

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

Where:

- A is the predicted rate of soil loss in tonnes per hectare per year;
- R is the rainfall erosivity factor based on the total erosive power of storms during an average year and is dependent on local weather conditions;
- K is the soil erodibility factor, which has been specifically derived for the Crocodile, Limpopo and Zambezi SMU;
- LS is the slope length-gradient factor that describes the combined effect of slope length and gradient on soil loss. The LS factor is a ratio that corresponds to soil loss per unit area of an experimental plot of known length and gradient;
- C is referred to as the cover and management factor which compares cropping practices, residue management, and soil cover to a standard clean fallow plot. C-factors for different agricultural uses and management practices are developed based on their observed deviation from the standard clean fallow plot; and
- P is the conservation or support practice factor and reflects the impact of support practices on the average annual erosion rate. It is the ratio of soil loss with contouring and/or strip cropping to that with straight row farming up-and-down slope.

The K factor was determined according to the methodology described in the *Prediction of Sheet and Rill Erosion over the Australian Continent, Incorporating Monthly Soil Loss Distribution* (Lu *et al.* 2001) using the equation:

$$K = 2.77(100\ P_{125})^{1.14}(10^{-7})\ (12\text{-}2OC) + (3.29\times10^{-3})\ (PP\text{-}3)$$

Where:

- K is the RUSLE soil erodibility factor, SI Units of t ha h ha^{-1} MJ^{-1} mm^{-1}
- P_{125} is the percentage of soil clay, silt and sand particles less than 0.125mm diameter
- OC is the Organic Carbon content; and
- PP is the soil profile permeability class.

9.3.1 Pre-mining erosion prediction

Table 72 displays all the parameters relevant to the determination of the soil K factor and the resultant K factor for topsoil of the three SMUs.

Table 72 Soil RUSLE K factors

SMU	P_{125}	OC	PP	K (t.ha.h)/(ha.MJ.mm)
Crocodile	33	3.5	3	0.014
Limpopo	39	1	3	0.033
Zambezi	57	1.1	4	0.055

The R factor adopted for the three SMUs within or adjacent to the VCP boundary has been derived from the *Queensland Spatial Catalogue* (Queensland Government 2020) which contains input R factor datasets available for use in the RUSLE. An average R-value of 1729.45 MJ/mm per ha/hr/yr for land within the Project area was determined using a vector analysis GIS tool to extract the available factor data. Grid cells that occupy less than 10% of the Project area were excluded from the analysis.

A P-factor of 0.8 has been adopted for this assessment based on undisturbed “loose” soil to a depth of 0.3 m.

Slope characteristics for the pre-mining landscape within each SMU boundary were investigated with lidar imagery. The 10th percentile, median and 90th percentile slope values and corresponding slope length were used to determine the LS-factor for each SMU.

Groundcover characteristics were also assessed to determine an appropriate C-factor for each SMU. The C-factor represents the characteristic vegetation, rock, and wood debris cover within each SMU.

Estimated pre-mining erosion rates for the three SMUs are provided in Table 73.

Table 73 Predicted soil loss per slope characteristics of the pre-mining landform

Slope value	C	Gradient (%)	A (tonnes/ha.yr)
Crocodile 10th percentile	0.015	4	0.4
Crocodile Median	0.015	12	1.7
Crocodile 90th percentile	0.015	39	7.2
Limpopo 10th percentile	0.075	1	0.6
Limpopo Median	0.075	3	1.8
Limpopo 90th percentile	0.075	14	11.2
Zambezi 10th percentile	0.005	2	0.2
Zambezi Median	0.005	8	1.2
Zambezi 90th percentile	0.005	38	9.7

By way of comparison with the estimates provided in Table 73, Lu *et al* (2003) estimated sheetwash and rill erosion over the Australian continent as having a national average of 4.1 t/ha.yr but with rates of 5-25 times this being common in northern Australia. A georeferenced overlay of Lu's mapping highlights the Project as falling within the 10-50 t/ha.year range of erosion rates. Lu's estimates of gross erosion do not account for rock cover, and therefore may represent overestimates. Lu acknowledges that the full erosion potential may not be realised for some areas of Queensland and northern Australia because of the high percentage of rock cover and shallow soil depth. The estimates used in this assessment account for rock cover, as part of the C-factor, and are therefore considered to be more representative.

9.3.2 Post-mining erosion prediction

The K-factor values for the three SMUs and the R-factor used in the baseline erosion investigation have been used for the post-mining erosion assessment (refer Table 72).

A P-factor of 0.9 has been adopted for this assessment based on contour ripping of the rehabilitated landform that is assumed to be undertaken after the placement of topsoil as a standard rehabilitation practice.

For the assessment of soil erosion on the rehabilitated landform, slope length and steepness (L and S factor) and the cover management factor (C-factor) are the principal variables impacting the assessment results. These factors have been adjusted independently to predict how changes to these factors influence the erosion potential of the proposed landform.

Slope Analysis

An investigation regarding how gradient influences erosion potential was included in this assessment to quantify the erosion risk associated with the design of the rehabilitated landform.

Gradient values used in the analysis vary from 1%, 5%, 10%, and 15% as these are reflective of the slopes proposed across the rehabilitated landform. An assumed conservative uninterrupted slope length of 100 m between contour banks has been used.

Cover-type Analysis

The C-factors used in this assessment are representative of the land cover objectives proposed for rehabilitation at the Project. Rehabilitation areas will be revegetated with grass with rock mulch being applied to areas where slopes exceed 10%. The assessment also shows the change in predicted erosions rates as vegetation cover is established and then progressively increases on the rehabilitated landform. The C-factors used in this RUSLE assessment reflect the existing land uses of the land.

Estimated erosion rates for each of the three SMU topsoils and a range of gradients and management types are provided in Table 74.

Table 74 Predicted soil loss as a factor of slope and management practice

SMU	Management Type	C	Gradient (%)	A (tonnes/ha.yr)
Crocodile	Bare ground (pre-vegetation)	1	1	4.36
	Bare ground (pre-vegetation)	1	5	29.42
	Bare ground (pre-vegetation)	1	10	167.96
	30% rock mulch (pre-vegetation)	0.325	10	23.16
	30% rock mulch (pre-vegetation)	0.325	15	42.24
	30% grass cover	0.325	1	1.42
	30% grass cover	0.325	5	9.56
	30% grass cover	0.325	10	54.59
	30% rock mulch with 30% grass cover	0.1	10	7.13
	30% rock mulch with 30% grass cover	0.1	15	13.00
	50% grass cover	0.15	1	0.65
	50% grass cover	0.15	5	4.41
	50% grass cover	0.15	10	25.19
	30% rock mulch with 50% grass cover	0.05	10	3.56
	30% rock mulch with 50% grass cover	0.05	15	6.50
	70% grass cover	0.05	1	0.22
	70% grass cover	0.05	5	1.47
	70% grass cover	0.05	10	8.4
	30% rock mulch with 70% grass cover	0.018	10	1.28
	30% rock mulch with 70% grass cover	0.018	15	2.34
Limpopo	Bare ground (pre-vegetation)	1	1	10.27

SMU	Management Type	C	Gradient (%)	A (tonnes/ha.yr)
	Bare ground (pre-vegetation)	1	5	69.34
	Bare ground (pre-vegetation)	1	10	167.96
	30% rock mulch (pre-vegetation)	0.325	10	54.59
	30% rock mulch (pre-vegetation)	0.325	15	99.58
	30% grass cover	0.325	1	3.34
	30% grass cover	0.325	5	22.54
	30% grass cover	0.325	10	54.59
	30% rock mulch with 30% grass cover	0.1	10	16.80
	30% rock mulch with 30% grass cover	0.1	15	30.64
	50% grass cover	0.15	1	1.54
	50% grass cover	0.15	5	10.40
	50% grass cover	0.15	10	25.19
	30% rock mulch with 50% grass cover	0.05	10	8.40
	30% rock mulch with 50% grass cover	0.05	15	15.32
	70% grass cover	0.05	1	0.51
	70% grass cover	0.05	5	3.47
	70% grass cover	0.05	10	8.40
	30% rock mulch with 70% grass cover	0.018	10	3.02
	30% rock mulch with 70% grass cover	0.018	15	5.52
Zambezi	Bare ground (pre-vegetation)	1	1	17.12
	Bare ground (pre-vegetation)	1	5	115.57
	Bare ground (pre-vegetation)	1	10	167.96
	30% rock mulch (pre-vegetation)	0.325	10	90.98
	30% rock mulch (pre-vegetation)	0.325	15	165.96
	30% grass cover	0.325	1	5.56
	30% grass cover	0.325	5	37.56
	30% grass cover	0.325	10	54.59
	30% rock mulch with 30% grass cover	0.1	10	27.99
	30% rock mulch with 30% grass cover	0.1	15	51.07

SMU	Management Type	C	Gradient (%)	A (tonnes/ha.yr)
	50% grass cover	0.15	1	2.57
	50% grass cover	0.15	5	17.34
	50% grass cover	0.15	10	25.19
	30% rock mulch with 50% grass cover	0.05	10	14.00
	30% rock mulch with 50% grass cover	0.05	15	25.53
	70% grass cover	0.05	1	0.86
	70% grass cover	0.05	5	5.78
	70% grass cover	0.05	10	14.00
	30% rock mulch with 70% grass cover	0.018	10	5.04
	30% rock mulch with 70% grass cover	0.018	15	9.19

9.3.3 Assessment outcome

The results of the assessment confirm that erosion is most effectively controlled through the establishment of a vegetative cover across the land surface, particularly in areas of greater slope.

In general, lower gradient slopes (<10%) will achieve better than baseline erosion rates once 50% vegetation cover is established, with no other specific rehabilitation practices implemented. Likewise, higher gradient slopes (>10%) will achieve baseline erosion rates at 70% vegetation cover. However, the erosion prediction suggests that steeper slopes in the Zambezi SMU may require 70% vegetation cover in conjunction with the 30% rock mulch to achieve baseline erosion rates. It is likely that higher erosion rates estimated for the Zambezi SMU can be attributed to the model's consideration of previous land disturbance (larger C-factors) on soil with a higher P_{125} value (57%). Vegetation cover is defined as including live and senescent vegetation connected to a plant and providing physical ground cover. For this assessment, we have excluded litter as there was insufficient information to understand the extent to which this might control erosion however, it should be noted that in some circumstances litter can provide effective control of erosion.

This assessment indicates that the establishment of a ground cover to about 50% cover is integral to achieving erosion rates likely to be similar if not better than that existing prior to disturbance. Most rehabilitated landforms would be expected to achieve this level of cover within the first year or two of seeding. Implementation of a range of mitigation measures including rock mulching, hay mulching and the use of cover crops are all options available should seasonal climatic conditions delay the achievement of a stable rehabilitated landform

9.4 EROSION OF REHABILITED LANDFORMS

Erosion of rehabilitated landforms reduces the likelihood of revegetation success, and in extreme cases can compromise the structural integrity of the landform, making it unstable and unsafe. In addition, if not managed correctly, erosion can result in the release of suspended sediments and potential contaminants into the receiving environment.

The rehabilitated landform design for the Project should consider implementing controls to manage surface runoff on final landform slopes. Such controls may include:

- Limiting side slopes of spoil to a maximum slope of 1V:6H (approximately 16%) or less;
- Construction of graded banks on slopes at a recommended spacing of 80 m for slopes of 1V:6H (MCA 1998). Larger contour drains are generally more stable and longer lasting. It is recommended that drains/berms are a minimum of 5 m wide and a minimum of 500 mm in height. Berms should be constructed of compacted material (IE Aust Erosion and Sediment Control Guidelines);
- Graded banks should convey water to engineered rock-lined spine drains on steep slopes. A competent basalt or alternative rock source is recommended. The use of geofabric in construction of rock-lined spine drains is also recommended;
- To reduce the need for engineered drains on steep slopes, landform modelling can be centred around gentle concave slopes or terraced profiles, or in accordance with geomorphic principles. For materials prone to erosion, designs such as these can significantly reduce runoff velocity and erosion by a magnitude of two or three times, however, this approach can be difficult to implement where space is a limiting factor;
- Maintaining a high vegetative ground cover across the rehabilitation landform, particularly where the gradient exceeds 10% (Section 9.3);
- The use of rock mulches can also assist in reducing erodibility, as well as increasing infiltration (Commonwealth of Australia, 2016);
- Rehabilitated areas should be ripped to reduce compaction from heavy machinery, encourage infiltration of water and prevent erosion. If engineered waterways are included in the landform, areas should be ripped on a grade (e.g. 0.5%). Otherwise, areas should be ripped on the contour. Ripping depths will vary depending on the type of spoil material, depth of topsoil and equipment used for rehabilitation operations. Typical ripping depths for this Project would be about 400mm to 500 mm; and
- Avoiding the use of any sodic subsoil material for use as a subsoil medium (see section 6.4).

9.5 SOIL DEGRADATION

Stripping, stockpiling and handling of topsoil can potentially have a negative impact on the chemical and physical attributes of the soil. Impacts associated with mining activities include the following:

- exposure of sodic subsoils during soil stripping. This is applicable to the Limpopo and Zambezi SMUs within the Project area;
- loss of soil physical structure due to excavation and handling;
- loss of the soil seedbank; and
- impacts on soil fertility due to mixing with subsoils and resulting changes in soil chemistry as subsoils are exposed to oxygen.

Physiochemical changes to the soil may impact on the viability of the soil seed bank and reduce the likelihood of successful rehabilitation if not well managed. Management recommendations to reduce the risk of soil degradation and improve the chances of rehabilitation success include:

- Segregation of saline or sodic soils and clear demarcation and labelling/recording of stockpiles to ensure appropriate use of the resource. The SMU's that contain horizons with sodic properties include both the Limpopo SMU (sodic below a depth of 0.5 m) and the Zambezi SMU (sodic below a depth of 0.5 m);

- Minimising the handling of topsoil;

- Ensuring that when required, stockpiles are generally less than 2 m high and contoured to encourage water to drain;

- If topsoil resources are to be stockpiled for a period in excess of six months, testing of soil properties prior to use in rehabilitation should be carried out. The proponent could consider conducting soil physiochemical analysis of stockpiled topsoil resources to assess for changes in topsoil quality (changes to soil chemistry and biological activity as a result of being stockpiled). Key parameters that should be considered during this additional testing, if undertaken, include pH, ESP, CEC (major cations), organic matter content and other essential nutrients such as nitrate, phosphorous and sulphate; and

- The application of fertilisers, soil ameliorants and an appropriate seed mix are recommended for some SMU's to increase the likelihood of rehabilitation success. Recommendations relevant to SMU's requiring amendments are discussed in Section 6.1.

9.6 EROSION MONITORING ON REHABILITATED LANDFORMS

Erosion monitoring across the landform will be integral to the early detection of erosion and will allow for early intervention. Erosion monitoring can be undertaken using physical observation in the field or remotely with the use of aerial photography and lidar imagery. A brief description of suitable methodologies is provided below.

9.6.1 Field Assessment Methodologies

In-field erosion monitoring is based on visual assessments taken over time. Permanent monitoring transects, 50 m in length should be established across the landform to provide a basis for temporal assessments. Visual observations should be taken whilst traversing the 50 m transects on foot and recording the number and average depth of any erosion features, rill lines or gullies. It should be noted that the placement of the permanent transects may not be a true reflection of erosion across the rehabilitated landforms. General observations should therefore also be undertaken during the monitoring event. Visual assessments should identify any evidence of excessive sediment movement, including the formation of rills, removal of soil around the base of plants and accumulation of loose sediment at the base of slopes. In-field erosion monitoring should also include an assessment of the water quality of run-off water released from the catchment of a given rehabilitation area.

Table 74 records and classifies the severity of erosion observations. The overall classification of the erosion on each transect was based on the most severe characteristic of the erosion observed, i.e. either the number of rills/gullies or the average depth. For example, a transect may present only one or two rills, however, if an average depth of 25 cm is recorded, the transect will be classified as having moderate erosion.

Table 75 Erosion classifications

Erosion classification	Minor	Moderate	Major	Extensive
No. of rill(s)/gully(ies)*	< 15	15–30	31–50	> 50
Average depth (cm)	< 10	10–30	30–60	> 60

**Gully: highly visible form of soil erosion, with steep-sided, incised, drainage lines greater than 30 cm deep*

9.6.2 Remote Sensing Methodologies

The advent of remote sensing technologies, the increasing availability of satellite imagery and the development of accurate, near-field, point-cloud surveying capability (e.g. LiDAR) creates a number of options for monitoring indicators relevant to the assessment of rehabilitated areas and sheet, rill and/ or gully erosion development more specifically. For rehabilitation assessments, there needs to be a good understanding of how such technologies work, as they bring their own specific requirements which must be addressed (e.g. coordinate reference systems, datum points, object interference etc.).

Various remote sensing technologies are now able to be used for the assessment of rehabilitated areas. They can be used for assessing the same area over time which can be useful to assess sheet erosion and or the development of rill and gully erosion over time, as well as detection of existing rill and gully erosion. It is generally recommended that such technologies be used in conjunction with the in-field monitoring technologies discussed above to provide a calibration for what is being measured.

10.0 REFERENCES

Bourne GF and Tuck GA (1993). Resource Information, in RN Thwaites and JM Maher (eds.) *Understanding and Managing Soils in the Central Highlands*, Department of Primary Industries Training Series QE93002, Brisbane.

Brooks JD and Smith JW (1969). The diagenesis of plant lipids during the formation of coal, petroleum and natural gas—II. Coalification and the formation of oil and gas in the Gippsland Basin, *Geochimica et Cosmochimica Acta*, 33(10), pp. 1183-1194

Bureau of Meteorology (2018) Queensland River Basins. Available from: <http://www.bom.gov.au/qld/flood/brochures/qld/map.pdf>

Bureau of Rural Science (1991). Digital Atlas of Australian Soils. Department of Agriculture, Fisheries and Forestry. Commonwealth of Australia. Available from: http://www.asris.csiro.au/themes/Atlas.html#Atlas_Digital (Accessed 06.08.10)

Connolly EL and Guerinot ML (2002). Iron stress in plants. *Genome Biology*, *3*(8), reviews1024.1–reviews1024.4.

CRDC (2020). Best Management Practices for Nitrogen (N) Fertilizer Use on Dairy Pastures - More Profit from Nitrogen Program. Retrieved from: https://www.crdc.com.au/more-profit-nitrogen (Viewed on 17th August 2020).

Daws MI, Standish J, Koch JM and Morald TK (2013). Nitrogen and phosphorus fertilizer regime affect jarrah forest restoration after bauxite mining in Western Australia. *Applied Vegetation Science*, 16 (4): pp. 610-618.

Department of Environment and Heritage Protection (2011) *Mackenzie River Sub-basin Environmental Values and Water Quality Objectives Basin No. 130 (part), including all waters of the Mackenzie River Sub-basin*. Available from: https://www.ehp.qld.gov.au/water/policy/pdf/plans/fitzroy_mackenzie_river_wqo_290911.pdf

Department of Environment and Science (2018) Fitzroy Drainage Basin – Facts and Maps. Available from: https://wetlandinfo.des.qld.gov.au/wetlands/facts-maps/basin-fitzroy/

Department of Environment and Science (2019). *Isaac River drainage sub-basin — facts and maps.* [Online] available at: https://wetlandinfo.des.qld.gov.au/wetlands/facts-maps/sub-basin-isaac-river/

Department of Minerals and Energy (1995). Technical Guidelines for Environmental Management of Exploration and Mining in Queensland – Land Suitability Assessment Techniques. Queensland Government. Brisbane, Queensland.

Department of Primary Industries Victoria (n.d.). Fertilizing Pastures. Retrieved from: http://www.ccmaknowledgebase.vic.gov.au/shkb/brown_book/documents/15_Sulphur/Greener_pastures_Chapter5.pdf (viewed 17th August 2020).

Dickins JM and Malone EJ (1973). *Geology of the Bowen Basin, Queensland. Bureau of Mineral Resources, Geology and Geophysics Bulletin No. 130.* Australian Government Publishing Service, Canberra.

DPIRD (2020). Department of Primary Industries and Regional Development. Agriculture and Food. Managing dispersive (sodic) soils. Retrieved from: https://www.agric.wa.gov.au/dispersive-and-sodic-soils/managing-dispersive-sodic-soils. (Viewed 17th August 2020).

DSITI and DNRM (2013). *Regional Land Suitability Frameworks for Queensland*. Queensland Government (Department of Science, Information Technology and Innovation and Department of Natural Resources and Mines), Brisbane Queensland. Chapter 10 – Suitability Framework for the Inland Fitzroy and Southern Burdekin area.

DSITI and DNRM (2015). *Guidelines for Agricultural Land Evaluation in Queensland* (2nd edition). Queensland Government (Department of Science, Information Technology and Innovation and Department of Natural Resources and Mines), Brisbane Queensland.

Emerson WW (1967). A classification of soil aggregates based on their coherence in water, *Australian Journal of Soil Research,* 5, pp. 47-57

Geoscience Australia (2019) Province and Sedimentary Basin Geology - Bowen Basin. Available from: http://www.ga.gov.au/scientific-topics/energy/province-sedimentary-basin-geology/petroleum/onshore-australia/bowen-basin

Government of South Australia (2013) Standard Soil Test Methods and Guidelines for Interpretation of Soil Results. Retrieved from: <https://www.naturalresources.sa.gov.au/southeast/land/soil-management/Soil-testing-andobservation?BestBetMatch=standard%20soil%20est%20methods|b7dc1d2c-0a3f-428b-b83a90df9be8fdaa|02988d82-57e4-44c1-9647-a32500af070b|en-AU>

Hazelton P and Murphy B (2016) Interpreting Soil Test Results – What do all the Numbers Mean? Third Edition. CSIRO Publishing, Melbourne.

Hutton AC (2009) Geological Setting of Australasian Coal Deposits, *Australasian Coal Mining Practice* (pp. 40-84)

Isbell RF (1996). The Australian Soil Classification. Australian Soil and Land Survey Handbook Series. CSIRO Publishing, Melbourne.

Kabata-Pendias A and Pendias H (2001). Trace Elements in Soils and Plants (3rd Edition) CRC Press, New York.

Keipert NL (2005). Effect of different stockpiling procedures in open cut coal mine rehabilitation in the Hunter Valley, NSW, Australia, PhD thesis, University of New England.

Kelly (2006). Recycled organics in mine site rehabilitation. Report prepared for the Department of Environment and Conservation NSW.

Lu H, Gallant J, Prosser IP, Moran C, Priestly G (2001). *The prediction of Sheet and Rill Erosion Over the Australian Continent, Incorporating Monthly Soil Loss Distribution*, Technical Report 13/01, CSIRO Land and Water, Canberra, Australia.

McKenzie NJ, Grundy MJ, Webster R and Ringrose-Voase (2008). Guidelines for Surveying Soil and Land Resources. Australian Soil and Land Survey Handbook Series. CSIRO Publishing, Melbourne.

MLA (n.d.) Meat and Livestock Australia. Beef Cattle feedlots: waste management and utilization. Retrieved from: https://www.mla.com.au/globalassets/mla-corporate/research-and-development/program-areas/feeding-finishing-and-nutrition/manure-handbook/section-5-utilisation-of-manure-and-effluent-2016_07_28.pdf (viewed 17 August 2020).

Mutton AJ (2003) Queensland Coals - Physical and Chemical Properties, Colliery and Company Information. Department of Natural Resources and Mines. Available from: https://www.dnrm.qld.gov.au/?a=267497

National Committee on Soil and Terrain (2009). Australian Soil and Land Survey Field Handbook, Third Edition. Australian Soil and Land Survey Handbook Series. CSIRO Publishing, Melbourne.

NSW Government (2015), Transport Roads & Maritime Services. Guidelines for batter surface stabilisation.

Queensland Spatial Catalogue - QSpatial (2020). Interactive Web Resource. Available from: http://qldspatial.information.qld.gov.au/catalogue/, Queensland Government.

Rayment GE and Bruce RC (1984). *Soil testing and some soil test interpretations used by the Queensland DPI*. Queensland Department of Primary Industries Information Series QI 84029, Brisbane.

Rayment GE and Lyons D (2011). Soil Chemical Methods – Australasia. Australian Soil and Land Survey Handbook Series. CSIRO Publishing, Melbourne.

Smith KA, Ball T, Conen F, Dobbie KE, Massheder A and Rey A (2018) Exchange of greenhouse gases between soil and atmosphere: interactions of soil physical factors and biological processes. *European Journal of Soil Science, 69*(1), pp. 10-20

Story R, Galloway RW, Gunn RH and Fitzpatrick EA (1967), *Lands of the Isaac-Comet Area, Queensland. Land Research Series No 19.* CSIRO, Melbourne.

Thwaites RN and Maher JM (eds.) (1993). *Understanding and Managing Soils in the Central Highlands*, Department of Primary Industries Training Series, Brisbane.

Victoria Government (2013). Corangamite Region 'Brown Book' – How to optimise your soils to enhance productivity, retrieved from: https://www.ccmaknowledgebase.vic.gov.au/brown_book/12_Superphosphate.htm (viewed 18 August 2020)2

Withnall IW (1989). Precambrian and Palaeozoic geology of the south eastern Georgetown Inlier, north Queensland. Queensland Department of Mines, Report 2, pp. 102

Withnall IW and Cranfield LC (2012). Queensland Geological framework. Department of Natural Resources and Mines, Queensland Minerals. Retrieved from https://www.dnrm.qld.gov.au/__data/assets/pdf_file/0007/197647/geology-of-queensland.pdf

Appendix A Lab Results

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB1920844**	Page	: 1 of 29
Client	: **AARC ENVIRONMENTAL SOLUTIONS PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: MR GARETH BRAMSTON	Contact	: Customer Services EB
Address	:	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: +61 07 3217 8772	Telephone	: +61-7-3243 7222
Project	: Vulcan Project Soils	Date Samples Received	: 08-Aug-2019 13:40
Order number	:	Date Analysis Commenced	: 09-Aug-2019
C-O-C number	: ----	Issue Date	: 20-Aug-2019 16:53
Sampler	: MEGHAN BARNARD		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 43		
No. of samples analysed	: 43		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ankit Joshi	Inorganic Chemist	Sydney Inorganics, Smithfield, NSW
Ben Felgendrejeris	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- ALS is not NATA accredited for the analysis of Exchangeable Aluminium and Exchange Acidity in soils when performed under ALS Method ED005.
- ALS is not NATA accredited for the analysis of Exchangeable Cations on Alkaline Soils when performed under ALS Method ED006.
- **Bulk Density analysis will be conducted by ALS Environmental, Sydney, NATA accreditation no. 825, Site No. 10911 (Micro site no. 14913).**
- ED092 (DTPA Extractable Metals): Sample EB1920844 – 009 (VP2 - 10-10cm) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- EG005T (Total Metals by ICP-AES): Sample EB1920844 – 031 (VP20 - 10-10cm) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- ED006 (Exchangeable Cations on Alkaline Soils): Unable to calculate Calcium/Magnesium Ratio results as required Calcium and/or Magnesium results are less than the limit of reporting.
- ED006 (Exchangeable Cations on Alkaline Soils): Unable to calculate Magnesium/Potassium Ratio result as required Potassium and/or Magnesium results are less than the limit of reporting.
- ED005 (Exchange Acidity by 1M Potassium Chloride): It is recognised that the Exchange Acidity is less than the Exchangeable Aluminium for certain samples. However, the difference is within experimental variation of the methods.
- ED007 (Exchangeable Cations): Unable to calculate Magnesium/Potassium Ratio result as required Exchangeable Potassium results are less than the limit of reporting.
- ED005 (Exchange Acidity by 1M Potassium Chloride): Sample EB1920844 – 015 (VP29 - 80-90cm) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- EA058 Emerson: V. = Very, D. = Dark, L. = Light, VD. = Very Dark
- ED007 and ED008: When Exchangeable Al is reported from these methods, it should be noted that Rayment & Lyons (2011) suggests Exchange Acidity by 1M KCl - Method 15G1 (ED005) is a more suitable method for the determination of exchange acidity (H+ + Al3+).
- ALS is not NATA accredited for the analysis of bulk density in a soil matrix.

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	VP25 - 10-10cm	VP25 - 20-30cm	VP25 - 50-60cm	VP25 - 80-90cm	VP30 - 10-10cm
			Client sampling date / time	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00
Compound	CAS Number	LOR	Unit	EB1920844-001	EB1920844-002	EB1920844-003	EB1920844-004	EB1920844-005
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	6.4	6.7	7.8	9.0	6.4
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	18	5	59	174	13
EA051 : Bulk Density								
ø Bulk Density	BULK_DENSITY	1	kg/m3	1580	----	----	----	2130
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	1.8	2.8	7.2	9.1	1.5
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Very Dark Brown (7.5YR 2.5/2)	Dark Brown (7.5YR 3/4)	Brown (10YR 4/3)	Dark Grayish Brown (10YR 4/2)	Very Dark Brown (10YR 2/2)
Texture	----	-	-	Clayey Sand	Loamy Sand	Sandy Clay Loam	Clay Loam, Sandy	Sandy Clay Loam
Emerson Class Number	EC/TC	-	-	3	4	2	2	3
EA150: Particle Sizing								
+75µm	----	1	%	75	----	----	----	59
+150µm	----	1	%	43	----	----	----	39
+300µm	----	1	%	19	----	----	----	26
+425µm	----	1	%	10	----	----	----	18
+600µm	----	1	%	4	----	----	----	10
+1180µm	----	1	%	1	----	----	----	2
+2.36mm	----	1	%	<1	----	----	----	<1
+4.75mm	----	1	%	<1	----	----	----	<1
+9.5mm	----	1	%	<1	----	----	----	<1
+19.0mm	----	1	%	<1	----	----	----	<1
+37.5mm	----	1	%	<1	----	----	----	<1
+75.0mm	----	1	%	<1	----	----	----	<1
EA150: Soil Classification based on Particle Size								
Clay (<2 µm)	----	1	%	9	----	----	----	12
Silt (2-60 µm)	----	1	%	14	----	----	----	25
Sand (0.06-2.00 mm)	----	1	%	77	----	----	----	62
Gravel (>2mm)	----	1	%	<1	----	----	----	1
Cobbles (>6cm)	----	1	%	<1	----	----	----	<1
EA152: Soil Particle Density								
Soil Particle Density (Clay/Silt/Sand)	----	0.01	g/cm3	2.43	----	----	----	2.31
ED006: Exchangeable Cations on Alkaline Soils								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	VP25 - 10-10cm	VP25 - 20-30cm	VP25 - 50-60cm	VP25 - 80-90cm	VP30 - 10-10cm
				Client sampling date / time	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00
Compound	CAS Number	LOR	Unit		EB1920844-001	EB1920844-002	EB1920844-003	EB1920844-004	EB1920844-005
					Result	Result	Result	Result	Result
ED006: Exchangeable Cations on Alkaline Soils - Continued									
ø Exchangeable Calcium	----	0.2	meq/100g		----	----	1.1	1.7	----
ø Exchangeable Magnesium	----	0.2	meq/100g		----	----	3.1	5.7	----
ø Exchangeable Potassium	----	0.2	meq/100g		----	----	<0.2	<0.2	----
ø Exchangeable Sodium	----	0.2	meq/100g		----	----	0.9	2.3	----
ø Cation Exchange Capacity	----	0.2	meq/100g		----	----	5.1	10.0	----
ø Exchangeable Sodium Percent	----	0.2	%		----	----	18.5	23.3	----
ø Calcium/Magnesium Ratio	----	0.2	-		----	----	0.4	0.3	----
ED007: Exchangeable Cations									
Exchangeable Calcium	----	0.1	meq/100g		2.3	1.3	----	----	2.9
Exchangeable Magnesium	----	0.1	meq/100g		0.8	0.4	----	----	1.1
Exchangeable Potassium	----	0.1	meq/100g		0.4	0.1	----	----	0.5
Exchangeable Sodium	----	0.1	meq/100g		<0.1	<0.1	----	----	<0.1
Cation Exchange Capacity	----	0.1	meq/100g		3.4	1.8	----	----	4.5
Exchangeable Sodium Percent	----	0.1	%		0.6	1.0	----	----	1.0
Calcium/Magnesium Ratio	----	0.1	-		2.9	3.2	----	----	2.6
Magnesium/Potassium Ratio	----	0.1	-		2.3	3.2	----	----	2.1
ED021: Bicarbonate Extractable Potassium (Colwell)									
Bicarbonate Extractable K (Colwell)	----	100	mg/kg		311	105	<100	133	477
ED040S : Soluble Sulfate by ICPAES									
Sulfate as SO4 2-	14808-79-8	10	mg/kg		<10	----	----	----	<10
Sulfur as S	63705-05-5	10	mg/kg		<10	----	----	----	<10
Silica	7631-86-9	1	mg/kg		48	----	----	----	36
Silicon	7440-21-3	1	mg/kg		23	----	----	----	17
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	10	mg/kg		<10	<10	40	160	<10
ED091 : Calcium Chloride Extractable Boron									
ø Boron	7440-42-8	0.2	mg/kg		<0.2	----	----	----	<0.2
ED092: DTPA Extractable Metals									
ø Copper	7440-50-8	1.00	mg/kg		<1.00	----	----	----	<1.00
ø Iron	7439-89-6	1.00	mg/kg		60.7	----	----	----	30.6
ø Manganese	7439-96-5	1.00	mg/kg		8.92	----	----	----	13.8
ø Zinc	7440-66-6	1.00	mg/kg		<1.00	----	----	----	1.52
EK057G: Nitrite as N by Discrete Analyser									
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg		<0.1	----	----	----	0.3

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	VP25 - 10-10cm	VP25 - 20-30cm	VP25 - 50-60cm	VP25 - 80-90cm	VP30 - 10-10cm
				Client sampling date / time	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00
Compound	CAS Number	LOR	Unit		EB1920844-001	EB1920844-002	EB1920844-003	EB1920844-004	EB1920844-005
					Result	Result	Result	Result	Result
EK058G: Nitrate as N by Discrete Analyser									
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg		**2.6**	----	----	----	**0.7**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		**2.6**	----	----	----	**1.0**
EK080: Bicarbonate Extractable Phosphorus (Colwell)									
Bicarbonate Ext. P (Colwell)	----	5	mg/kg		<5	<5	<5	<5	<5
EP004: Organic Matter									
Organic Matter	----	0.5	%		**2.0**	----	----	----	**2.4**
Total Organic Carbon	----	0.5	%		**1.1**	----	----	----	**1.4**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	VP30 - 20-30cm	VP30 - 50-60cm	VP30 - 80-90cm	VP2 - 10-10cm	VP2 - 20-30cm
			Client sampling date / time	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00
Compound	CAS Number	LOR	Unit	EB1920844-006	EB1920844-007	EB1920844-008	EB1920844-009	EB1920844-010
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	7.0	7.4	8.6	5.8	5.2
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	14	9	101	16	7
EA051 : Bulk Density								
ø Bulk Density	BULK_DENSITY	1	kg/m3	----	----	----	5030	----
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	2.4	1.7	8.0	0.9	3.8
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Very Dark Grayish Brown (10YR 3/2)	Brown (10YR 4/3)	Brown (10YR 4/3)	Black (10YR 2/1)	Gray (10YR 5/1)
Texture	----	-	-	Sandy Clay Loam	Clayey Sand	Sandy Clay	Loamy Sand	Loamy Sand
Emerson Class Number	EC/TC	-	-	3	3	4	4	3
EA150: Particle Sizing								
+75µm	----	1	%	----	----	----	89	----
+150µm	----	1	%	----	----	----	83	----
+300µm	----	1	%	----	----	----	62	----
+425µm	----	1	%	----	----	----	40	----
+600µm	----	1	%	----	----	----	20	----
+1180µm	----	1	%	----	----	----	3	----
+2.36mm	----	1	%	----	----	----	<1	----
+4.75mm	----	1	%	----	----	----	<1	----
+9.5mm	----	1	%	----	----	----	<1	----
+19.0mm	----	1	%	----	----	----	<1	----
+37.5mm	----	1	%	----	----	----	<1	----
+75.0mm	----	1	%	----	----	----	<1	----
EA150: Soil Classification based on Particle Size								
Clay (<2 µm)	----	1	%	----	----	----	3	----
Silt (2-60 µm)	----	1	%	----	----	----	8	----
Sand (0.06-2.00 mm)	----	1	%	----	----	----	88	----
Gravel (>2mm)	----	1	%	----	----	----	1	----
Cobbles (>6cm)	----	1	%	----	----	----	<1	----
EA152: Soil Particle Density								
Soil Particle Density (Clay/Silt/Sand)	----	0.01	g/cm3	----	----	----	2.50	----
ED005: Exchange Acidity								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	VP30 - 20-30cm	VP30 - 50-60cm	VP30 - 80-90cm	VP2 - 10-10cm	VP2 - 20-30cm
				Client sampling date / time	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00
Compound	CAS Number	LOR	Unit		EB1920844-006	EB1920844-007	EB1920844-008	EB1920844-009	EB1920844-010
					Result	Result	Result	Result	Result
ED005: Exchange Acidity - Continued									
ø Exchange Acidity	----	0.1	meq/100g		----	----	----	<0.1	1.4
ø Exchangeable Aluminium	----	0.1	meq/100g		----	----	----	<0.1	1.4
ED006: Exchangeable Cations on Alkaline Soils									
ø Exchangeable Calcium	----	0.2	meq/100g		----	1.5	8.4	----	----
ø Exchangeable Magnesium	----	0.2	meq/100g		----	<0.2	0.6	----	----
ø Exchangeable Potassium	----	0.2	meq/100g		----	<0.2	0.4	----	----
ø Exchangeable Sodium	----	0.2	meq/100g		----	<0.2	<0.2	----	----
ø Cation Exchange Capacity	----	0.2	meq/100g		----	1.5	9.4	----	----
ø Exchangeable Sodium Percent	----	0.2	%		----	<0.2	<0.2	----	----
ø Calcium/Magnesium Ratio	----	0.2	-		----	----	12.9	----	----
ø Magnesium/Potassium Ratio	----	0.2	-		----	----	1.8	----	----
ED007: Exchangeable Cations									
Exchangeable Calcium	----	0.1	meq/100g		2.8	----	----	1.0	<0.1
Exchangeable Magnesium	----	0.1	meq/100g		1.1	----	----	0.5	0.2
Exchangeable Potassium	----	0.1	meq/100g		0.5	----	----	0.2	0.1
Exchangeable Sodium	----	0.1	meq/100g		<0.1	----	----	<0.1	<0.1
Cation Exchange Capacity	----	0.1	meq/100g		----	----	----	----	1.9
Cation Exchange Capacity	----	0.1	meq/100g		4.4	----	----	1.8	----
Exchangeable Sodium Percent	----	0.1	%		1.4	----	----	1.7	6.6
Calcium/Magnesium Ratio	----	0.1	-		2.5	----	----	2.0	<0.1
Magnesium/Potassium Ratio	----	0.1	-		2.1	----	----	2.7	2.3
ED021: Bicarbonate Extractable Potassium (Colwell)									
Bicarbonate Extractable K (Colwell)	----	100	mg/kg		122	126	259	179	118
ED040S : Soluble Sulfate by ICPAES									
Sulfate as SO4 2-	14808-79-8	10	mg/kg		----	----	----	<10	----
Sulfur as S	63705-05-5	10	mg/kg		----	----	----	<10	----
Silica	7631-86-9	1	mg/kg		----	----	----	36	----
Silicon	7440-21-3	1	mg/kg		----	----	----	17	----
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	10	mg/kg		<10	<10	20	10	<10
ED091 : Calcium Chloride Extractable Boron									
ø Boron	7440-42-8	0.2	mg/kg		----	----	----	<0.2	----
ED092: DTPA Extractable Metals									
ø Copper	7440-50-8	1.00	mg/kg		----	----	----	<1.00	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	VP30 - 20-30cm	VP30 - 50-60cm	VP30 - 80-90cm	VP2 - 10-10cm	VP2 - 20-30cm
				Client sampling date / time	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00
Compound	CAS Number	LOR	Unit		EB1920844-006	EB1920844-007	EB1920844-008	EB1920844-009	EB1920844-010
					Result	Result	Result	Result	Result
ED092: DTPA Extractable Metals - Continued									
ø **Iron**	7439-89-6	1.00	mg/kg		----	----	----	**48.1**	----
ø **Manganese**	7439-96-5	1.00	mg/kg		----	----	----	**5.67**	----
ø **Zinc**	7440-66-6	1.00	mg/kg		----	----	----	<1.00	----
EK057G: Nitrite as N by Discrete Analyser									
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg		----	----	----	**0.1**	----
EK058G: Nitrate as N by Discrete Analyser									
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg		----	----	----	**1.5**	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		----	----	----	**1.6**	----
EK080: Bicarbonate Extractable Phosphorus (Colwell)									
Bicarbonate Ext. P (Colwell)	----	5	mg/kg		<5	<5	<5	<5	<5
EP004: Organic Matter									
Organic Matter	----	0.5	%		----	----	----	**1.7**	----
Total Organic Carbon	----	0.5	%		----	----	----	**1.0**	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	VP2 - 50-60cm	VP29 - 10-10cm	VP29 - 20-30cm	VP29 - 50-60cm	VP29 - 80-90cm
			Client sampling date / time	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00
Compound	CAS Number	LOR	Unit	EB1920844-011	EB1920844-012	EB1920844-013	EB1920844-014	EB1920844-015
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	5.0	6.6	6.8	5.5	5.7
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	19	57	12	161	312
EA051 : Bulk Density								
ø Bulk Density	BULK_DENSITY	1	kg/m3	----	2640	----	----	----
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	11.6	1.1	1.1	9.0	8.2
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Brown (10YR 5/3)	Very Dark Grayish Brown (10YR 3/2)	Brown (7.5YR 4/3)	Brown (10YR 5/3)	Light Yellowish Brown (10YR 6/4)
Texture	----	-	-	Sandy Clay Loam	Loamy Sand	Loamy Sand	Sandy Clay	Sandy Clay
Emerson Class Number	EC/TC	-	-	4	4	4	3	3
EA150: Particle Sizing								
+75µm	----	1	%	----	86	----	----	----
+150µm	----	1	%	----	74	----	----	----
+300µm	----	1	%	----	51	----	----	----
+425µm	----	1	%	----	22	----	----	----
+600µm	----	1	%	----	8	----	----	----
+1180µm	----	1	%	----	2	----	----	----
+2.36mm	----	1	%	----	<1	----	----	----
+4.75mm	----	1	%	----	<1	----	----	----
+9.5mm	----	1	%	----	<1	----	----	----
+19.0mm	----	1	%	----	<1	----	----	----
+37.5mm	----	1	%	----	<1	----	----	----
+75.0mm	----	1	%	----	<1	----	----	----
EA150: Soil Classification based on Particle Size								
Clay (<2 µm)	----	1	%	----	6	----	----	----
Silt (2-60 µm)	----	1	%	----	6	----	----	----
Sand (0.06-2.00 mm)	----	1	%	----	87	----	----	----
Gravel (>2mm)	----	1	%	----	1	----	----	----
Cobbles (>6cm)	----	1	%	----	<1	----	----	----
EA152: Soil Particle Density								
Soil Particle Density (Clay/Silt/Sand)	----	0.01	g/cm3	----	2.48	----	----	----
ED005: Exchange Acidity								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	VP2 - 50-60cm	VP29 - 10-10cm	VP29 - 20-30cm	VP29 - 50-60cm	VP29 - 80-90cm
				Client sampling date / time	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00
Compound	CAS Number	LOR	Unit		EB1920844-011	EB1920844-012	EB1920844-013	EB1920844-014	EB1920844-015
					Result	Result	Result	Result	Result
ED005: Exchange Acidity - Continued									
ø Exchange Acidity	----	0.1	meq/100g		6.0	----	----	0.6	1.0
ø Exchangeable Aluminium	----	0.1	meq/100g		6.9	----	----	0.4	0.1
ED007: Exchangeable Cations									
Exchangeable Calcium	----	0.1	meq/100g		<0.1	1.5	0.3	0.3	----
Exchangeable Magnesium	----	0.1	meq/100g		1.2	0.8	0.2	7.7	----
Exchangeable Potassium	----	0.1	meq/100g		0.2	0.6	0.2	0.8	----
Exchangeable Sodium	----	0.1	meq/100g		0.1	<0.1	<0.1	1.1	----
Cation Exchange Capacity	----	0.1	meq/100g		10.5	----	----	9.4	----
Cation Exchange Capacity	----	0.1	meq/100g		----	3.0	0.7	----	----
Exchangeable Sodium Percent	----	0.1	%		9.8	0.6	1.6	11.0	----
Calcium/Magnesium Ratio	----	0.1	-		<0.1	1.9	1.5	<0.1	----
Magnesium/Potassium Ratio	----	0.1	-		7.4	1.4	1.1	10.3	----
ED008: Exchangeable Cations									
Exchangeable Calcium	----	0.1	meq/100g		----	----	----	----	0.1
Exchangeable Magnesium	----	0.1	meq/100g		----	----	----	----	10.0
Exchangeable Potassium	----	0.1	meq/100g		----	----	----	----	0.5
Exchangeable Sodium	----	0.1	meq/100g		----	----	----	----	1.1
Cation Exchange Capacity	----	0.1	meq/100g		----	----	----	----	12.8
Exchangeable Sodium Percent	----	0.1	%		----	----	----	----	9.6
Calcium/Magnesium Ratio	----	0.1	-		----	----	----	----	<0.1
Magnesium/Potassium Ratio	----	0.1	-		----	----	----	----	20.8
ED021: Bicarbonate Extractable Potassium (Colwell)									
Bicarbonate Extractable K (Colwell)	----	100	mg/kg		<100	418	211	498	410
ED040S : Soluble Sulfate by ICPAES									
Sulfate as SO4 2-	14808-79-8	10	mg/kg		----	10	----	----	----
Sulfur as S	63705-05-5	10	mg/kg		----	<10	----	----	----
Silica	7631-86-9	1	mg/kg		----	40	----	----	----
Silicon	7440-21-3	1	mg/kg		----	19	----	----	----
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	10	mg/kg		10	20	<10	200	420
ED091 : Calcium Chloride Extractable Boron									
ø Boron	7440-42-8	0.2	mg/kg		----	<0.2	----	----	----
ED092: DTPA Extractable Metals									
ø Copper	7440-50-8	1.00	mg/kg		----	<1.00	----	----	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	VP2 - 50-60cm	VP29 - 10-10cm	VP29 - 20-30cm	VP29 - 50-60cm	VP29 - 80-90cm
				Client sampling date / time	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00
Compound	CAS Number	LOR	Unit		EB1920844-011	EB1920844-012	EB1920844-013	EB1920844-014	EB1920844-015
					Result	Result	Result	Result	Result
ED092: DTPA Extractable Metals - Continued									
ø **Iron**	7439-89-6	1.00	mg/kg		----	**63.3**	----	----	----
ø **Manganese**	7439-96-5	1.00	mg/kg		----	**8.80**	----	----	----
ø **Zinc**	7440-66-6	1.00	mg/kg		----	**2.20**	----	----	----
EK057G: Nitrite as N by Discrete Analyser									
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg		----	**0.2**	----	----	----
EK058G: Nitrate as N by Discrete Analyser									
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg		----	**7.1**	----	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		----	**7.3**	----	----	----
EK080: Bicarbonate Extractable Phosphorus (Colwell)									
Bicarbonate Ext. P (Colwell)	----	5	mg/kg		<5	**15**	<5	<5	<5
EP004: Organic Matter									
Organic Matter	----	0.5	%		----	**2.2**	----	----	----
Total Organic Carbon	----	0.5	%		----	**1.2**	----	----	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	VP17 - 10-10cm	VP17 - 20-30cm	VP17 - 50-60cm	VP17 - 80-90cm	VP31 - 10-10cm
			Client sampling date / time	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00
Compound	CAS Number	LOR	Unit	EB1920844-016	EB1920844-017	EB1920844-018	EB1920844-019	EB1920844-020
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	5.5	5.5	5.8	5.6	8.1
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	4	5	35	154	135
EA051 : Bulk Density								
ø Bulk Density	BULK_DENSITY	1	kg/m3	2160	----	----	----	1830
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	1.6	2.4	3.8	8.6	5.5
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Very Dark Brown (10YR 2/2)	Dark Brown (10YR 3/3)	Brown (10YR 5/3)	Dark Yellowish Brown (10YR 4/4)	Black (10YR 2/1)
Texture	----	-	-	Loamy Sand	Loamy Sand	Clay Loam, Sandy	Clay Loam, Sandy	Sandy Clay
Emerson Class Number	EC/TC	-	-	3	4	4	4	4
EA150: Particle Sizing								
+75µm	----	1	%	80	----	----	----	51
+150µm	----	1	%	62	----	----	----	34
+300µm	----	1	%	37	----	----	----	18
+425µm	----	1	%	25	----	----	----	12
+600µm	----	1	%	16	----	----	----	8
+1180µm	----	1	%	6	----	----	----	4
+2.36mm	----	1	%	2	----	----	----	2
+4.75mm	----	1	%	<1	----	----	----	<1
+9.5mm	----	1	%	<1	----	----	----	<1
+19.0mm	----	1	%	<1	----	----	----	<1
+37.5mm	----	1	%	<1	----	----	----	<1
+75.0mm	----	1	%	<1	----	----	----	<1
EA150: Soil Classification based on Particle Size								
Clay (<2 µm)	----	1	%	10	----	----	----	28
Silt (2-60 µm)	----	1	%	8	----	----	----	19
Sand (0.06-2.00 mm)	----	1	%	79	----	----	----	51
Gravel (>2mm)	----	1	%	3	----	----	----	2
Cobbles (>6cm)	----	1	%	<1	----	----	----	<1
EA152: Soil Particle Density								
Soil Particle Density (Clay/Silt/Sand)	----	0.01	g/cm3	2.48	----	----	----	2.13
ED005: Exchange Acidity								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	VP17 - 10-10cm	VP17 - 20-30cm	VP17 - 50-60cm	VP17 - 80-90cm	VP31 - 10-10cm
			Client sampling date / time	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00
Compound	CAS Number	LOR	Unit	EB1920844-016	EB1920844-017	EB1920844-018	EB1920844-019	EB1920844-020
				Result	Result	Result	Result	Result
ED005: Exchange Acidity - Continued								
ø Exchange Acidity	----	0.1	meq/100g	0.7	0.8	0.4	0.3	----
ø Exchangeable Aluminium	----	0.1	meq/100g	0.6	0.8	0.4	0.2	----
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	----	----	----	----	8.8
ø Exchangeable Magnesium	----	0.2	meq/100g	----	----	----	----	6.2
ø Exchangeable Potassium	----	0.2	meq/100g	----	----	----	----	0.3
ø Exchangeable Sodium	----	0.2	meq/100g	----	----	----	----	0.2
ø Cation Exchange Capacity	----	0.2	meq/100g	----	----	----	----	15.5
ø Exchangeable Sodium Percent	----	0.2	%	----	----	----	----	1.4
ø Calcium/Magnesium Ratio	----	0.2	-	----	----	----	----	1.4
ø Magnesium/Potassium Ratio	----	0.2	-	----	----	----	----	22.4
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	0.8	0.1	<0.1	<0.1	----
Exchangeable Magnesium	----	0.1	meq/100g	0.5	0.6	1.8	5.4	----
Exchangeable Potassium	----	0.1	meq/100g	0.4	0.3	0.2	0.2	----
Exchangeable Sodium	----	0.1	meq/100g	<0.1	<0.1	0.3	1.5	----
Cation Exchange Capacity	----	0.1	meq/100g	2.3	1.8	2.7	7.3	----
Exchangeable Sodium Percent	----	0.1	%	1.0	2.6	12.1	21.5	----
Calcium/Magnesium Ratio	----	0.1	-	1.6	0.2	<0.1	<0.1	----
Magnesium/Potassium Ratio	----	0.1	-	1.5	2.2	11.4	33.3	----
ED021: Bicarbonate Extractable Potassium (Colwell)								
Bicarbonate Extractable K (Colwell)	----	100	mg/kg	335	224	175	118	182
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	<10	----	----	----	<10
Sulfur as S	63705-05-5	10	mg/kg	<10	----	----	----	<10
Silica	7631-86-9	1	mg/kg	34	----	----	----	62
Silicon	7440-21-3	1	mg/kg	16	----	----	----	29
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	<10	<10	50	110	10
ED091 : Calcium Chloride Extractable Boron								
ø Boron	7440-42-8	0.2	mg/kg	<0.2	----	----	----	<0.2
ED092: DTPA Extractable Metals								
ø Copper	7440-50-8	1.00	mg/kg	<1.00	----	----	----	<1.00
ø Iron	7439-89-6	1.00	mg/kg	82.1	----	----	----	27.0

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	VP17 - 10-10cm	VP17 - 20-30cm	VP17 - 50-60cm	VP17 - 80-90cm	VP31 - 10-10cm
				Client sampling date / time	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00
Compound	CAS Number	LOR	Unit		EB1920844-016	EB1920844-017	EB1920844-018	EB1920844-019	EB1920844-020
					Result	Result	Result	Result	Result
ED092: DTPA Extractable Metals - Continued									
ø **Manganese**	7439-96-5	1.00	mg/kg		**4.64**	----	----	----	**24.5**
ø **Zinc**	7440-66-6	1.00	mg/kg		<1.00	----	----	----	<1.00
EK057G: Nitrite as N by Discrete Analyser									
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg		**0.1**	----	----	----	**0.2**
EK058G: Nitrate as N by Discrete Analyser									
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg		**0.2**	----	----	----	**0.2**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		**0.3**	----	----	----	**0.4**
EK080: Bicarbonate Extractable Phosphorus (Colwell)									
Bicarbonate Ext. P (Colwell)	----	5	mg/kg		<5	<5	<5	<5	<5
EP004: Organic Matter									
Organic Matter	----	0.5	%		**1.8**	----	----	----	**3.6**
Total Organic Carbon	----	0.5	%		**1.0**	----	----	----	**2.1**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	VP31 - 20-30cm	VP31 - 50-60cm	VP31 - 80-90cm	VP32 - 10-10cm	VP32 - 20-30cm
			Client sampling date / time	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00
Compound	CAS Number	LOR	Unit	EB1920844-021	EB1920844-022	EB1920844-023	EB1920844-024	EB1920844-025
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.4	9.5	9.6	6.8	8.5
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	54	321	575	11	142
EA051 : Bulk Density								
ø Bulk Density	BULK_DENSITY	1	kg/m3	----	----	----	2890	----
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	12.2	13.1	12.9	2.4	7.8
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Black (10YR 2/1)	Black (10YR 2/1)	Black (10YR 2/1)	Very Dark Brown (7.5YR 2.5/2)	Very Dark Brown (7.5YR 2.5/3)
Texture	----	-	-	Sandy Clay	Sandy Clay	Sandy Clay	Sandy Clay Loam	Clay Loam, Sandy
Emerson Class Number	EC/TC	-	-	3	3	4	3	3
EA150: Particle Sizing								
+75µm	----	1	%	----	----	----	55	----
+150µm	----	1	%	----	----	----	44	----
+300µm	----	1	%	----	----	----	27	----
+425µm	----	1	%	----	----	----	18	----
+600µm	----	1	%	----	----	----	11	----
+1180µm	----	1	%	----	----	----	4	----
+2.36mm	----	1	%	----	----	----	<1	----
+4.75mm	----	1	%	----	----	----	<1	----
+9.5mm	----	1	%	----	----	----	<1	----
+19.0mm	----	1	%	----	----	----	<1	----
+37.5mm	----	1	%	----	----	----	<1	----
+75.0mm	----	1	%	----	----	----	<1	----
EA150: Soil Classification based on Particle Size								
Clay (<2 µm)	----	1	%	----	----	----	32	----
Silt (2-60 µm)	----	1	%	----	----	----	11	----
Sand (0.06-2.00 mm)	----	1	%	----	----	----	55	----
Gravel (>2mm)	----	1	%	----	----	----	2	----
Cobbles (>6cm)	----	1	%	----	----	----	<1	----
EA152: Soil Particle Density								
Soil Particle Density (Clay/Silt/Sand)	----	0.01	g/cm3	----	----	----	2.24	----
ED006: Exchangeable Cations on Alkaline Soils								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	VP31 - 20-30cm	VP31 - 50-60cm	VP31 - 80-90cm	VP32 - 10-10cm	VP32 - 20-30cm
				Client sampling date / time	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00
Compound	CAS Number	LOR	Unit		EB1920844-021	EB1920844-022	EB1920844-023	EB1920844-024	EB1920844-025
					Result	Result	Result	Result	Result
ED006: Exchangeable Cations on Alkaline Soils - Continued									
ø Exchangeable Calcium	----	0.2	meq/100g		9.4	5.7	4.3	----	4.3
ø Exchangeable Magnesium	----	0.2	meq/100g		10.1	16.4	17.7	----	10.0
ø Exchangeable Potassium	----	0.2	meq/100g		<0.2	<0.2	<0.2	----	<0.2
ø Exchangeable Sodium	----	0.2	meq/100g		1.5	4.5	5.8	----	2.1
ø Cation Exchange Capacity	----	0.2	meq/100g		21.0	26.6	27.7	----	16.4
ø Exchangeable Sodium Percent	----	0.2	%		7.0	16.9	20.8	----	13.0
ø Calcium/Magnesium Ratio	----	0.2	-		0.9	0.3	0.2	----	0.4
ED007: Exchangeable Cations									
Exchangeable Calcium	----	0.1	meq/100g		----	----	----	3.7	----
Exchangeable Magnesium	----	0.1	meq/100g		----	----	----	3.0	----
Exchangeable Potassium	----	0.1	meq/100g		----	----	----	0.2	----
Exchangeable Sodium	----	0.1	meq/100g		----	----	----	0.2	----
Cation Exchange Capacity	----	0.1	meq/100g		----	----	----	7.0	----
Exchangeable Sodium Percent	----	0.1	%		----	----	----	2.4	----
Calcium/Magnesium Ratio	----	0.1	-		----	----	----	1.2	----
Magnesium/Potassium Ratio	----	0.1	-		----	----	----	14.1	----
ED021: Bicarbonate Extractable Potassium (Colwell)									
Bicarbonate Extractable K (Colwell)	----	100	mg/kg		<100	<100	<100	146	<100
ED040S : Soluble Sulfate by ICPAES									
Sulfate as SO4 2-	14808-79-8	10	mg/kg		----	----	----	<10	----
Sulfur as S	63705-05-5	10	mg/kg		----	----	----	<10	----
Silica	7631-86-9	1	mg/kg		----	----	----	38	----
Silicon	7440-21-3	1	mg/kg		----	----	----	18	----
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	10	mg/kg		40	180	540	<10	80
ED091 : Calcium Chloride Extractable Boron									
ø Boron	7440-42-8	0.2	mg/kg		----	----	----	<0.2	----
ED092: DTPA Extractable Metals									
ø Copper	7440-50-8	1.00	mg/kg		----	----	----	<1.00	----
ø Iron	7439-89-6	1.00	mg/kg		----	----	----	26.6	----
ø Manganese	7439-96-5	1.00	mg/kg		----	----	----	6.80	----
ø Zinc	7440-66-6	1.00	mg/kg		----	----	----	<1.00	----
EK057G: Nitrite as N by Discrete Analyser									
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg		----	----	----	0.2	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	VP31 - 20-30cm	VP31 - 50-60cm	VP31 - 80-90cm	VP32 - 10-10cm	VP32 - 20-30cm
				Client sampling date / time	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00
Compound	CAS Number	LOR	Unit		EB1920844-021	EB1920844-022	EB1920844-023	EB1920844-024	EB1920844-025
					Result	Result	Result	Result	Result
EK058G: Nitrate as N by Discrete Analyser									
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg		----	----	----	0.3	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		----	----	----	0.5	----
EK080: Bicarbonate Extractable Phosphorus (Colwell)									
Bicarbonate Ext. P (Colwell)	----	5	mg/kg		<5	<5	<5	<5	<5
EP004: Organic Matter									
Organic Matter	----	0.5	%		----	----	----	2.7	----
Total Organic Carbon	----	0.5	%		----	----	----	1.6	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	VP32 - 50-60cm	VP32 - 80-90cm	VP23 - 10-10cm	VP23 - 20-30cm	VP23 - 50-60cm
			Client sampling date / time	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00
Compound	CAS Number	LOR	Unit	EB1920844-026	EB1920844-027	EB1920844-028	EB1920844-029	EB1920844-030
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	9.5	9.5	6.1	6.1	6.1
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	582	641	12	5	2
EA051 : Bulk Density								
ø Bulk Density	BULK_DENSITY	1	kg/m3	----	----	2880	----	----
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	8.0	7.6	2.4	3.0	1.5
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Brown (7.5YR 4/3)	Dark Yellowish Brown (10YR 4/4)	Very Dark Grayish Brown (10YR 3/2)	Very Dark Grayish Brown (10YR 3/2)	Dark Brown (10YR 3/3)
Texture	----	-	-	Sandy Clay	Clay Loam, Sandy	Loamy Sand	Loamy Sand	Loamy Sand
Emerson Class Number	EC/TC	-	-	4	4	3	3	4
EA150: Particle Sizing								
+75µm	----	1	%	----	----	86	----	----
+150µm	----	1	%	----	----	61	----	----
+300µm	----	1	%	----	----	39	----	----
+425µm	----	1	%	----	----	26	----	----
+600µm	----	1	%	----	----	14	----	----
+1180µm	----	1	%	----	----	3	----	----
+2.36mm	----	1	%	----	----	<1	----	----
+4.75mm	----	1	%	----	----	<1	----	----
+9.5mm	----	1	%	----	----	<1	----	----
+19.0mm	----	1	%	----	----	<1	----	----
+37.5mm	----	1	%	----	----	<1	----	----
+75.0mm	----	1	%	----	----	<1	----	----
EA150: Soil Classification based on Particle Size								
Clay (<2 µm)	----	1	%	----	----	7	----	----
Silt (2-60 µm)	----	1	%	----	----	6	----	----
Sand (0.06-2.00 mm)	----	1	%	----	----	86	----	----
Gravel (>2mm)	----	1	%	----	----	1	----	----
Cobbles (>6cm)	----	1	%	----	----	<1	----	----
EA152: Soil Particle Density								
Soil Particle Density (Clay/Silt/Sand)	----	0.01	g/cm3	----	----	2.56	----	----
ED006: Exchangeable Cations on Alkaline Soils								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	VP32 - 50-60cm	VP32 - 80-90cm	VP23 - 10-10cm	VP23 - 20-30cm	VP23 - 50-60cm
				Client sampling date / time	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00
Compound	CAS Number	LOR	Unit		EB1920844-026	EB1920844-027	EB1920844-028	EB1920844-029	EB1920844-030
					Result	Result	Result	Result	Result
ED006: Exchangeable Cations on Alkaline Soils - Continued									
ø Exchangeable Calcium	----	0.2	meq/100g		**3.0**	**2.1**	----	----	----
ø Exchangeable Magnesium	----	0.2	meq/100g		**9.5**	**9.6**	----	----	----
ø Exchangeable Potassium	----	0.2	meq/100g		<0.2	<0.2	----	----	----
ø Exchangeable Sodium	----	0.2	meq/100g		**2.8**	**3.2**	----	----	----
ø Cation Exchange Capacity	----	0.2	meq/100g		**15.3**	**14.9**	----	----	----
ø Exchangeable Sodium Percent	----	0.2	%		**18.2**	**21.6**	----	----	----
ø Calcium/Magnesium Ratio	----	0.2	-		**0.3**	**0.2**	----	----	----
ED007: Exchangeable Cations									
Exchangeable Calcium	----	0.1	meq/100g		----	----	**1.3**	**1.2**	**0.9**
Exchangeable Magnesium	----	0.1	meq/100g		----	----	**0.7**	**0.6**	**0.5**
Exchangeable Potassium	----	0.1	meq/100g		----	----	**0.2**	**0.2**	**0.1**
Exchangeable Sodium	----	0.1	meq/100g		----	----	<0.1	<0.1	<0.1
Cation Exchange Capacity	----	0.1	meq/100g		----	----	**2.2**	**2.1**	**1.6**
Exchangeable Sodium Percent	----	0.1	%		----	----	**0.5**	**0.8**	**1.4**
Calcium/Magnesium Ratio	----	0.1	-		----	----	**1.8**	**2.0**	**1.8**
Magnesium/Potassium Ratio	----	0.1	-		----	----	**3.9**	**3.2**	**3.8**
ED021: Bicarbonate Extractable Potassium (Colwell)									
Bicarbonate Extractable K (Colwell)	----	100	mg/kg		<100	<100	**208**	**218**	**164**
ED040S : Soluble Sulfate by ICPAES									
Sulfate as SO4 2-	14808-79-8	10	mg/kg		----	----	<10	----	----
Sulfur as S	63705-05-5	10	mg/kg		----	----	<10	----	----
Silica	7631-86-9	1	mg/kg		----	----	**38**	----	----
Silicon	7440-21-3	1	mg/kg		----	----	**18**	----	----
ED045G: Chloride by Discrete Analyser									
Chloride	16887-00-6	10	mg/kg		**620**	**730**	<10	<10	<10
ED091 : Calcium Chloride Extractable Boron									
ø Boron	7440-42-8	0.2	mg/kg		----	----	<0.2	----	----
ED092: DTPA Extractable Metals									
ø Copper	7440-50-8	1.00	mg/kg		----	----	<1.00	----	----
ø Iron	7439-89-6	1.00	mg/kg		----	----	**76.0**	----	----
ø Manganese	7439-96-5	1.00	mg/kg		----	----	**4.24**	----	----
ø Zinc	7440-66-6	1.00	mg/kg		----	----	<1.00	----	----
EK057G: Nitrite as N by Discrete Analyser									
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg		----	----	<0.1	----	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	VP32 - 50-60cm	VP32 - 80-90cm	VP23 - 10-10cm	VP23 - 20-30cm	VP23 - 50-60cm
				Client sampling date / time	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00
Compound	CAS Number	LOR	Unit		EB1920844-026	EB1920844-027	EB1920844-028	EB1920844-029	EB1920844-030
					Result	Result	Result	Result	Result
EK058G: Nitrate as N by Discrete Analyser									
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg		----	----	**1.0**	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg		----	----	**1.0**	----	----
EK080: Bicarbonate Extractable Phosphorus (Colwell)									
Bicarbonate Ext. P (Colwell)	----	5	mg/kg		<5	<5	<5	<5	<5
EP004: Organic Matter									
Organic Matter	----	0.5	%		----	----	**2.1**	----	----
Total Organic Carbon	----	0.5	%		----	----	**1.2**	----	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	VP20 - 10-10cm	VP20 - 20-30cm	VP20 - 50-60m	VP10 - 10-10cm	VP10 - 20-30cm
			Client sampling date / time	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00
Compound	CAS Number	LOR	Unit	EB1920844-031	EB1920844-032	EB1920844-033	EB1920844-034	EB1920844-035
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	5.6	5.3	5.4	4.6	4.9
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	32	11	21	128	25
EA051 : Bulk Density								
ø Bulk Density	BULK_DENSITY	1	kg/m3	2620	----	----	2870	----
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	2.2	3.2	12.3	2.0	5.0
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Very Dark Gray (10YR 3/1)	Dark Brown (7.5YR 3/4)	Dark Reddish Brown (2.5YR 2.5/4)	Black (10YR 2/1)	Very Dark Brown (10YR 2/2)
Texture	----	-	-	Loamy Sand	Loamy Sand	Sandy Clay	Clayey Sand	Clayey Sand
Emerson Class Number	EC/TC	-	-	3	3	4	3	3
EA150: Particle Sizing								
+75µm	----	1	%	65	----	----	73	----
+150µm	----	1	%	39	----	----	49	----
+300µm	----	1	%	13	----	----	38	----
+425µm	----	1	%	8	----	----	26	----
+600µm	----	1	%	5	----	----	15	----
+1180µm	----	1	%	2	----	----	5	----
+2.36mm	----	1	%	<1	----	----	2	----
+4.75mm	----	1	%	<1	----	----	<1	----
+9.5mm	----	1	%	<1	----	----	<1	----
+19.0mm	----	1	%	<1	----	----	<1	----
+37.5mm	----	1	%	<1	----	----	<1	----
+75.0mm	----	1	%	<1	----	----	<1	----
EA150: Soil Classification based on Particle Size								
Clay (<2 µm)	----	1	%	14	----	----	12	----
Silt (2-60 µm)	----	1	%	19	----	----	10	----
Sand (0.06-2.00 mm)	----	1	%	66	----	----	75	----
Gravel (>2mm)	----	1	%	1	----	----	3	----
Cobbles (>6cm)	----	1	%	<1	----	----	<1	----
EA152: Soil Particle Density								
Soil Particle Density (Clay/Silt/Sand)	----	0.01	g/cm3	2.30	----	----	2.29	----
ED005: Exchange Acidity								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	VP20 - 10-10cm	VP20 - 20-30cm	VP20 - 50-60m	VP10 - 10-10cm	VP10 - 20-30cm
			Client sampling date / time	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00
Compound	CAS Number	LOR	Unit	EB1920844-031	EB1920844-032	EB1920844-033	EB1920844-034	EB1920844-035
				Result	Result	Result	Result	Result
ED005: Exchange Acidity - Continued								
ø Exchange Acidity	----	0.1	meq/100g	<0.1	1.1	1.8	1.1	2.4
ø Exchangeable Aluminium	----	0.1	meq/100g	<0.1	1.0	2.0	0.9	2.8
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	3.6	1.0	1.5	1.3	0.1
Exchangeable Magnesium	----	0.1	meq/100g	0.7	0.6	3.2	0.6	0.5
Exchangeable Potassium	----	0.1	meq/100g	0.4	0.2	0.2	0.5	0.3
Exchangeable Sodium	----	0.1	meq/100g	<0.1	<0.1	0.2	<0.1	<0.1
Cation Exchange Capacity	----	0.1	meq/100g	----	2.9	6.9	3.7	3.5
Cation Exchange Capacity	----	0.1	meq/100g	4.8	----	----	----	----
Exchangeable Sodium Percent	----	0.1	%	1.3	1.9	3.8	3.2	9.2
Calcium/Magnesium Ratio	----	0.1	-	5.1	1.7	0.5	2.2	0.2
Magnesium/Potassium Ratio	----	0.1	-	1.6	3.0	16.0	1.2	1.4
ED021: Bicarbonate Extractable Potassium (Colwell)								
Bicarbonate Extractable K (Colwell)	----	100	mg/kg	361	216	143	446	380
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	10	----	----	30	----
Sulfur as S	63705-05-5	10	mg/kg	<10	----	----	<10	----
Silica	7631-86-9	1	mg/kg	25	----	----	31	----
Silicon	7440-21-3	1	mg/kg	12	----	----	14	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	<10	<10	10	50	10
ED091 : Calcium Chloride Extractable Boron								
ø Boron	7440-42-8	0.2	mg/kg	<0.2	----	----	0.3	----
ED092: DTPA Extractable Metals								
ø Copper	7440-50-8	1.00	mg/kg	<1.00	----	----	<1.00	----
ø Iron	7439-89-6	1.00	mg/kg	45.4	----	----	226	----
ø Manganese	7439-96-5	1.00	mg/kg	12.0	----	----	8.00	----
ø Zinc	7440-66-6	1.00	mg/kg	1.40	----	----	<1.00	----
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	0.1	----	----	0.2	----
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	10.9	----	----	35.8	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	11.0	----	----	36.0	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	VP20 - 10-10cm	VP20 - 20-30cm	VP20 - 50-60m	VP10 - 10-10cm	VP10 - 20-30cm
				Client sampling date / time	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00
Compound	CAS Number	LOR	Unit		EB1920844-031	EB1920844-032	EB1920844-033	EB1920844-034	EB1920844-035
					Result	Result	Result	Result	Result
EK080: Bicarbonate Extractable Phosphorus (Colwell)									
Bicarbonate Ext. P (Colwell)	----	5	mg/kg		<5	<5	<5	<5	<5
EP004: Organic Matter									
Organic Matter	----	0.5	%		**2.5**	**----**	**----**	**4.1**	**----**
Total Organic Carbon	----	0.5	%		**1.4**	**----**	**----**	**2.4**	**----**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	VP10 - 50-60cm	VP10 - 80-90cm	VP27 - 10-10cm	VP27 - 20-30cm	VP27 - 50-60cm
			Client sampling date / time	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00
Compound	CAS Number	LOR	Unit	EB1920844-036	EB1920844-037	EB1920844-038	EB1920844-039	EB1920844-040
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	5.9	6.0	5.5	5.2	5.3
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	20	108	46	42	59
EA051 : Bulk Density								
ø Bulk Density	BULK_DENSITY	1	kg/m3	----	----	2780	----	----
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	11.6	9.9	1.0	4.3	5.3
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Dark Reddish Brown (5YR 3/4)	Dark Reddish Brown (5YR 3/4)	Very Dark Gray (10YR 3/1)	Dark Gray (10YR 4/1)	Dark Gray (10YR 4/1)
Texture	----	-	-	Sandy Clay Loam	Sandy Clay	Sandy Clay Loam	Sandy Clay	Sandy Clay
Emerson Class Number	EC/TC	-	-	3	2	3	3	3
EA150: Particle Sizing								
+75µm	----	1	%	----	----	60	----	----
+150µm	----	1	%	----	----	41	----	----
+300µm	----	1	%	----	----	21	----	----
+425µm	----	1	%	----	----	13	----	----
+600µm	----	1	%	----	----	7	----	----
+1180µm	----	1	%	----	----	3	----	----
+2.36mm	----	1	%	----	----	2	----	----
+4.75mm	----	1	%	----	----	<1	----	----
+9.5mm	----	1	%	----	----	<1	----	----
+19.0mm	----	1	%	----	----	<1	----	----
+37.5mm	----	1	%	----	----	<1	----	----
+75.0mm	----	1	%	----	----	<1	----	----
EA150: Soil Classification based on Particle Size								
Clay (<2 µm)	----	1	%	----	----	15	----	----
Silt (2-60 µm)	----	1	%	----	----	23	----	----
Sand (0.06-2.00 mm)	----	1	%	----	----	60	----	----
Gravel (>2mm)	----	1	%	----	----	2	----	----
Cobbles (>6cm)	----	1	%	----	----	<1	----	----
EA152: Soil Particle Density								
Soil Particle Density (Clay/Silt/Sand)	----	0.01	g/cm3	----	----	2.37	----	----
ED005: Exchange Acidity								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	VP10 - 50-60cm	VP10 - 80-90cm	VP27 - 10-10cm	VP27 - 20-30cm	VP27 - 50-60cm
			Client sampling date / time	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00
Compound	CAS Number	LOR	Unit	EB1920844-036	EB1920844-037	EB1920844-038	EB1920844-039	EB1920844-040
				Result	Result	Result	Result	Result
ED005: Exchange Acidity - Continued								
ø Exchange Acidity	----	0.1	meq/100g	1.2	0.2	<0.1	0.8	0.5
ø Exchangeable Aluminium	----	0.1	meq/100g	1.2	0.2	<0.1	0.6	0.4
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	<0.1	<0.1	1.3	0.6	0.6
Exchangeable Magnesium	----	0.1	meq/100g	5.6	7.4	1.0	2.4	3.5
Exchangeable Potassium	----	0.1	meq/100g	0.6	0.4	<0.1	<0.1	<0.1
Exchangeable Sodium	----	0.1	meq/100g	0.6	1.4	0.1	0.3	0.4
Cation Exchange Capacity	----	0.1	meq/100g	8.1	9.6	----	4.2	4.9
Cation Exchange Capacity	----	0.1	meq/100g	----	----	2.5	----	----
Exchangeable Sodium Percent	----	0.1	%	8.4	15.4	5.2	8.2	8.9
Calcium/Magnesium Ratio	----	0.1	-	<0.1	<0.1	1.3	0.2	0.2
Magnesium/Potassium Ratio	----	0.1	-	9.5	16.3	----	----	----
ED021: Bicarbonate Extractable Potassium (Colwell)								
Bicarbonate Extractable K (Colwell)	----	100	mg/kg	385	292	<100	<100	<100
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	----	----	30	----	----
Sulfur as S	63705-05-5	10	mg/kg	----	----	<10	----	----
Silica	7631-86-9	1	mg/kg	----	----	158	----	----
Silicon	7440-21-3	1	mg/kg	----	----	74	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	20	140	40	50	110
ED091 : Calcium Chloride Extractable Boron								
ø Boron	7440-42-8	0.2	mg/kg	----	----	<0.2	----	----
ED092: DTPA Extractable Metals								
ø Copper	7440-50-8	1.00	mg/kg	----	----	<1.00	----	----
ø Iron	7439-89-6	1.00	mg/kg	----	----	163	----	----
ø Manganese	7439-96-5	1.00	mg/kg	----	----	5.16	----	----
ø Zinc	7440-66-6	1.00	mg/kg	----	----	<1.00	----	----
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	----	----	0.2	----	----
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	----	----	0.3	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	----	----	0.5	----	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	VP10 - 50-60cm	VP10 - 80-90cm	VP27 - 10-10cm	VP27 - 20-30cm	VP27 - 50-60cm
				Client sampling date / time	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00
Compound	CAS Number	LOR	Unit		EB1920844-036	EB1920844-037	EB1920844-038	EB1920844-039	EB1920844-040
					Result	Result	Result	Result	Result
EK080: Bicarbonate Extractable Phosphorus (Colwell)									
Bicarbonate Ext. P (Colwell)	----	5	mg/kg		<5	<5	<5	<5	**12**
EP004: Organic Matter									
Organic Matter	----	0.5	%		**----**	**----**	**2.5**	**----**	**----**
Total Organic Carbon	----	0.5	%		**----**	**----**	**1.4**	**----**	**----**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	VP5 - 0-10cm	VP5 - 20-30cm	VP5 - 50-60cm	----	----
			Client sampling date / time	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	----	----
Compound	CAS Number	LOR	Unit	EB1920844-041	EB1920844-042	EB1920844-043	--------	--------
				Result	Result	Result	----	----
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	5.4	5.4	5.6	----	----
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	14	7	6	----	----
EA051 : Bulk Density								
ø Bulk Density	BULK_DENSITY	1	kg/m3	2110	----	----	----	----
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	0.1	%	2.9	2.6	1.9	----	----
EA058: Emerson Aggregate Test								
Color (Munsell)	----	-	-	Dark Reddish Brown (2.5YR 2.5/3)	Reddish Brown (2.5YR 5/3)	Reddish Brown (2.5YR 4/4)	----	----
Texture	----	-	-	Gravelly Sand	Gravelly Sand	Gravelly Sand	----	----
Emerson Class Number	EC/TC	-	-	8	7	7	----	----
EA150: Particle Sizing								
+75µm	----	1	%	80	----	----	----	----
+150µm	----	1	%	67	----	----	----	----
+300µm	----	1	%	54	----	----	----	----
+425µm	----	1	%	48	----	----	----	----
+600µm	----	1	%	42	----	----	----	----
+1180µm	----	1	%	35	----	----	----	----
+2.36mm	----	1	%	28	----	----	----	----
+4.75mm	----	1	%	20	----	----	----	----
+9.5mm	----	1	%	7	----	----	----	----
+19.0mm	----	1	%	<1	----	----	----	----
+37.5mm	----	1	%	<1	----	----	----	----
+75.0mm	----	1	%	<1	----	----	----	----
EA150: Soil Classification based on Particle Size								
Clay (<2 µm)	----	1	%	8	----	----	----	----
Silt (2-60 µm)	----	1	%	10	----	----	----	----
Sand (0.06-2.00 mm)	----	1	%	52	----	----	----	----
Gravel (>2mm)	----	1	%	30	----	----	----	----
Cobbles (>6cm)	----	1	%	<1	----	----	----	----
EA152: Soil Particle Density								
Soil Particle Density (Clay/Silt/Sand)	----	0.01	g/cm3	1.88	----	----	----	----
ED005: Exchange Acidity								

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	VP5 - 0-10cm	VP5 - 20-30cm	VP5 - 50-60cm	----	----
			Client sampling date / time	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	----	----
Compound	CAS Number	LOR	Unit	EB1920844-041	EB1920844-042	EB1920844-043	--------	--------
				Result	Result	Result	----	----
ED005: Exchange Acidity - Continued								
ø **Exchange Acidity**	----	0.1	meq/100g	**1.7**	**1.7**	**1.3**	----	----
ø **Exchangeable Aluminium**	----	0.1	meq/100g	**1.7**	**1.9**	**1.4**	----	----
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	**3.1**	**0.1**	<0.1	----	----
Exchangeable Magnesium	----	0.1	meq/100g	**1.5**	**1.0**	**1.0**	----	----
Exchangeable Potassium	----	0.1	meq/100g	**0.8**	**0.2**	**0.1**	----	----
Exchangeable Sodium	----	0.1	meq/100g	<0.1	<0.1	<0.1	----	----
Cation Exchange Capacity	----	0.1	meq/100g	**7.3**	**3.1**	**2.4**	----	----
Exchangeable Sodium Percent	----	0.1	%	**1.5**	**1.3**	**1.5**	----	----
Calcium/Magnesium Ratio	----	0.1	-	**2.1**	**0.1**	<0.1	----	----
Magnesium/Potassium Ratio	----	0.1	-	**1.9**	**4.0**	**7.6**	----	----
ED021: Bicarbonate Extractable Potassium (Colwell)								
Bicarbonate Extractable K (Colwell)	----	100	mg/kg	**617**	**208**	**144**	----	----
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	<10	----	----	----	----
Sulfur as S	63705-05-5	10	mg/kg	<10	----	----	----	----
Silica	7631-86-9	1	mg/kg	**36**	----	----	----	----
Silicon	7440-21-3	1	mg/kg	**17**	----	----	----	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	<10	<10	<10	----	----
ED091 : Calcium Chloride Extractable Boron								
ø **Boron**	7440-42-8	0.2	mg/kg	<0.2	----	----	----	----
ED092: DTPA Extractable Metals								
ø **Copper**	7440-50-8	1.00	mg/kg	<1.00	----	----	----	----
ø **Iron**	7439-89-6	1.00	mg/kg	**89.6**	----	----	----	----
ø **Manganese**	7439-96-5	1.00	mg/kg	**9.81**	----	----	----	----
ø **Zinc**	7440-66-6	1.00	mg/kg	<1.00	----	----	----	----
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N (Sol.)	14797-65-0	0.1	mg/kg	**0.1**	----	----	----	----
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N (Sol.)	14797-55-8	0.1	mg/kg	**2.2**	----	----	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N (Sol.)	----	0.1	mg/kg	**2.3**	----	----	----	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Client sample ID	VP5 - 0-10cm	VP5 - 20-30cm	VP5 - 50-60cm	----	----
				Client sampling date / time	08-Aug-2019 00:00	08-Aug-2019 00:00	08-Aug-2019 00:00	----	----
Compound	CAS Number	LOR	Unit		EB1920844-041	EB1920844-042	EB1920844-043	--------	--------
					Result	Result	Result	----	----
EK080: Bicarbonate Extractable Phosphorus (Colwell)									
Bicarbonate Ext. P (Colwell)	----	5	mg/kg		**8**	<5	<5	**----**	**----**
EP004: Organic Matter									
Organic Matter	----	0.5	%		**6.0**	**----**	**----**	**----**	**----**
Total Organic Carbon	----	0.5	%		**3.5**	**----**	**----**	**----**	**----**

Appendix B Soil Profile Data

Project Name:

Zambezi

Date:	20/07		**Site:**	**VP1**	
Location:	Close to dyno gate		**Coordinates:**	**E 0622172**	**N 7534691**
Landform Pattern:	PLA		**Micro Relief:**	**0**	
Landform Element:	PLA		**Rock Outcrops:**	**0**	
Morphological Type:	F		**S C Fragments:**	**0**	
Site Disturbance:	1		**Substrate:**	**0**	
Erosion:	SWXCS0		**Surface Condition:**	**S**	
Landform	Elevation:	251	**Permeability:**	**3**	
	Slope (%):	0	**Drainage:**	**4**	
	Relief:	<9	**Run-off:**	**2**	

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A	0-130		7.5YR4/3	0	S	0	G	0	D00N0	5.5	100
B1	130-300	CS	7.5YR4/4	0	S	0	G	0	D00N0	6	220
B2	300-880	DT	10YR5/4	M33D(OY)D	SCL	0	VS94PO	0	TSVN2	7	600

Vegetation: silver and yellow present

Notes: similar colours to vp7

Project Name:

Limpopo

Date:	20/07		**Site:**	**VP2**	
Location:	SE CORNER OF SIM CARD OPENER		**Coordinates:**	**E 0621443**	**N 7535596**
Landform Pattern:	PLA		**Micro Relief:**	**D**	
Landform Element:	PLA		**Rock Outcrops:**	**0**	
Morphological Type:	F		**S C Fragments:**	**0**	
Site Disturbance:	2		**Substrate:**	**0**	
Erosion:	SW1C0S1		**Surface Condition:**	**S**	
Landform	Elevation:	266	**Permeability:**	**3**	
	Slope (%):	2	**Drainage:**	**4**	
	Relief:	<9	**Run-off:**	**2**	

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A	0-240		5YR5/1	0	S	0	G	0	D00M0	6	100
B	240-600	DI	5YR5/2	M4P(5YR5/8)C	CS	0	VS8CO	0	T42N2	5.5	400

Vegetation:

Notes:

Project Name:

Crocodile

Date:	20/07/2019		**Site:**	**VP3**	
Location:	Far northern corner		**Coordinates:**	**E 0619398**	**N 7536891**
Landform Pattern:	RIS		**Micro Relief:**	**D**	
Landform Element:	HSL		**Rock Outcrops:**	**0**	
Morphological Type:	M		**S C Fragments:**	**53STMOT**	
Site Disturbance:	2		**Substrate:**	**1AF**	
Erosion:	PWXCXS1		**Surface Condition:**	**F(QFK)M**	
Landform	Elevation:	286	**Permeability:**	**2**	
	Slope (%):	8	**Drainage:**	**4**	
	Relief:	9-30	**Run-off:**	**3**	

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
01	1-2										
A1	240		7.5YR3/4	M21DRC	SCL	21APM (Source: SC)	G	0	D10N0	4.5	100
B	330	CT	2.5YR2.5/4	M42DRD	CL	0	VM23	0	D10N1	4,5	280
C	860	GI	*								

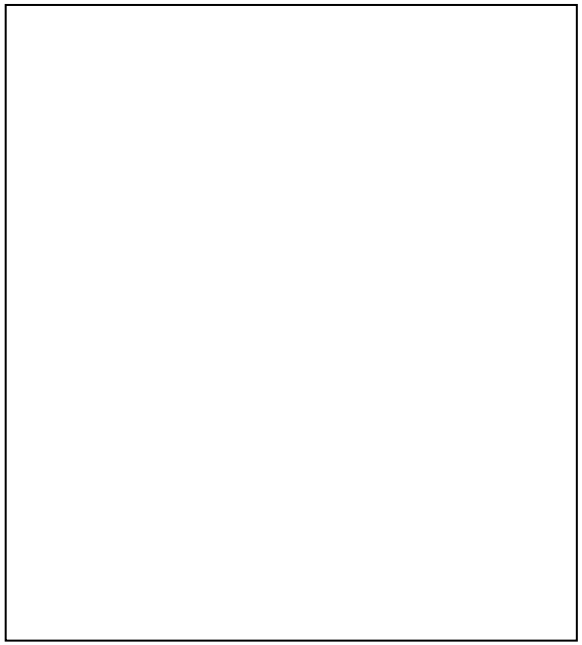
Vegetation: rock or substrate – rocks outer edge are bleached/grey, whilst inner core bright red

Notes:inner core: 2.5yr3/6, outer core: 2.5yr5/1

Project Name:

Crocodile

Date:	20/07/2019		**Site:**	**VP4**	
Location:	S-W SIDE OF SIM CARD OPENER BEND		**Coordinates:**	**E0619869**	**7535917N**
Landform Pattern:	PLT		**Micro Relief:**	**D**	
Landform Element:	PLA		**Rock Outcrops:**	**2SA**	
Morphological Type:	F		**S C Fragments:**	**34S**	
Site Disturbance:	2		**Substrate:**	**2XV(QF)VS**	
Erosion:	SWXCXS1		**Surface Condition:**	**S**	
Landform	Elevation:	306	**Permeability:**	**3**	
	Slope (%):	1	**Drainage:**	**4**	
	Relief:	<9	**Run-off:**	**3**	



[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	consistency	Field pH	
A	200		10YR2/1	0	LS	FINE SAND	VW2PO	0	D10N0	5	100
B2	400	CI	2.5YR5/8	0	S		VS5PO	0	D10N0	5.5	300
B3	500	AS	5YR5/8	0	S		G	0	D10N0	5.5	450

Vegetation: some yellow plants present

Notes: om present in a horizon

Project Name:

Crocodile

Date:	20/07		**Site:**	**VP5**	
Location:	End of lower road		**Coordinates:**	**E 0620132**	**N 7534334**
Landform Pattern:	RIS		**Micro Relief:**	**D**	
Landform Element:	HSL		**Rock Outcrops:**	**1SA**	
Morphological Type:	M		**S C Fragments:**	**44AROT + CHARCOAL**	
Site Disturbance:	2		**Substrate:**	**2XV(QF)M**	
Erosion:	SWXCXS1		**Surface Condition:**	**F**	
Landform	Elevation:	327	**Permeability:**	**3**	
	Slope (%):	5	**Drainage:**	**4**	
	Relief:	9-30	**Run-off:**	**3**	

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A			10YR2/1	M1PYD	S	31A_CC	G	0	D00NO	5.5	100
ROCK	200-530	GB	10YR5/2	N	ROCK	67RPROT	0	0		5	350
B	530-800	AS	7.5YR5/3	M2DYD	S	N	VM7PL	0	D40N0	5	700

Vegetation: yellow fluff ball tree

Notes: A lot of charcoal present contributing to the dark colour of A

Project Name:

Crocodile

Date:	19/07/2019		**Site:**	**VP6**	
Location:	N-W CORNER		**Coordinates:**	**E0618158**	**N7534318**
Landform Pattern:	PLT		**Micro Relief:**	**D**	
Landform Element:	PLA		**Rock Outcrops:**	**0**	
Morphological Type:	F		**S C Fragments:**	**22ST**	
Site Disturbance:	2		**Substrate:**	**0**	
Erosion:	SWXC0S0		**Surface Condition:**	**S**	
Landform	Elevation:	331	**Permeability:**	**3**	
	Slope (%):	4 º	**Drainage:**	**6**	
	Relief:	<9	**Run-off:**	**2**	

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
O1	SURFACE										
A	0-180		10YR2/2	0	CS	11R(U)M	W3PO	0	D10N0	5.5	170
UPPER B	180-255	AS	10YR3/2	0	LS	12R(U)VS	W3PO	0	D10N0	5.5	220
CONFINING	244-350	SS	R/O/Y	0		63A(U)VS	S5AB	0	D60_0	N	300
LOWER B	410	SS	10YR3/1	0	LS	12A(U)M	W3PO	0	D10N0	5.5	380

Vegetation:

Notes:

Project Name:

Limpopo

Date:	20/07		**Site:**	**VP7**	
Location:	Just past second N gate		**Coordinates:**	**E 0621394**	**N 7534825**
Landform Pattern:	PLA		**Micro Relief:**	**D**	
Landform Element:	PLA		**Rock Outcrops:**	**0**	
Morphological Type:	F		**S C Fragments:**	**0**	
Site Disturbance:	1		**Substrate:**	**0**	
Erosion:	SWXCXS1		**Surface Condition:**	**F**	
Landform	Elevation:	265	**Permeability:**	**3**	
	Slope (%):	0	**Drainage:**	**4**	
	Relief:	<9	**Run-off:**	**2 (GRASSCOVER)**	

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A	0-150		10YR3/2	0	S	0	G	0	D00N0	5	100
B1	150-550	GS	10YR5/6	0	S	0	VW2PO	0	D10N0	6	330
B2	550-1000	DT	10YR4/4	M43PRC	SL	0	VM3PO	0	T31N2	5.5	830

Vegetation: Silver trees present and grass cover

Notes:

Project Name:

Crocodile

Date:	21/07		**Site:**	**VP8**	
Location:	Along upper road next to valley		**Coordinates:**	**E 0621121**	**N 7534592**
Landform Pattern:	RIS		**Micro Relief:**	**D**	
Landform Element:	HSL		**Rock Outcrops:**	**2ZS (**ROCK OUT CROP STRONGER THAN SUBSTRATE)	
Morphological Type:	U		**S C Fragments:**	**62SPMOT**	
Site Disturbance:	1		**Substrate:**	**1AB(DL)m**	
Erosion:	PWXCXS2		**Surface Condition:**	**F**	
Landform	Elevation:	287	**Permeability:**	**1**	
	Slope (%):	10	**Drainage:**	**5**	
	Relief:	9-30	**Run-off:**	**3**	

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-60		10YR3/2	0	LS	44ATMM	G		D10N0	5.5	30
A2	60-220	AS	10YR3/3	0	LS	55ATMM	G		D10NO	5.5	130
C	220-690	GB	DARK TO RED SHALE	0						5.5	470

Vegetation: On a shaley ridge

Project Name:
Notes:

Limpopo

Date:	23/07/19		**Site:**	**VP9**	
Location:	AT SW OF UNCONNECTED RD		**Coordinates:**	**E 0622643**	**N 7524033**
Landform Pattern:	PLA		**Micro Relief:**	**D**	
Landform Element:	PLA		**Rock Outcrops:**		
Morphological Type:	F		**S C Fragments:**	**11U_(OT/IS)**	
Site Disturbance:	1		**Substrate:**		
Erosion:	PWXCXS1G2		**Surface Condition:**	**H**	
Landform	Elevation:	256	**Permeability:**	**2**	
	Slope (%):	0	**Drainage:**	**4**	
	Relief:	<9	**Run-off:**	**2**	

*MORE RED MOTTLING (>80%) HOWEVER SOME BROWN SIOL FROM UB STILL PRESENT

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-30		5YR2.5/1		CS		VW2PL		D10N0	7	20
A2	30-200	AS	7.5YR2.5/2		SL		VW3PO		D10N0	7	120
UB	200-860	AS	10YR3/2	M12FYD	LC		VS4PO		T51N3	8.5	620
LB	860-1070	DB	5YR4/6	*	MC		VS3PO		T53N3	8.5	920

Vegetation: LSLDB SOME BLACK WATTLE IN DISTANCE

Project Name:
Notes:

Sabie

Date:	21/07/19		**Site:**	**VP10**	
Location:	INWARDS OF E ROAD ZIG ZAG BEND		**Coordinates:**	**E 0624173**	**N 752924**
Landform Pattern:	PLA		**Micro Relief:**	**D**	
Landform Element:	PLA		**Rock Outcrops:**	**SANDSTONE**	
Morphological Type:	F		**S C Fragments:**	**21S_OT**	
Site Disturbance:	2		**Substrate:**	**0**	
Erosion:	S		**Surface Condition:**	**F**	
Landform	Elevation:	256	**Permeability:**	**3**	
	Slope (%):	0	**Drainage:**	**4**	
	Relief:	<9	**Run-off:**	**2**	

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-100		2.5YR2.5/1	0	LS	0	VW2PO	0	D01N0	4.5	50
A2	100-500	CS	2.5YR3/1	0	SL	0	G	0	D00N0	4.5	200
B	500-980	DB	2.5YR5/1	M43DRC	CLS	22SRS	VM3PO	0	T42N3	5	660

Vegetation: GRASSCOVER AND SHRUBS

Project Name:

Notes:

Sabie

Date:	24/07/2019		**Site:**	**VP 11**	
Location:	Rd towards triple gate		**Coordinates:**	**E 0623518**	**N 7527898**
Landform Pattern:	PLA		**Micro Relief:**	**D**	
Landform Element:	PLA		**Rock Outcrops:**		
Morphological Type:	F		**S C Fragments:**	**21A_IS**	
Site Disturbance:	2		**Substrate:**		
Erosion:	S		**Surface Condition:**	**F SOME C**	
Landform	Elevation:	253	**Permeability:**	**3**	
	Slope (%):	2	**Drainage:**	**4**	
	Relief:	<9	**Run-off:**	**2**	

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-70		5YR2.5/2		LS		G		D00N0	5.8	20
A2	70-420	AS	7.5YR4/4		CS		G		D00N0	5.5	180
B	420-970	CS	7.5YR4/1	M32DRD	MC		VM3PO		T31N3	5.5	

Vegetation: SIMILAR TO VP 20 MAYBE

Project Name:

Notes:

Sabie

Date:	22/07/19		**Site:**	**VP12**	
Location:	JUST BELOW RIDGE BY SNAKE TONGUE		**Coordinates:**	**E 0621935**	**N 7528227**
Landform Pattern:	HIL		**Micro Relief:**	**D**	
Landform Element:	FOO		**Rock Outcrops:**	**3SA**	
Morphological Type:	L		**S C Fragments:**	**56AROT**	
Site Disturbance:	2		**Substrate:**	**2PM(QFMmaybeS)M**	
Erosion:	S		**Surface Condition:**	**F**	
Landform	Elevation:	279	**3**	**F**	
	Slope (%):	8	**5**	**3**	
	Relief:	9-30	**Run-off:**	**3**	

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	50		2.5YR2.5/2		S		VW2PO		D10N0	5	30
A2	50-260	AS	2.5YR3/3	M11FOD	SL		VW2PO		D10N0	5	200
B	260-480	GS	2.5YR3/2		CL	42STMM	VW2PO		D21N2	5	350

Vegetation: ACACIA MONO. S, FEW BLOODWOOD* (CHECK)

Project Name:
Notes:

Limpopo

Date:	24/07/19		**Site:**	**VP13**	
Location:	AT THE END OF COW ROAD		**Coordinates:**	**E 0625893**	**N 7523732**
Landform Pattern:	PLA		**Micro Relief:**	**D**	
Landform Element:	PLA		**Rock Outcrops:**		
Morphological Type:	F		**S C Fragments:**	**21S_IS**	
Site Disturbance:	2		**Substrate:**		
Erosion:	S		**Surface Condition:**	**S**	
Landform	Elevation:	231	**Permeability:**	**4**	
	Slope (%):	0	**Drainage:**	**4**	
	Relief:	<9	**Run-off:**	**2**	

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A11	0-90		75YR4/4		S (K)		G		D00N0	7	20
A12	90-360	CS	10YR3/2		LS		VW3PO		D10N0	6	300
A2	360-710	CSGS	10YR5/2		LS (Z)		VW3PO		D10N0	6	550
B	710-980	GI	10YR4/2	M22D(OY)D	ZCL		VM3PO		T22N2	8	800R

Vegetation: SIMILAR VP20 POTENTIALLY

Project Name:

Sabie

Date:	22/07/19		**Site:**	**VP14**	
Location:	SW OF S DYNO GATE		**Coordinates:**	**E 0624777**	**N 7528253**
Landform Pattern:	PLA		**Micro Relief:**	**D**	
Landform Element:	PLA		**Rock Outcrops:**	**0**	
Morphological Type:	US		**S C Fragments:**	**21S_IS**	
Site Disturbance:	2		**Substrate:**		
Erosion:	PWXCXS1G1		**Surface Condition:**	**H -> MINOR G**	
Landform	Elevation:	221	**Permeability:**	**2**	
	Slope (%):	3	**Drainage:**	**4**	
	Relief:	<9	**Run-off:**	**2**	

**A HORIZON WAS NOT AS WET AS APPEARS IN PICTURE DUE TO DIFFICULTY OF REMOVAL FROM CORE

DEPTHS, BOUNDARY AND STRUCTURE INNACURATE DUE TO DIFFICULTY OF REMOVAL

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	140		7.5YR3/3		S		G		D00N0	5.5	70
A2	140-330	CS	7.5YR4/4		S	42U_S	G		D00N0	5.5	240
ROCK	330-520	GS	RED & BROWN ROCKS		S	65ST_VS	G			6	470
B	520-1030	CS	7.5YR5/1	M>44PRD	MC	42U_S	VM3PO		T41N3	5.5	740
			A LOT OF RED MOTTLE	HOWEVER, SOIL STILL GREY							

Vegetation: SW SIDE HAS BLACK WATTLE, NE SIDE HAS DARK SHRUBBY

Project Name:

Limpopo

Date:	21/07		**Site:**	**VP15**	
Location:	E of right angled bend		**Coordinates:**	**E 0618033**	**N 7531375**
Landform Pattern:			**Micro Relief:**	**D**	
Landform Element:	PLA		**Rock Outcrops:**	**2SA**	
Morphological Type:	PLA		**S C Fragments:**	**0**	
Site Disturbance:	F		**Substrate:**	**2XV(QFM)M**	
Erosion:	0		**Surface Condition:**	**F**	
Landform	Elevation:	415	**Permeability:**	**3**	
	Slope (%):	3	**Drainage:**	**5**	
	Relief:	<9	**Run-off:**	**2**	

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-50		2.5YR3/1	0	S	0	G	0	D0N0	5.5	20
A2	50-280	BS	2.5YR4/2	M22DYD	S	0	G	0	D1N0	5.5	200
B	280-390	BG	5YR5/2	M33PRC	CS	0	V3PO	0	T3N1	5.5	330
C	390-410	AS									

Vegetation: yellow and silver trees

Notes: similar to VP2

Project Name:

Sabie

Date:	23/07/19		**Site:**	**VP16**	
Location:	EN ROUTE TO TRIPLE GATE		**Coordinates:**	**E 0624196**	**N 7525914**
Landform Pattern:	PLS		**Micro Relief:**	**D**	
Landform Element:	HSL		**Rock Outcrops:**		
Morphological Type:	M		**S C Fragments:**	**ONLY UNDECOMPOSED OM**	
Site Disturbance:	2		**Substrate:**		
Erosion:	S		**Surface Condition:**	**S**	
Landform	Elevation:	244	**Permeability:**	**3**	
	Slope (%):	4	**Drainage:**	**4**	
	Relief:	<9	**Run-off:**	**3**	

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A11	0-230		7.5YR3/3		S		G		D00N0	7	200
A12	230-360	GS	7.5YR3/4		S		G		D00N0	6.5	370
A2	360-670	CS	7.5YR4/6		S		G		D00N0	7	700
B	670-770	AS	5YR4/6		CSL		G(CONSOLIDATED)		T21N1	6.5	820

Vegetation: VARIATIONS OF GUM

Notes:

Project Name:

Limpopo

Date:	23/07/19		**Site:**	**VP17**	
Location:	SOUTH OF VP12/20		**Coordinates:**	**E 0621336**	**N 7527694**
Landform Pattern:	RIS		**Micro Relief:**	**D**	
Landform Element:	FOO		**Rock Outcrops:**		
Morphological Type:	F		**S C Fragments:**	**11S_OY**	
Site Disturbance:	2		**Substrate:**	**2PV(QFMmS)**	
Erosion:	PWXCXS1G2		**Surface Condition:**	**S**	
Landform	Elevation:	295	**Permeability:**	**3**	
	Slope (%):	3	**Drainage:**	**4**	
	Relief:	9-30	**Run-off:**	**4**	

A2->b – similar colour but texture difference

Ub->lb – similar texture but different colour

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-200		7.5YR3/4		LS		GW2PO		D10N0	5	20
A2	200-500	GS	7.5YR4/6		LS		GW3PO		D10N0	5	30
UB	500-700	GS	7.5YR4/6	M22F(OY)D	SCL	22URS	GM4PO		T30N1	6	660
LB	700-1000	CB	10YR4/4	M32D(OR)C	CL	22URS	GM4PO		T31N2	6	860

Vegetation:lower plain dominated by silver boys&blackwattle w/ eucalypts on ridge

Notes:

Project Name:

Limpopo

Date:	21/07		**Site:**	**VP18**	
Location:	Northerly point on triple gate		**Coordinates:**	**E 0622928**	**7532441 N**
Landform Pattern:	PLA		**Micro Relief:**	**D**	
Landform Element:	PLA		**Rock Outcrops:**	**1SA**	
Morphological Type:	F		**S C Fragments:**	**21S_OT**	
Site Disturbance:	2		**Substrate:**	**0**	
Erosion:	SWXCXSX		**Surface Condition:**	**S**	
Landform	Elevation:	243	**Permeability:**	**3**	
	Slope (%):	2	**Drainage:**	**5**	
	Relief:	<9	**Run-off:**	**2**	

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-150		0	S	S	-	G	-	D00N0	5	90
A2	150-560	CS	0	CS	CS	-	G	-	D10N0	5.5	360
B	560-1010	AS	M23DRD	CL	CL	-	V3PO	-	T32N3	6.5	840

Vegetation: Yellow, long skinny-dark bark and silver

Notes:

Project Name:

Zambezi

Date:	23/07/19		**Site:**	**VP19**	
Location:	Open plain , s of VP11		**Coordinates:**	**E 0623552**	**N 7527004**
Landform Pattern:	PLA		**Micro Relief:**	**D**	
Landform Element:	PLA		**Rock Outcrops:**	**1(SA/ZS)**	
Morphological Type:	F		**S C Fragments:**	**11R_OT**	
Site Disturbance:	2		**Substrate:**		
Erosion:	S		**Surface Condition:**	**F**	
Landform	Elevation:	254	**Permeability:**		
	Slope (%):	0	**Drainage:**	**REFER TO PHOTOS**	
	Relief:	<9	**Run-off:**		

*A1 couldve probably been further subdivided into A11 AND A12

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-120		7.5YR3/3		LS		GW2PL		D10N0	5	50
A2	120-390	AS	7.5YR4/3		LS		GW3PL		D10N0	6	200
UB	390-640	AW	7.5YR6/1	M32DYD	ZCL	22RS	GM4PO		T31N2	6	470
LB	640-910	DS	7.5YR6/1	M32D(YO)D	ZCL	22RS	GM4PO	1KN2	T31N3	6	800

Vegetation: LSLDB, KNEE HEIGHT AND YELLOW GRASS

Notes:

Project Name:

Sabie

Date:	22/07/19		**Site:**	**VP20**	
Location:	NEAR END OF SNAKE TONGUE		**Coordinates:**	**E 0620593**	**N 7528364**
Landform Pattern:	RIS		**Micro Relief:**	**D**	
Landform Element:	FOO		**Rock Outcrops:**		
Morphological Type:	L		**S C Fragments:**	**21A_IS**	
Site Disturbance:	2		**Substrate:**	**2PV(QFMmaybeS)VW**	
Erosion:	PWXCXS1		**Surface Condition:**	**SLIGHT C**	
Landform	Elevation:	354	**Permeability:**	**3**	
	Slope (%):	5	**Drainage:**	**5**	
	Relief:	9-30	**Run-off:**	**3**	

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-40		2.5YR2.5/1		LS		VM3CO		D10N0	5	20
A2	40-330	AS	5YR3/3		CS		G		D00N0	5	180
B	330-600	CS	5YR5/1	M43DRD	CLS	12S_OT	VM3PO		T41N2	5	500

Vegetation: ACACIA MONO. S, GUM -> SIMILAR TO RED MOTTLED STUFF SEEN EARLIER

Project Name:

Sabie

Date:	21/07		**Site:**	**VP21**	
Location:	NW CORNER, SW OF RED DAM		**Coordinates:**	**E 0616998**	**N 75322415**
Landform Pattern:	RIS		**Micro Relief:**	**D**	
Landform Element:	HSL		**Rock Outcrops:**	**Q (SURROUNDING OUTCROPS)**	
Morphological Type:	F		**S C Fragments:**	**11UROT**	
Site Disturbance:	1		**Substrate:**	**X**	
Erosion:	PWXCXS2		**Surface Condition:**	**H**	
Landform	Elevation:	368	**Permeability:**	**3**	
	Slope (%):	3	**Drainage:**	**4**	
	Relief:	9-30	**Run-off:**	**2 (ALMOST 100% GROUNDCO**	

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	140		5YR2.5/1	0	L	0	V3PO	0	D20N1	6	50
A2	140-410	CS	5YR2.5/2	0	SCL	0	V4PO	0	D20N1	6	250
B	410-820	GI	5YR3/3	M23RD	CL	0	V4SB	0	T42N3	6	600

Vegetation: A lot of gum trees and dark bark long skinny leaves

Project Name:

Notes:

Limpopo

Date:	21/07/19		**Site:**	**VP22**	
Location:	// TO HIGHWAY		**Coordinates:**	**E**	**N**
Landform Pattern:	PLA		**Micro Relief:**	**D**	
Landform Element:	PLA		**Rock Outcrops:**	**0**	
Morphological Type:	F		**S C Fragments:**	**21S_OT**	
Site Disturbance:	2		**Substrate:**	**0**	
Erosion:	S		**Surface Condition:**	**S**	
Landform	Elevation:	242	**Permeability:**	**4**	
	Slope (%):	0	**Drainage:**	**4**	
	Relief:	<9	**Run-off:**	**2**	

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	100		2.5YR2.5/2	0	S	0	G	0	D00N0	5.5	50
A2	100-480	CS	2.5YR5/3	M22FYD	S	0	G	0	D10N0	5.5	300
B	480-900	DS	2.5YR6/1	M43PRC	SL	21S_S	G	0	T41N3	5.5	700

Vegetation:

Project Name:
Notes:

Zambezi

Date:	21/07/19		**Site:**	**VP23**	
Location:	Near melaleuca watercourse		**Coordinates:**	**E**	**N**
Landform Pattern:	PLA		**Micro Relief:**	**D**	
Landform Element:	PLA		**Rock Outcrops:**	**0**	
Morphological Type:	F		**S C Fragments:**	**0**	
Site Disturbance:	2		**Substrate:**	**0**	
Erosion:	S		**Surface Condition:**	**M**	
Landform	Elevation:	210	**Permeability:**	**3**	
	Slope (%):	0	**Drainage:**	**5**	
	Relief:	9-30	**Run-off:**	**2**	

Anomaly

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-140	AS	5YR2.5/2	0	S	0	G	0	T0010	5.5	90
A2	140-310	SS	5YR2.5/2	0	S	0	G	0	“”	6	290
B	310-700	AS	7.5YR4/4	0	S	0	G	0	D0010	6	580

Vegetation: A1 AND A2 WERE INCREDIBLY SIMILAR HOWEVER, SEPERATED BY A THIN YELLOW SANDY BAND. GUM TREES, MALALEUCA, BLACK WATTLE

Project Name:

Notes:

Limpopo

Date:	22/07/19		**Site:**	**VP24**	
Location:	JUST NE OF DYNO GATE		**Coordinates:**	**E062492**	**N 7529540**
Landform Pattern:	PLS		**Micro Relief:**	**D**	
Landform Element:	PLS		**Rock Outcrops:**		
Morphological Type:	F		**S C Fragments:**	**11ST_OT**	
Site Disturbance:	2		**Substrate:**		
Erosion:	PWXCXS1G1		**Surface Condition:**	**L**	
Landform	Elevation:	231	**Permeability:**	**3**	
	Slope (%):	1	**Drainage:**	**5**	
	Relief:	<9M	**Run-off:**	**1 VEG + SANDY SOIL**	

Anomaly

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-180		2.5Y3/2		S		G		D00N0	5	80
A2	180- 850	GS	2.5Y5/4		S		G		T00N0	5	500

Vegetation: BLACK WATTLE, MALALEUCA

Project Name:
Notes:

Zambezi

Date:	24/07/2019		**Site:**	**VP25**	
Location:	South of VP39		**Coordinates:**	**E 0629401**	**N 7525245**
Landform Pattern:	PLA		**Micro Relief:**	**D**	
Landform Element:	PLA		**Rock Outcrops:**		
Morphological Type:	F		**S C Fragments:**		
Site Disturbance:	1		**Substrate:**		
Erosion:	S		**Surface Condition:**	**S**	
Landform	Elevation:	202	**Permeability:**	**3**	
	Slope (%):	0	**Drainage:**	**4**	
	Relief:	<9M	**Run-off:**	**2**	

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-150		2.5YR2.5/2		LS		G		T00NO	6.5	20
A2	150-385	GS	7.5YR4/4		LS		G		T00N0	8	260
UB	385-680	CI	10YR5/6	M3D(YO)D	SCL		VM3PO		T21U1	7.5	600
LB	680-960	GS	10YR5/4	M3D(OY)D	CLS		VM3PO		T21N2	8.5	810

Vegetation: dense grass, more trees than VP31, POPLAR boxes (compare with VP16 as this also had polar box)

Project Name:

Notes:

Kei

Date:	25/07/19		**Site:**	**VP26**	
Location:	Pointy corner		**Coordinates:**	**E 0630829**	**N 7522138**
Landform Pattern:	PLA		**Micro Relief:**	**D**	
Landform Element:	PLA		**Rock Outcrops:**		
Morphological Type:	F		**S C Fragments:**		
Site Disturbance:	1		**Substrate:**		
Erosion:	PWXCX51G1		**Surface Condition:**	**F**	
Landform	Elevation:	215	**Permeability:**	**3**	
	Slope (%):	0	**Drainage:**	**4**	
	Relief:	<9M	**Run-off:**	**1**	

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A11	0-170		10YR3/2		SL (F)		G		D00N0	5.5	20
A12	170-420	DS	10YR4/4		SL		G		D00N0	6.5	300
A2	420-630	GS	10YR4/4		SL		G		D00N0	7	550
B	630-980	CS	10YR4/3	M33D0C	ZCL		VM3PO		T31N3	7	850

Vegetation: Poplar boxes, black spear grass

Project Name:
Notes:

Fish

Date:	25/07/19		**Site:**	**VP27**	
Location:	Nxt to car graveyard		**Coordinates:**	**E 0629951**	**N 7522644**
Landform Pattern:	PLA		**Micro Relief:**	**D**	
Landform Element:	PLA		**Rock Outcrops:**		
Morphological Type:	F		**S C Fragments:**	**22S_IS (maybe sesquioxides)**	
Site Disturbance:	2		**Substrate:**	**2XV(QMD)S**	
Erosion:	PWXCXS1G1		**Surface Condition:**	**S,C**	
Landform	Elevation:	218	**Permeability:**	**3**	
	Slope (%):	3	**Drainage:**	**4**	
	Relief:	<9M	**Run-off:**	¾	

Bloodwood-low fertility, skeletal soils

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-90		10YR4/1		LS		VW3PL		D10N0	6	20
A2	90-380	CS	10YR5/1		CLS		VW2PO		D11N2	5.5	240
B	380-540	AS	10YR5/1	M12D(RO)D	ZCL	1(1/2)S_S	VM3PO		T32N3	5.5	520
SUBS	540	SS									

Vegetation: Poplar box, some black wattle, dominant was bloodwood

Project Name:

Notes:

Limpopo

Date:	25/07/19		**Site:**	**VP28**	
Location:	Far south		**Coordinates:**	**E 0629153**	**N 7521863**
Landform Pattern:	PLA		**Micro Relief:**	**D**	
Landform Element:	PLA		**Rock Outcrops:**		
Morphological Type:	F		**S C Fragments:**	**214S_IS/OT**	
Site Disturbance:	2		**Substrate:**	**-**	
Erosion:	S		**Surface Condition:**	**F**	
Landform	Elevation:	218	**Permeability:**	**3**	
	Slope (%):	0	**Drainage:**	**4**	
	Relief:	<9M	**Run-off:**	**2 (SANDY TOP,SOIL, FLAT+VEG**	

-Had a 40mm band of sand between UB and LB (had same colour and texture as A2 but consistency different T21N0 and pH 6.5)

-LB had a much sandier texture than UB

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A11	0-70		10YR4/3	-	LS (F)	-	G		D00N0	6	20
A12	70-280	GS	10YR4/4	-	LS (F)	-	G		D00N0	5.5	200
A2	280-360	CS	10YR5/4	-	LS (F)	-	G		D00N0	5.5	320
UB	360-520	CS	10YR5/3	M1FYD	CLS	-	VM3PO		D41N3	5.5	410
LB	560-920	GI	10YR5/3	M1FYD	SL	11S_S	G (MASSIVE)		D00N1	7	630

Vegetation: Black wattle, silver leaf iron bark

Project Name:
Notes:

Zambezi

Date:	24/07/2019		**Site:**	**VP29**	
Location:	Near nose shaped watercourse		**Coordinates:**	**E 0628119**	**N 7523174**
Landform Pattern:	PLA		**Micro Relief:**	**D**	
Landform Element:	PLA		**Rock Outcrops:**		
Morphological Type:	F		**S C Fragments:**		
Site Disturbance:	3		**Substrate:**		
Erosion:	S		**Surface Condition:**	**S**	
Landform	Elevation:	217	**Permeability:**	**2**	
	Slope (%):	0	**Drainage:**	**4**	
	Relief:	<9M	**Run-off:**	**Slow run-off**	

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-140		10YR3/2		LS (K)		G		D00N0	6.5	40
A2	140-260	CS	10YR5/4		LS (K)		G		D00N0	7	220
UB	260-550	AS	10YR6/2	M42D(RBO)D	CLS		VM3PO		T32N2	6.5	410
LB	550-920	GS	10YR7/2	M22D(OY)D	CLS		VM3PO		T32N2	6	780

Vegetation: Poplar Boxes and grassy (black wattle further south)

Project Name:

Notes:

Kei

Date:	25/07/19		**Site:**	**VP30**	
Location:	@southern cow yards		**Coordinates:**	**E 0630290**	**N 7523999**
Landform Pattern:	PLA		**Micro Relief:**	**D**	
Landform Element:	PLA		**Rock Outcrops:**		
Morphological Type:	F		**S C Fragments:**		
Site Disturbance:	4		**Substrate:**		
Erosion:	PWXCXS1		**Surface Condition:**	**F**	
Landform	Elevation:	208	**Permeability:**	**3**	
	Slope (%):	0	**Drainage:**	**4**	
	Relief:	<9M	**Run-off:**	**3**	

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A11	0-180		7.5YR3/2		CS		VW3PO/PL		D10N0	6	20
A12	180-530	GS	7.5YR3/4		LS (F)		G		D00N0	7	400
A2	530-740	CS	10YR4/4		LS (F)		G		D00N0	7.5	660
B	740-1020	GB	10YR4/2	M12FYD	MC		VM4PO		T33N3	7.5	809

Vegetation: Poplar box

Project Name:

Notes:

Orange

Date:	24/07/2019		**Site:**	**VP31**	
Location:	S of OP 40		**Coordinates:**	**E 0628635**	**N 7526061**
Landform Pattern:	PLA		**Micro Relief:**	**N (maybe S)**	
Landform Element:	PLA		**Rock Outcrops:**		
Morphological Type:	F		**S C Fragments:**		
Site Disturbance:	2		**Substrate:**		
Erosion:	S		**Surface Condition:**	**G, potentially M**	
Landform	Elevation:	213	**Permeability:**	**2**	
	Slope (%):	0	**Drainage:**		
	Relief:	<9M	**Run-off:**	**2 -> flat**	

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-40		2.5Y2.5/1		LC		VM2PO		D21N3	7	20
A2	40-360	AS	2.5Y3/1		LMC	11SRS	VS4PO		T42N2	8.5	200
B	360-980	AS	2.5Y3/1		LMC	21SRS	VS4PO	2KN2	T262N2	9	650

Vegetation: Open grassland with shrubs (concaberry…carissa xxx)

Project Name:

Notes:

Komati

Date:	22/07/19		**Site:**	**VP32**	
Location:	// WITH SARAJI ROAD		**Coordinates:**	**E 0626996**	**N 7528119**
Landform Pattern:	PLA		**Micro Relief:**	**N SOME CRACKING**	
Landform Element:	PLA		**Rock Outcrops:**		
Morphological Type:	F		**S C Fragments:**	**21S_IS**	
Site Disturbance:	2		**Substrate:**		
Erosion:	S		**Surface Condition:**	**G/H**	
Landform	Elevation:	229	**Permeability:**	**2**	
	Slope (%):	2	**Drainage:**	**4**	
	Relief:	<9	**Run-off:**	**2**	

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-80		7.5YR3/3		CS		GW3PO		D10N0	5	50
A2	80-450	CS	7.5 YR 4/4	M32DOD	SCL		GM3PO		T32N2	8	300
U B	450-860	AS	7.5YR5/6		CL		GM4PR	4KN2	T42N3	9	700
L B	860-1040	DS	7.5YR4/4		CL		GM4PR	4KN2	T42N3	9	1000

Vegetation: GHOST GUM (CONFIRM ON PHOTOS) -> CALCAROUS SODOSOL

Project Name:
Notes:

Limpopo

Date:	24/07/2019		**Site:**	**VP 33**	
Location:	Near tributary confluence		**Coordinates:**	**E 0625335**	**N 7522263**
Landform Pattern:	PLA		**Micro Relief:**	**D**	
Landform Element:	PLA		**Rock Outcrops:**		
Morphological Type:	F		**S C Fragments:**	**21S_(IS/OT)**	
Site Disturbance:	2		**Substrate:**		
Erosion:	PWXCXS1		**Surface Condition:**	**F SOME C**	
Landform	Elevation:		**Permeability:**		
	Slope (%):	0	**Drainage:**		
	Relief:	<9M	**Run-off:**		

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A11	0-100		7.5YR4/3		SL		VW2PL		D10N0	6	40
A12	100-270	AS	7.5YR3/4		SL		G		D00N0	6	240
A2	270-400	CS	7.5YR4/6		SL		G		D00N0	6	360
UB	400-860	CS	7.5YR5/8		SCL		VW3PO		T21W1	5.5	560
LB	860-920	AS	5YR4/6		CLS		VW3PO		T21N2	5,5	900

Vegetation: Silver leaf iron bark, couple black wattle, some poplar

Project Name:

Notes:

Komati

Date:	23/07/2019		**Site:**	**VP34**	
Location:	IN PUNCHBOWL		**Coordinates:**	**E 0626643**	**N 7526781**
Landform Pattern:	PLA		**Micro Relief:**	**N/S (GILGAI APPROX 20CM)**	
Landform Element:	PLA		**Rock Outcrops:**		
Morphological Type:	F		**S C Fragments:**		
Site Disturbance:	3		**Substrate:**		
Erosion:	S		**Surface Condition:**	**G**	
Landform	Elevation:	236	**Permeability:**	**2**	
	Slope (%):	0	**Drainage:**	**3**	
	Relief:	<9	**Run-off:**	**3**	

UPPER HALF, BLACK AND CRACKY LIKE VERT, BUT BOTTM HALF IS A BROWN CLAY

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-80		10YR2/1		LMC		VM2PO		T21N1	8.5	21
A2	80-320	AS	10YR2/2		LMC	11S_2	VM3PO	2KN2	T21N1	8.5	160
UB	320-790	GS	7.5YR4/6		MC	11S_S	VW2PO	4KN3	T12N3	8.5	500
LB	790-1190	CB	7.5YR6/4		CLS		VW2PO	5KN3	T12N2	8.5	1070

Vegetation:

Project Name:

Notes:

Orange

Date:	22/07/19		**Site:**	**VP35**	
Location:	Off the southern border of zig zag bend		**Coordinates:**	**E0625692**	**N 7528649**
Landform Pattern:	PLA		**Micro Relief:**	**N**	
Landform Element:	PLA		**Rock Outcrops:**		
Morphological Type:	F		**S C Fragments:**	**11U_OT**	
Site Disturbance:	2		**Substrate:**		
Erosion:	PWXCXS2		**Surface Condition:**	**G MAYBE M TOO**	
Landform	Elevation:	233	**Permeability:**	**2**	
	Slope (%):	0	**Drainage:**	**4**	
	Relief:	<9	**Run-off:**	**2**	

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	130		10YR2/1		LC		VM3PO		D32N3	6	100
A2	130-640	DS	10YR2/1		LMC		VM5SB		T52N3	8.5	380
B	640-1200	DS	10YR3/1		LMC	SOME SAND PRESENT IN PATCHES	G		T52N3	8.5	1000

Vegetation: ACACIA MONO S.

Project Name:
Notes:

Zambezi

Date:	23/07/2019		**Site:**	**VP36`**	
Location:	PAST VD11 TOWARDS TRIP GATE		**Coordinates:**	**E 0624632**	**N 7527796**
Landform Pattern:	PLA		**Micro Relief:**	**D**	
Landform Element:	PLA		**Rock Outcrops:**	**X - assume sandstone**	
Morphological Type:	F		**S C Fragments:**	**Only veg**	
Site Disturbance:	2		**Substrate:**	**2XV(QMmS)**	
Erosion:	PWXCXS2		**Surface Condition:**	**F**	
Landform	Elevation:	246	**Permeability:**	¾	
	Slope (%):	3	**Drainage:**	**4**	
	Relief:	<9M	**Run-off:**	**2**	

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-200		7.5YR4/2		S		G		D00N0	5.5	20
A2	200-360	CS	7.5YR5/4		S		G		D00N0	5.5	310
B	360-640	CI	10YR5/2	M32D(RO)D	CLS	11SRS	VM3PO		T32N2	6.5	500
C	640-680	AS	2XV(QFmS)								

Vegetation: Some black wattle and eucalypts

Project Name:
Notes:

Zambezi

Date:	23/07/19		**Site:**	**VP37**	
Location:	NEAR CATTLE YARDS		**Coordinates:**	**E 0625149**	**N 7524622**
Landform Pattern:	PLA		**Micro Relief:**	**D**	
Landform Element:	PLA		**Rock Outcrops:**		
Morphological Type:	F		**S C Fragments:**		
Site Disturbance:	2		**Substrate:**		
Erosion:	PWXCXS1G2		**Surface Condition:**	**F341**	
Landform	Elevation:	229	**Permeability:**	**3**	
	Slope (%):	0	**Drainage:**	**4**	
	Relief:	<9	**Run-off:**	**1**	

- Ph COULD BE OFF DUE TO PRESENCE of COWS IN CATTLE YARD

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A11	50		7.5YR2.5/2		LS		GW2PO		D10N0	8.5	35
A12	50-240	AS	7.5YR3/3		LS		GW2PL		D10N0	7.5	320
A2	240-490	GS	7.5YR5/4	M1DYC	LS		GW2PO		D10N0	7	520
UB	490-700	AS	7.5YR5/4	M2D(OR)C	ZCL	11U_S	GM4PL		T31N2	7	600
LB	700-850	AS	7.5YR6/1		LC	11U_S	GS4PO		T41N3	8	780

Vegetation: GUM TREES, FEW BLACK WATTLE, EUCALYPTS

Project Name:
Notes:

Zambezi

Date:	24/07/2019		**Site:**	**VP38**	
Location:	@ hook corner		**Coordinates:**	**E 0624909**	**N 7524427**
Landform Pattern:	PLA		**Micro Relief:**	**D**	
Landform Element:	PLA		**Rock Outcrops:**		
Morphological Type:	F		**S C Fragments:**		
Site Disturbance:	2		**Substrate:**		
Erosion:	S		**Surface Condition:**	**S**	
Landform	Elevation:	208	**Permeability:**	**4 (ONLY SAND OBSERVED)**	
	Slope (%):	0	**Drainage:**	**4**	
	Relief:	<9m	**Run-off:**	**1**	

Suspicious that this is the same as VP25, just the B horizon is deeper therefore was not observed.

- Split A horizons

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A11	0-130		7.5YR2.5/2		ZL		VW2PO		D21N0	7	60
A12	130-550	AS	7.5YR3/2		LS		VW2PL		D20N0	6.5	300
A2	550-950	GS	10YR4/4		S		G		T00N0	7	800

Vegetation: Poplar box and grass

Project Name:

Notes:

Komati

Date:	22/07/19		**Site:**	**VP39**	
Location:	Close to triple gate		**Coordinates:**	**E 0625688**	**N 7527648**
Landform Pattern:	PLA		**Micro Relief:**	**N**	
Landform Element:	PLA		**Rock Outcrops:**		
Morphological Type:	F		**S C Fragments:**	**21A_IS**	
Site Disturbance:	2		**Substrate:**		
Erosion:	S		**Surface Condition:**	**G**	
Landform	Elevation:	227	**Permeability:**	**2**	
	Slope (%):	0	**Drainage:**	**4**	
	Relief:	<9	**Run-off:**	**2**	

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-80		7.5YR2.5/1		SCL		GM3PO		D21N2	7	
A2	80-520	AS	7.5YR3/3	M22DOD	MC	51A_VSA	GM4PO		D21N2	8.5	
U B	520-780	CB	7.5YR3/4		MC	51A_VSM	GM4PO	3KN2W	T42N3	8.5	
L B	780-1020	DS	7.5YR5/8		MC	51A_VSM	GM4PO	5KN3W	T42N3	8.5	

Vegetation: GUMS, GRASS , SHRUB WITH SMALL ROUND LEAVES -> LOOKS LIKE THE SODOSOL

Project Name:
Notes:

Orange

Date:	23/07/19		**Site:**	**VP40**	
Location:	IN Punchbowl next to saraji rd		**Coordinates:**	**E 0627472**	**N 7527245**
Landform Pattern:	PLA		**Micro Relief:**	**N/S GILGAI**	
Landform Element:	PLA		**Rock Outcrops:**		
Morphological Type:	F		**S C Fragments:**		
Site Disturbance:	3		**Substrate:**		
Erosion:	S		**Surface Condition:**	**G**	
Landform	Elevation:	218	**Permeability:**	**2**	
	Slope (%):	0	**Drainage:**	**2**	
	Relief:	<9	**Run-off:**	**M**	

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-100		10YR2/1		LMC	11S_5	G (MASSIVE)		D21N1	7	10
UB	100-600	AS	7.5YR2.5/1		LMC	11S_5	V3PO		T32N1	7.5	320
LB	600-1110	DS	10YR3/1		LMC	11S_5	V3PO	2NK2	T43N1	9	1030

Vegetation: OPEN GRASSLAND

Project Name:
Notes:

Zambezi

Date:	24/07/2019		**Site:**	**VP41**	
Location:	Wnw of VP 37		**Coordinates:**	**E 0626905**	**N 7524931**
Landform Pattern:	PLA		**Micro Relief:**	**D**	
Landform Element:	PLA		**Rock Outcrops:**		
Morphological Type:	F		**S C Fragments:**	**21S_IS**	
Site Disturbance:	2		**Substrate:**		
Erosion:	PWXCXS1		**Surface Condition:**	**G, F**	
Landform	Elevation:	226	**Permeability:**		
	Slope (%):	0	**Drainage:**		
	Relief:	<9M	**Run-off:**		

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A1	0-130		7.5YR4/2		LS		VW3PL		D10N0	6	80
A2	130-280	CS	7.5YR5/2		LS		G		D00N0	7	220
UB	280-770	GI	2.5Y5/3	M2F(YD)D	CLS		VM4PO		T32N2	9	450
LB	770-1090	CS	2.5Y5/1	M1F(Y)D	ZCL	11S_S	VM4PO		T31N2	9	970

Vegetation: Poplar box, shrubs

Project Name:

Notes:

Zambezi

Date:	24/07/2019		**Site:**	**VP42**	
Location:	Off the “track”		**Coordinates:**	**E 0628019**	**N 7524657**
Landform Pattern:	PLA		**Micro Relief:**	**D**	
Landform Element:	PLA		**Rock Outcrops:**		
Morphological Type:	F		**S C Fragments:**		
Site Disturbance:	1		**Substrate:**		
Erosion:	S		**Surface Condition:**	**S/F**	
Landform	Elevation:	200	**Permeability:**	**3**	
	Slope (%):	0	**Drainage:**	**4**	
	Relief:	<9M	**Run-off:**	**2**	

[Soil Description]

Horizon	Depth (mm)	Boundary	Colour	Mottles	Texture	Coarse Fragments	Structure	Segregations	Consistency	Field pH	
A11	0-80		7.5YR2.5/2		LS		GW2PL		D10N0	6.5	20
A12	80-460	CS	7.5YR3/2		LS		GW2PO		D10N0	6.5	180
A2	460-610	GS	7.5YR2.5/3		ZCL		GM3PO		T33N1	7	540
UB	610-780	CS	7.5YR3/4		ZCL	21S_S	GM3PO		T33N1	7	700
LB	780-940	GS	5YR5/6		LMC		GM3PO		T33N3	7	900

Vegetation:Poplar, shrubs and grass

Appendix C Soil Observation Data

Obs	Date	Site ID	Vegetation	Soil Description/Unit	Notes
1	19-Jul	OP1	Eucalyptus crebra	Crocodile	W to E, change from yellow to red soil
2	19-Jul	OP2	Eucalyptus populnea	Boundary	West side = red, east side + yellow
3	20-Jul	OP3	Eucalyptus crebra	Boundary	W=valley, E = similar to VP3
4	20-Jul	OP4	Eucalyptus populnea	Limpopo	Pale sandy
5	20-Jul	OP5	Eucalyptus crebra	Crocodile	similar to VP3
6	20-Jul	OP6	Eucalyptus crebra, grass	Limpopo	
7	20-Jul	OP7	Eucalyptus crebra, grass	Crocodile	
8	20-Jul	OP8	Eucalyptus populnea, Eucalyptus crebra	Boundary	NE- Yellow sandy, SW - red rocky
9	20-Jul	OP9	Eucalyptus populnea, Eucalyptus crebra	Limpopo	Yellow sandy
10	21-Jul	OP10	Eucalyptus crebra	Boundary	W-red rocky E - yellow sandy
11	21-Jul	OP11	Eucalyptus populnea, Eucalyptus crebra	Boundary	E - red rocky , W - yellow sandy
12	21-Jul	OP12	Eucalyptus populnea, Eucalyptus crebra	Limpopo	Pale sandy, footlsope to SW
13	21-Jul	OP13	Eucalyptus populnea	Boundary	NW - brown sandy, SE - yellower
14	21-Jul	OP14	Eucalyptus populnea, Eucalyptus crebra	Boundary	W-red rocky E - yellow sandy
15	21-Jul	OP15	Type of Gum trees?	Komati	S - valley, N - flat
16	21-Jul	OP16		Crocodile	Brown shaley soil with sz substrate exposed
17	21-Jul	OP17		Crocodile	Brown shaley soil with sz substrate exposed
18	21-Jul	OP18	Malaleuca - watercourse	Zambezi	
19	22-Jul	OP19	Eucalyptus populnea, Eucalyptus crebra	Boundary	S - red rocky, N - yellow sandy
20	22-Jul	OP20	Eucalyptus populnea	Limpopo	S-wards - yellow sandy
21	22-Jul	OP21	Looks like sheoak? Confirm	Boundary	N - red sandy, S vertosol
22	22-Jul	OP22	Gum/ Eucalyptus populnea	Boundary	SE - red brown, like VP 32
23	22-Jul	OP23	""	Boundary	E-wards, change to vert
24	22-Jul	OP24	Change from dense eucalypt to grassy	Boundary	SE- red/brown cracking to dark vert
25	22-Jul	OP25		Boundary	
26	22-Jul	OP26	Change to Eucalyptus populnea	Boundary	We-wards - brown to sandy
27	22-Jul	OP27	Disappearance of Eucalyptus populnea	Boundary	W- less sandy , red to cracky
28	22-Jul	OP28	Change to Eucalyptus populnea	Boundary	W- less sandy more red brown
29	22-Jul	OP29	Eucalyptus crebra	Boundary	W - no sandy, hard brown

Obs	Date	Site ID	Vegetation	Soil Description/Unit	Notes
30	22-Jul	OP30	Eucalyptus populnea, Corymbia erythophloia	Boundary	NW - yellow sandy, SE - red rocky
31	22-Jul	OP31		Boundary	SE - going from VP 20 ground cover down ridge to yellow sandy
32	23-Jul	OP32	Eucalyptus populnea	Komati	Red brown cracking
33	23-Jul	OP33	Eucalyptus crebra	Boundary	Goes from yellow sandy to red cracky
34	23-Jul	OP34	Eucalyptus populnea	Boundary	NE - away from red to sandy yellow
35	23-Jul	OP35	Open grassland with Eucalyptus crebra	Boundary	Still sandy but firmer
36	23-Jul	OP36		Boundary	Orangey sandy soil, sevee erosion
37	23-Jul	OP37	Dense veg with shrubs	Boundary	SW-wards - sandy to firm orange/brown cracking
38	23-Jul	OP38	Change from Eucalyptus crebra, to Eucalyptus populnea	Boundary	SW-wards, change from brown cracking to yellow sandy
39	23-Jul	OP39	Change from Eucalyptus populnea to Eucalyptus crebra	Boundary	change to brown cracking
40	23-Jul	OP40	Change from Eucalyptus crebra, to Eucalyptus populnea	Boundary	NE - orange firm to yellow sandy
41	23-Jul	OP41	Eucalyptus crebra	Limpopo	
42	23-Jul	OP42	Open grassland with eucalpyts	Boundary	S - change to dark cracking
43	23-Jul	OP43	Dense eucalypts	Boundary	change from dark cracking to brown cracking
44	24-Jul	OP44	Change to Eucalyptus populnea	Boundary	S - dark cracking to brown cracking
45	24-Jul	OP45	Eucalyptus populnea	Limpopo	S - yellow sandy
46	24-Jul	OP46	Change to Eucalyptus populnea	Limpopo	S - yellow sandy
47	24-Jul	OP47	Change to shrublands	Limpopo	Ground lighter coloured
48	25-Jul	OP48	Change to Eucalyptus populnea		S-N - becomes browner
49	25-Jul	OP49	Malaleuca - watercourse	Zambezi	sandy
50	25-Jul	OP50	Acacia Excelsa	Fish	skeletal looking soil
51	25-Jul	OP51	Malaleuca - watercourse	Zambezi	
52	25-Jul	OP52	Spear head grass	Kei	Soil gets sandier and lighter
53	25-Jul	OP53	Acacia Excelsa	Fish	Light grey sand
54	25-Jul	OP54	Acacia Excelsa	Fish	Light grey sand

Obs	Date	Site ID	Vegetation	Soil Description/Unit	Notes
55	25-Jul	OP55	Eucalyptus crebra	Boundary	N-wards - less sand to brown cracking
56	25-Jul	OP56	Malaleuca - watercourse	Zambezi	Yellow sandy
57	25-Jul	OP57	Change to shrublands	Boundary	Soil darker
58	25-Jul	OP58	Eucalyptus populnea	Boundary	Ground firmer wqith cracking
59	25-Jul	OP59	Malaleuca - watercourse	Zambezi	Sandy
60	25-Jul	OP60	Open shrubby	Orange	change to dark vert
61	25-Jul	OP61	Open shrubby	Orange	
62	25-Jul	OP62	Open shrubby	Komati	Soil becomes brown cracking
63	25-Jul	OP63	Open shrubby	Orange	W - change from vert to brown cracking
64	25-Jul	OP64		Boundary	S - change from brown to vert
65	25-Jul	OP65		Boundary	Boundary between dark vert and brown cracking
66	25-Jul	OP66		Boundary	W - change to brown cracking

Appendix D Sampling Site Locations

ID	Sample Location	SMU	Latitude (GDA94)	Longitude (GDA94)	Elevation (m)	Time	Sample Type
66	VP1	Limpopo	-22.2891	148.186	221.958	2019-07-20T06:31:56Z	Detailed Profile
67	VP10	Sabie	-22.3382	148.206	253.123	2019-07-21T06:01:13Z	Detailed Profile
67	VP10	Sabie	-22.3382	148.206	253.123	2019-07-21T06:01:13Z	Detailed Profile
68	VP11	Sabie	-22.3504	148.2	247.991	2019-07-22T05:42:39Z	Detailed Profile
69	VP12	Sabie	-22.3475	148.184	262.36	2019-07-22T05:07:01Z	Detailed Profile
70	VP13	Limpopo	-22.3878	148.223	167.617	2019-07-24T03:40:18Z	Detailed Profile
71	VP14	Sabie	-22.3471	148.212	205.387	2019-07-21T20:49:12Z	Detailed Profile
71	VP14	Sabie	-22.3471	148.212	205.387	2019-07-21T20:49:12Z	Detailed Profile
72	VP15	Limpopo	-22.3194	148.146	364.653	2019-07-20T22:44:08Z	Detailed Profile
73	VP16	Zambezi	-22.3683	148.206	188.452	2019-07-23T02:58:12Z	Detailed Profile
74	VP17	Limpopo	-22.3524	148.178	242.206	2019-07-22T21:05:54Z	Detailed Profile
75	VP18	Limpopo	-22.3094	148.193	205.966	2019-07-21T02:45:16Z	Detailed Profile
75	VP18	Limpopo	-22.3094	148.193	205.966	2019-07-21T02:45:16Z	Detailed Profile
75	VP18	Zambezi	-22.3094	148.193	205.966	2019-07-21T02:45:16Z	Detailed Profile
76	VP19	Zambezi	-22.3585	148.2	193.061	2019-07-22T22:27:01Z	Detailed Profile
77	VP2	Limpopo	-22.281	148.179	206.507	2019-07-20T02:12:40Z	Detailed Profile
78	VP20	Sabie	-22.3464	148.171	330.941	2019-07-22T03:40:15Z	Detailed Profile
80	VP22	Limpopo	-22.3264	148.205	225.635	2019-07-21T04:58:00Z	Detailed Profile
81	VP23	Zambezi	-22.3227	148.2	210.286	2019-07-21T04:11:54Z	Detailed Profile
82	VP24	Limpopo	-22.3355	148.213	190.831	2019-07-22T00:12:20Z	Detailed Profile
83	VP25	Zambezi	-22.3739	148.257	137.049	2019-07-23T21:44:31Z	Detailed Profile
84	VP26	Kei	-22.4019	148.271	133.606	2019-07-25T01:12:13Z	Detailed Profile
85	VP27	Fish	-22.3974	148.262	135.174	2019-07-24T23:50:48Z	Detailed Profile
86	VP28	Limpopo	-22.4045	148.255	157.437	2019-07-24T20:42:42Z	Detailed Profile

ID	Sample Location	SMU	Latitude (GDA94)	Longitude (GDA94)	Elevation (m)	Time	Sample Type
87	VP29	Zambezi	-22.3927	148.245	139.214	2019-07-24T00:38:58Z	Detailed Profile
88	VP3	Crocodile	-22.2694	148.159	213.906	2019-07-19T22:28:23Z	Detailed Profile
89	VP30	Kei	-22.3851	148.266	127.093	2019-07-24T22:33:57Z	Detailed Profile
90	VP31	Orange	-22.3666	148.249	154.395	2019-07-23T20:27:47Z	Detailed Profile
91	VP32	Komati	-22.3481	148.233	192.306	2019-07-22T01:13:23Z	Detailed Profile
92	VP33	Zambezi	-22.4011	148.218	153.994	2019-07-24T01:50:39Z	Detailed Profile
93	VP34	Komati	-22.3602	148.23	197.857	2019-07-23T04:56:11Z	Detailed Profile
94	VP35	Orange	-22.3434	148.221	190.981	2019-07-21T22:50:59Z	Detailed Profile
95	VP36	Limpopo	-22.3512	148.21	207.953	2019-07-23T04:01:39Z	Detailed Profile
96	VP37	Limpopo	-22.3799	148.216	164.519	2019-07-22T23:55:17Z	Detailed Profile
97	VP38	Zambezi	-22.3813	148.257	128.586	2019-07-23T22:56:37Z	Detailed Profile
98	VP39	Komati	-22.3525	148.221	223.283	2019-07-22T06:33:02Z	Detailed Profile
99	VP4	Crocodile	-22.2782	148.164	246.741	2019-07-20T01:02:42Z	Detailed Profile
100	VP40	Orange	-22.356	148.238	185.746	2019-07-23T06:02:30Z	Detailed Profile
101	VP41	Zambezi	-22.3769	148.233	170.22	2019-07-24T04:43:05Z	Detailed Profile
102	VP42	Zambezi	-22.3793	148.244	163.268	2019-07-24T06:12:48Z	Detailed Profile
103	VP5	Crocodile	-22.2925	148.166	279.986	2019-07-20T03:50:31Z	Detailed Profile
104	VP6	Crocodile	-22.2927	148.147	331.062	2019-07-19T05:26:33Z	Detailed Profile
105	VP7	Limpopo	-22.288	148.178	230.795	2019-07-20T05:26:45Z	Detailed Profile
106	VP8	Crocodile	-22.2901	148.176	235.049	2019-07-21T00:35:31Z	Detailed Profile
107	VP9	Limpopo	-22.3854	148.191	191.344	2019-07-23T01:11:31Z	Detailed Profile

Appendix D- Terrestrial Ecology Assessment Report



Terrestrial Ecology Assessment for the Vulcan Coal Mine Amendment

For Vitrinite Pty Ltd.

September 2022










VITRINITE
BRIGHTER COAL

METSERVE
Mining & Energy Technical Services Pty Ltd

This report has been prepared solely for the benefit of Vitrinite Pty Ltd. Mining and Energy Technical Services Pty Ltd (METServe) accepts no liability for the use or interpretation of any information contained in this report for any other purpose other than intended, or for its use by any party other than the above named Client.

Document History and Status

Issue	Revision	Prepared by	Issued to	Date	Reviewed by
001	Draft	Chris Wiley	Internal	28/6/2022	Damien Plucknett
002	Draft	Damien Plucknett	Internal	15/7/2022	Chris Wiley
003	Final	Chris Wiley	Vitrinite	5/9/2022	Andrea Wyatt

Printed: **31 October 2022**

Last saved: **31 October 2022**

Radix ID: **302006**

Project Manager: **Dave Moss**

Name of Organisation: **Vitrinite Pty Ltd.**

Name of Project: **Vulcan Coal Mine**

Name of Document: **Terrestrial Ecological Assessment for the Vulcan Coal Mine Amendment**

Document Version: **003**

Project Number: **VI010**

310 Edward St
Brisbane City
QLD 4000

ABN 94 143 463 316

TABLE OF CONTENTS

1 EXECUTIVE SUMMARY 1
2 INTRODUCTION 1
2.1 LOCATION 1
2.2 EXISTING LAND-USE 1
2.3 PROPOSED ACTIVITIES 3
2.4 RELEVANT LEGISLATION 4
2.4.1 Queensland 4
2.4.2 Commonwealth 6
3 METHODS 7
3.1 LITERATURE REVIEW 7
3.2 FIELD SURVEYS 7
3.2.1 Flora 7
3.2.2 Fauna 9
3.2.2.1 Seasonal Conditions 9
3.2.2.2 General Approach 9
3.2.2.3 Comprehensive Trap Sites 10
3.2.2.4 Supplementary Targeted Surveys 11
3.2.2.5 Total Survey Effort 12
3.3 GROUNDWATER-DEPENDENT ECOSYSTEMS 14
4 ENVIRONMENTAL VALUES 15
4.1 OVERVIEW OF THE REGION'S ECOLOGY 15
4.1.1 Habitat Features 15
4.1.2 Vegetation Communities 19
4.1.3 Groundwater-dependent Ecosystems 22
4.1.3.1 Review of Groundwater Use by Terrestrial Vegetation 22
4.1.3.2 Depth to Groundwater 24
4.1.3.3 National Atlas of Groundwater Dependent Ecosystems 24
4.1.3.4 Water Quality 26
4.1.3.5 Potential Groundwater-dependent Ecosystems 26
4.1.4 Biodiversity 28
4.1.4.1 Thoroughness of Surveys 28
4.1.4.2 Species at their Distributional Limit 28
4.2 ENVIRONMENTALLY SENSITIVE AREAS 29
4.3 MATTERS OF NATIONAL ENVIRONMENTAL SIGNIFICANCE 31
4.3.1 Threatened Ecological Communities 31

4.3.1.1 Brigalow 31
4.3.1.2 Poplar Box Woodland on Alluvium 31
4.3.1.3 Semi-evergreen Vine Thicket 31
4.3.2 Threatened Species 31
4.3.2.1 Squatter Pigeon 35
4.3.2.2 Koala 40
4.3.2.3 Central Greater Glider 44
4.3.2.4 White-throated Needletail 46
4.3.2.5 Ornamental Snake 46
4.3.2.6 Yakka Skink 50
4.3.2.7 Northern Quoll 50
4.3.2.8 Australian Painted-snipe 53
4.3.2.9 Red Goshawk 55
4.3.2.10 Annual Wiregrass 55
4.3.2.11 Ghost Bat 56
4.3.2.12 Dunmall's Snake 56
4.3.2.13 Allan's Lerista 56
4.3.2.14 King Blue-grass 57
4.3.2.15 Hairy Bluegrass 57
4.3.3 Migratory Species 58
4.3.3.1 Rufous Fantail 61
4.3.3.2 White-throated Needletail 61
4.3.3.3 Fork-tailed Swift 61
4.3.3.4 Latham's Snipe 63
4.3.3.5 Oriental Cuckoo 63
4.3.3.6 Black-faced Monarch 63
4.3.3.7 Satin Flycatcher 64
4.3.3.8 Glossy Ibis 64
4.3.3.9 Sharp-tailed Sandpiper 64
4.3.3.10 Gull-billed Tern 65
4.4 STATE ENVIRONMENTAL SIGNIFICANCE 65
4.4.1 Protected Areas 65
4.4.2 Marine Matters 65
4.4.3 Designated Precinct in Strategic Environmental Areas 65
4.4.4 Wetlands and Watercourses 65
4.4.5 Secured Offset Areas 65

4.4.6 Regulated Vegetation 65
4.4.7 Threatened and Special Least Concern Wildlife 68
4.4.7.1 Glossy Black-cockatoo 68
4.4.7.2 Short-beaked Echidna 70
4.4.7.3 Common Death Adder 70
4.5 WEEDS AND PEST ANIMALS 72
5 ECOLOGICAL IMPACTS OF PROPOSED ACTIVITIES 74
5.1 GENERAL IMPACTS 74
5.1.1 Clearing 74
5.1.2 Habitat Fragmentation 77
5.1.3 Edge Effects 77
5.1.4 Direct Mortality 77
5.1.5 Vehicle Collisions 78
5.1.6 Dust 78
5.1.7 Groundwater Drawdown 78
5.1.8 Noise and Vibration 78
5.1.9 Artificial Lighting 78
5.1.10 Waste 79
5.1.11 Weeds and Pest Animals 79
5.1.12 Cumulative Impacts 80
5.1.13 Summary 80
5.2 RECOMMENDED MITIGATION MEASURES 80
5.3 RESIDUAL IMPACTS ON PROTECTED MATTERS 82
5.3.1 Regulated Vegetation 82
5.3.2 Groundwater-dependent Ecosystems 83
5.3.3 Matters of National Environmental Significance 86
5.3.3.1 Brigalow Threatened Ecological Community 86
5.3.3.2 Squatter Pigeon 87
5.3.3.3 Koala 89
5.3.3.4 Central Greater Glider 92
5.3.3.5 White-throated Needletail 94
5.3.3.6 Ornamental Snake 94
5.3.3.7 Yakka Skink 96
5.3.3.8 Northern Quoll 96
5.3.3.9 Australian Painted-snipe 99
5.3.3.10 Red Goshawk 99

5.3.3.11 Annual Wiregrass 99
5.3.3.12 Ghost Bat 99
5.3.3.13 Dunmall's Snake 99
5.3.3.14 Allan's Lerista 99
5.3.3.15 King Bluegrass 101
5.3.3.16 Hairy Bluegrass 101
5.3.3.17 Migratory Species 101
5.3.4 Species of State Environmental Significance 104
5.3.4.1 Short-beaked Echidna 105
5.3.4.2 Glossy Black-cockatoo 106
5.3.4.3 Common Death Adder 106
5.4 OFFSET REQUIREMENTS 108
5.4.1 National 108
5.4.2 State 108
6 REFERENCES CITED 109

FIGURES

Figure 2-1 Project Location 2
Figure 2-2 Proposed Lay-out of the amended Vulcan Coal Mine 5
Figure 3-1 Locations of flora surveys 8
Figure 3-2 Schematic diagram of the trapping array at each comprehensive trap site 11
Figure 3-3 Locations of fauna surveys 13
Figure 4-1 Habitat features of the survey area 17
Figure 4-2 Water features 18
Figure 4-3 Field-verified Regional Ecosystem map 21
Figure 4-4 Depth to groundwater in relation to the GDE Atlas 25
Figure 4-5 Possible groundwater-dependent terrestrial ecosystems 27
Figure 4-6 Environmentally sensitive areas 30
Figure 4-7 Photographs of threatened wildlife taken during surveys: A) Central Greater Glider, B) Koala, and C) Squatter Pigeons 32
Figure 4-8 Squatter Pigeon chicks in a nest beneath a grass tussock within the project area 35
Figure 4-9 Squatter Pigeon Habitat 39
Figure 4-10 Koala Habitat 43
Figure 4-11 Central Greater Glider Habitat 45
Figure 4-12 Ornamental Snake habitat suitability model predictions (Department of Environment and Science) 48
Figure 4-13 Potential Ornamental Snake Habitat 49

Figure 4-14 Potential habitat for the Northern Quoll 52
Figure 4-15 Potential habitat for Australian Painted-snipe 54
Figure 4-16 Rufous Fantail habitat 62
Figure 4-17 Regulated Vegetation Management Map 67
Figure 4-18 Habitat for the Glossy Black-cockatoo 69
Figure 4-19 Potential habitat for the Common Death Adder 71
Figure 5-1 Project footprint relative to field-verified Regional Ecosystems 76
Figure 5-2 Maximum drawdown of groundwater predicted as a result of the VCM 85
Figure 5-3 Project footprint relative to existing Squatter Pigeon habitat 88
Figure 5-4 Project footprint relative to Koala habitat 90
Figure 5-5 Project footprint relative to Central Greater Glider habitat 93
Figure 5-6 Project footprint relative to potential Ornamental Snake habitat 95
Figure 5-7 Project footprint relative to potential Northern Quoll habitat 98
Figure 5-8 Project footprint relative to potential Australian Painted-snipe habitat 100
Figure 5-9 Project footprint relative to Rufous Fantail habitat 103
Figure 5-10 Project footprint relative to potential habitat for the Common Death Adder 107

TABLES

Table 2-1 Proposed changes to the VCM 3
Table 3-1 Summary of sampling effort per broad vegetation group (BVG) 10
Table 3-2 Fauna survey effort across the survey area between October 2018 and October 2019 12
Table 4-1 Field-verified regional ecosystems recorded in the survey and project areas 20
Table 4-2 Published groundwater usage by local tree species 23
Table 4-3 Threatened species of national environmental significance flagged by databases as being potentially present in the local region 33
Table 4-4 Squatter Pigeon records per habitat type 37
Table 4-5 Distribution of Koala food trees across vegetation units 41
Table 4-6 Migratory species flagged by database searches as potentially occurring in or near the survey area 59
Table 4-7 Regulated vegetation constituting MSES 66
Table 4-8 Weeds recorded within ML 700060 72
Table 5-1 Maximum amount of vegetation to be disturbed for the VCM amendment 74
Table 5-2 Inherent Risk (without controls) that the VCM amendment could spread restricted weeds 80
Table 5-3 Recommended impact mitigation measures 81
Table 5-4 Regulated vegetation to be disturbed by the VCM amendment 82

Table 5-5 Area of each vegetation category contained within a defined distance of the defining banks of relevant watercourses 83
Table 5-6 Koala habitat to be cleared 89
Table 5-7 Definitions of "important habitat" and "ecologically significant proportion of the population" for migratory species potentially utilising the project area 101
Table 5-8 Assessment of significance of impacts to threatened species of state significance 104
Table 5-9 Assessment of significance of impacts to Special Least Concern species of state significance 105

APPENDICES

Appendix A Fauna trap site descriptions ..... A
Appendix B Vegetation data from secondary sites ..... B
Appendix C Flora and fauna recorded during surveys C
Appendix D AnaBat results ..... D

1 EXECUTIVE SUMMARY

The Vulcan Coal Mine (VCM) is a small-scale open-cut mine located in the Bowen Basin that has been operated by Vitrinite Pty Ltd (Vitrinite) for eight months. Vitrinite proposes to make a number of changes to the approved VCM. These changes include the construction of a new Coal Handling and Processing Plant (CHPP), a new rail loop and load-out facility, and a new open-cut pit. As these changes are subject to approval via an Environmental Authority (EA) amendment and referral under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), an assessment of the potential environmental impacts of these changes was undertaken.

This ecological impact assessment is based on a combination of field surveys and a review of past records of matters of environmental significance from the general region. Field surveys were undertaken in 2018-2020, spanned multiple seasons, and covered a broader region (6,982 ha) than the mining lease for the VCM (406.3 ha).

Field surveys detected 41 species of mammal, 135 species of bird, 36 species of reptile, 14 species of frog and 432 species of vascular plant across the region containing the VCM. Species accumulation curves fitted to the data estimated that the surveys successfully detected 88% of the plants, 100% of reptiles, 97% of amphibians, 100% of birds, 92% of non-bat mammals and 100% of the bats present within the survey area that could potentially have been detected using the methodology employed. This represents a thorough knowledge of the region's ecology.

No protected conservation estates, wetlands or watercourses of high ecological significance, secured offset areas, environmentally sensitive areas (category A, B or C), threatened ecological communities or remnant vegetation containing endangered or of concern regional ecosystems will be disturbed by the proposed amendment.

The footprint of the VCM amendment contains three regional ecosystems, all of which are listed as least concern under the *Vegetation Management Act 1999.* 10.6 ha of the footprint is remnant vegetation and 59.2 ha is regrowth vegetation. The remainder of the project's footprint comprises cleared pastures (23.6 ha).

Twenty-six species of plants and animals listed as threatened species under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) were flagged by database searches as being potentially present in the region. The following three matters of national environmental significance (MNES) were detected during surveys of the site, and each is likely to experience significant residual impacts from the project:

- Koala (*Phascolarctos cinereus*) (endangered) – 1.7 ha of high-quality habitat and 82.2 ha of low-quality habitat will be removed;
- Squatter Pigeon *(Geophaps scripta scripta*) (vulnerable) – 92.4 ha of foraging habitat (76.4 ha of which is also breeding habitat); and
- Central Greater Glider (*Petauroides armillatus*) (endangered) – 1.7 ha of habitat will be removed.

It is proposed that environmental offsets are to be provided in accordance with the *EPBC Act Environmental Offsets Policy 2012* for each of the above three matters prior to the commencement of the VCM amendment.

A fourth species (the vulnerable White-throated Needletail, *Hirundapus caudacutus*) was recorded within the mining lease, but will not be affected by the proposed VCM amendment. Additional impacts on the endangered Northern Quoll (*Dasyurus hallucatus*) are possible but not likely. This species was not recorded on site, and the habitat present is suboptimal.

Each of the three MNES likely to experience significant residual impacts are also matters of state environmental significance (MSES) protected under the *Nature Conservation Act 1992* (NC Act). However, as impacts to these matters are to be assessed under the EPBC Act, the Queensland Government cannot impose additional offset conditions on these matters.

No regulated vegetation that is a prescribed matter under Queensland's *Environmental Offsets Act 2014* will be impacted by the VCM amendment.

Minor impacts to the Short-beaked Echidna (*Tachyglossus aculeatus*) and Common Death Adder (*Acanthophis antarcticus*) (listed as special least concern and vulnerable under the NC Act, respectively) possibly qualify as significant, due to the disturbance of potential feeding and/or breeding sites, which qualify as "ecologically significant locations". These impacts are to be assessed by the Queensland Government to determine whether they are subject to further environmental offsets.

2 INTRODUCTION

The Vulcan Coal Mine (VCM) is a small-scale open-cut mine located in the Bowen Basin that has been in operation for six months. The VCM will extract approximately 6 million tonnes of run-of-mine (ROM) hard coking coal at a rate of up to 1.95 million tonnes per annum over a four-year period. Queensland Coking Coal Pty Ltd (QCC) and Queensland Coal Aust. No. 1 Pty Ltd (QCA1) hold the coal tenure associated with the VCM. Vitrinite Pty Ltd (Vitrinite) is the majority owner of both companies and, as such, Vitrinite is the proponent of the VCM. The VCM operates under Environmental Authority EA0002912, within the mining lease ML700060.

Vitrinite proposes to make a number of changes to the approved VCM. These are summarised in **Section 2.3**. As these changes are subject to approval via an Environmental Authority (EA) amendment and referral under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), an assessment of the potential environmental impacts of these changes are required.

As part of baseline studies undertaken for the original VCM, Mining and Energy Technical Services Pty Ltd (METServe) undertook extensive terrestrial ecological surveys and vegetation mapping of a broad area that encompassed the VCM mining lease in 2018-2020. This report uses the results of these surveys to assess the potential ecological impacts of the proposed VCM amendment.

The VCM mining lease occupies a much smaller area (406.3 ha) than that surveyed (6,982 ha) because, at the time ecology surveys commenced, the scale of the project was unknown. Nevertheless, the findings of all surveys—not only those within the project footprint—are presented in this report for two reasons. Firstly, it is valuable to place the ecological values of the project area into a broader regional context. Secondly, species recorded outside the proposed footprint, but in habitats that are also present within the footprint, could be impacted by the VCM amendment.

This report presents the findings of ecological surveys across 6,982 ha including and surrounding the VCM. It then assesses the potential impacts of the VCM amendment on local environmental values pertaining to terrestrial ecology. The VCM amendment will require assessment and approval by the Queensland and Commonwealth Governments, and this report is intended to provide supporting information for an EA amendment and EPBC Act referral.

2.1 LOCATION

Throughout this report, the "survey area" refers to the 6,982 ha area in which ecological surveys were undertaken. The "project area" refers to ML700060, and forms a part of the survey area. The "maximum disturbance footprint" refers to the portion of the project area that is proposed to be disturbed that lies outside the already-approved disturbance footprint of the VCM.

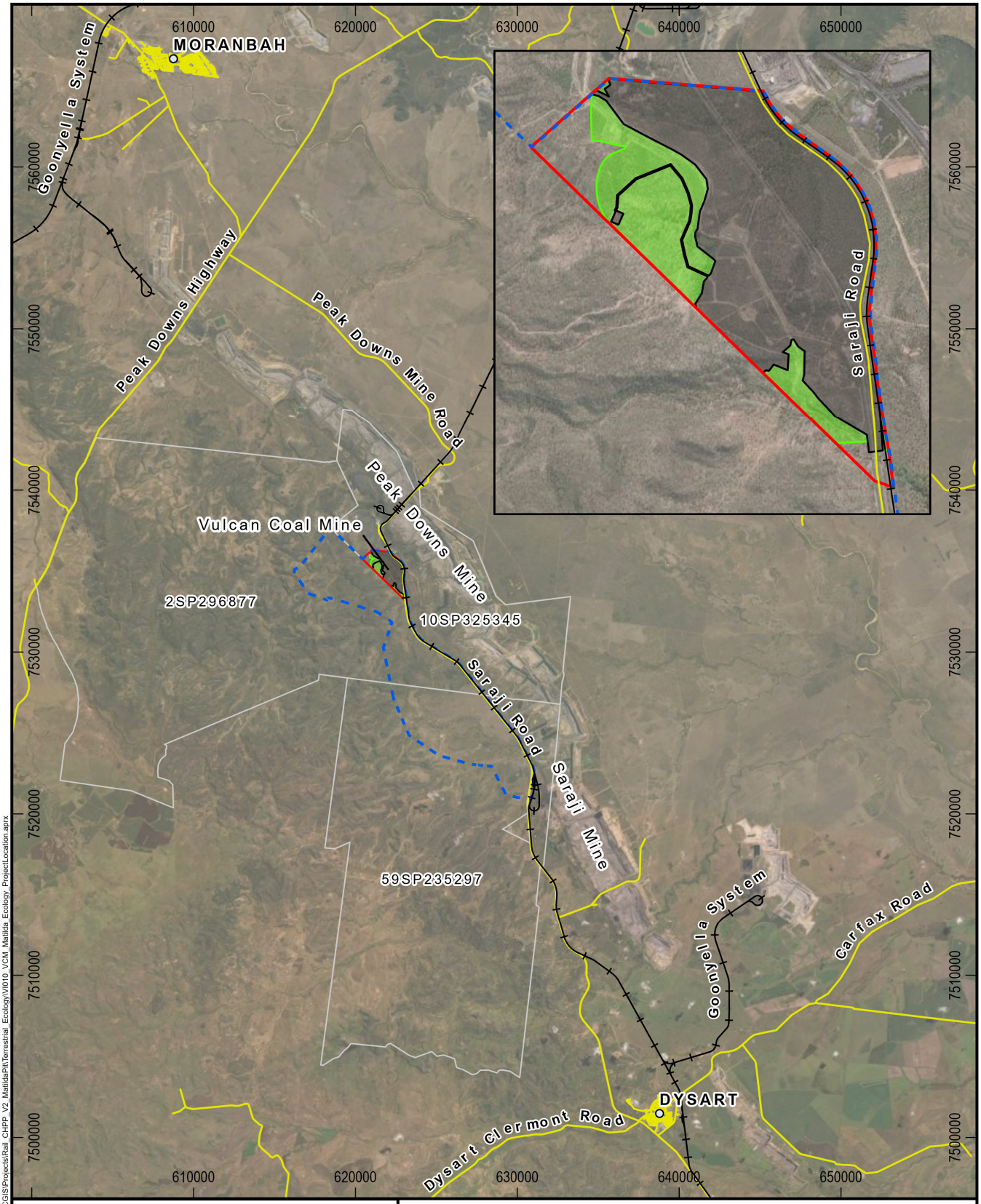
The survey area is located midway between Moranbah and Dysart, in the Bowen Basin of central Queensland (**Figure 2-1**). The project falls within the jurisdiction of the Isaac Regional Council. It lies immediately south and west of the Peak Downs Mine and Saraji Mine, alongside the Saraji Road. The project area is contained within the following properties:

- Lot 10 on Plan SP325345;
- Lot 26 on Plan CNS125; and
- Saraji Road road parcel.

The survey area falls within the Northern Bowen Basin subregion of the Brigalow Belt North bioregion, according to the Interim Biogeographic Regionalisation for Australia.

2.2 EXISTING LAND-USE

The project area is located on leasehold land that was used primarily for cattle grazing. It currently contains the VCM, the approved disturbance footprint of which covers 69% of the mining lease. The project area is bounded to the north and east by existing coal mining operations. A rail line and sealed highway (Saraji Road) run along the eastern edge of the project area.



Legend

- Town
- Road
- Railway
- Cadastral Boundary
- Survey Area
- ML 700060
- Approved Maximum Disturbance Footprint
- Proposed Additional Disturbance Footprint

Source: State of Queensland (Department of Resources) 2021-2022, Vitrinite 2022, METServe 2022, Earthstar Geographics, Maxar.

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\Terrestrial_Ecology\VI010_VCM_Matilda_Ecology_ProjectLocation.aprx

Vulcan Coal Mine Amendment

Project Location

0 2.5 5 10

Kilometers

Scale: 1:340,000 (A4)

31/05/2022

Datum: GDA2020
Projection: MGA55

FIGURE 2-1

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

2.3 PROPOSED ACTIVITIES

Since approval, the proponent has made several changes to the VCM that potentially change the magnitude of impacts to matters of environmental significance (**Table 2-1**). These amendments are the focus of this terrestrial ecological assessment. The locations of the new infrastructure are shown in **Figure 2-2**.

Table 2-1 Proposed changes to the VCM

Approved VCM	Proposed Change
Coal was to be hauled to a run-of-mine pad and crushed and screened using a mobile plant (Sorterra screening). All further washing and processing was to occur at an off-site facility. Crushing and screening was to occur 24 hours per day, seven days per week.	A new Coal Handling and Processing Plant (CHPP) is proposed, which is an open steel structure with three circuits, through which coal will be processed to produce a primary and secondary product (metallurgical and thermal). Tailings will be mechanically dewatered within the CHPP, which converts tailings into a solid cake for disposal in waste rock dumps. Recovered water will be recirculated to the process plant for reuse. Coarse, fine and dry tailings will be trucked and placed within existing waste rock dumps (primarily within the in-pit Waste Rock Dump). Coal products will be conveyed and stacked on the product coal stockpiles. Product coal will be reclaimed via dozer push into coal valves and conveyed to the train load-out facility. The CHPP will operate 24 hours per day, seven days per week. The CHPP and rail infrastructure (see below) will take 18 months to construct, and coal will continue to be trucked and processed off site until construction is completed.
Coal was to be trucked off site for toll washing at a nearby established facility. Haulage was to occur 24 hours per day, seven days per week.	A new rail loop and train load-out facility is proposed to transport coal processed on site to market. This rail loop will connect to the existing network in the south-east of the ML. The loop is positioned in the western portion of the ML, between the ML boundary and an existing flood levee that runs north-south through the ML. The loop will require approximately 4.5 km of rail to be located on the ML. A number of areas of cut and fill will be required along the alignment to produce required gradients. Controlled level crossings are proposed where the rail line crosses Saraji Road. Product coal will be transported by rail from the VCM using the Goonyella Rail network. Export options include Dalrymple Bay to the north and the RG Tanna terminal, in Gladstone, to the south. This will result in a reduction of heavy vehicular road traffic along Saraji Road and the Peak Downs highway by an average of 80 truck movements per 24 hours each way.
Coal was to be loaded into haul trucks using front-end loaders	The train load-out (TLO) facility will be positioned on the eastern side of the rail loop, on the western side of the existing flood levee. Coal will be transported by aerial conveyor, across the levee from the product stockpile to the TLO. Appropriate design controls will be incorporated to manage potential impacts on surface water systems from fugitive coal from the overpassing conveyor.
The original mine comprised a single open cut pit, which was to be back-filled with waste rock material following mining.	Following further drilling, the scale of the original open cut pit has been slightly reduced. A small second pit (Matilda Pit) is proposed within the rail loop, in addition to the original pit. Both pits will be back-filled with waste rock following mining.
Surface water management infrastructure was designed to divert clean water around operational areas and to manage runoff from disturbed areas. Mine water dams supplied water for dust suppression and receive accumulated pit water that requires removal.	The addition of the CHPP will increase the VCM's water demand, which will be supplied from the Bingegang pipeline. Vitrinite also has approval to receive mine-affected water from neighbouring mine sites. Water management infrastructure (sediment ponds, water diversion channels) has been modified to account for the CHPP, rail loop, Matilda Pit and TLO facility, and to ensure that clean water is diverted around operational areas and runoff from disturbed areas is captured

Approved VCM	Proposed Change
	in sediment dams. A new levee is proposed to be constructed to act as protection from ingress of floodwaters to the Matilda Pit for a 0.1% AEP event during the Operational Conditions of the VCM.
An explosive magazine was to be established away from operational areas and critical infrastructure.	An explosive magazine may be established as a temporary measure, but cannot be accommodated on site once the rail loop has been constructed, due to necessary exclusion zones around new infrastructure. Instead, the magazine will be located off-lease, to the south. A new access track to this magazine passes through the south of the lease.
The open cut mine pit was to be filled with waste rock to avoid the creation of a final void. Due to swelling of material, the in-pit waste rock dump had a proposed height of 15 m above the surrounding ground level. The slopes of this waste rock dump were to have a maximum gradient of 15%.	Waste material will continue to be deposited within the mined pit. However, due to additional tailings material to be deposited and a small reduction in the footprint of the main pit, the height of the final landform will be 30 m above the surrounding ground level. The slopes of the waste rock dump will retain a maximum gradient of 15%. The Matilda Pit will also have a raised final landform that will be 5–25 m above natural ground level.
The construction workforce was expected to consist of approximately 30 positions. The peak operation workforce was expected to comprise 116 positions, 40 of which were road haulage drivers.	Due to the additional infrastructure to be constructed, construction will require a workforce of approximately 130 people for a period of 18 months. The peak operational workforce is anticipated to comprise 80 positions, due to a reduced need for haulage drivers.
The previously approved combined clearing footprint of the VCM and bulk sample was 281.5 ha.	Due to additional infrastructure, product stockpiles and access roads, the revised clearing footprint will be 374.8 ha, which is 93.3 ha larger than the previously approved disturbance.

2.4 RELEVANT LEGISLATION

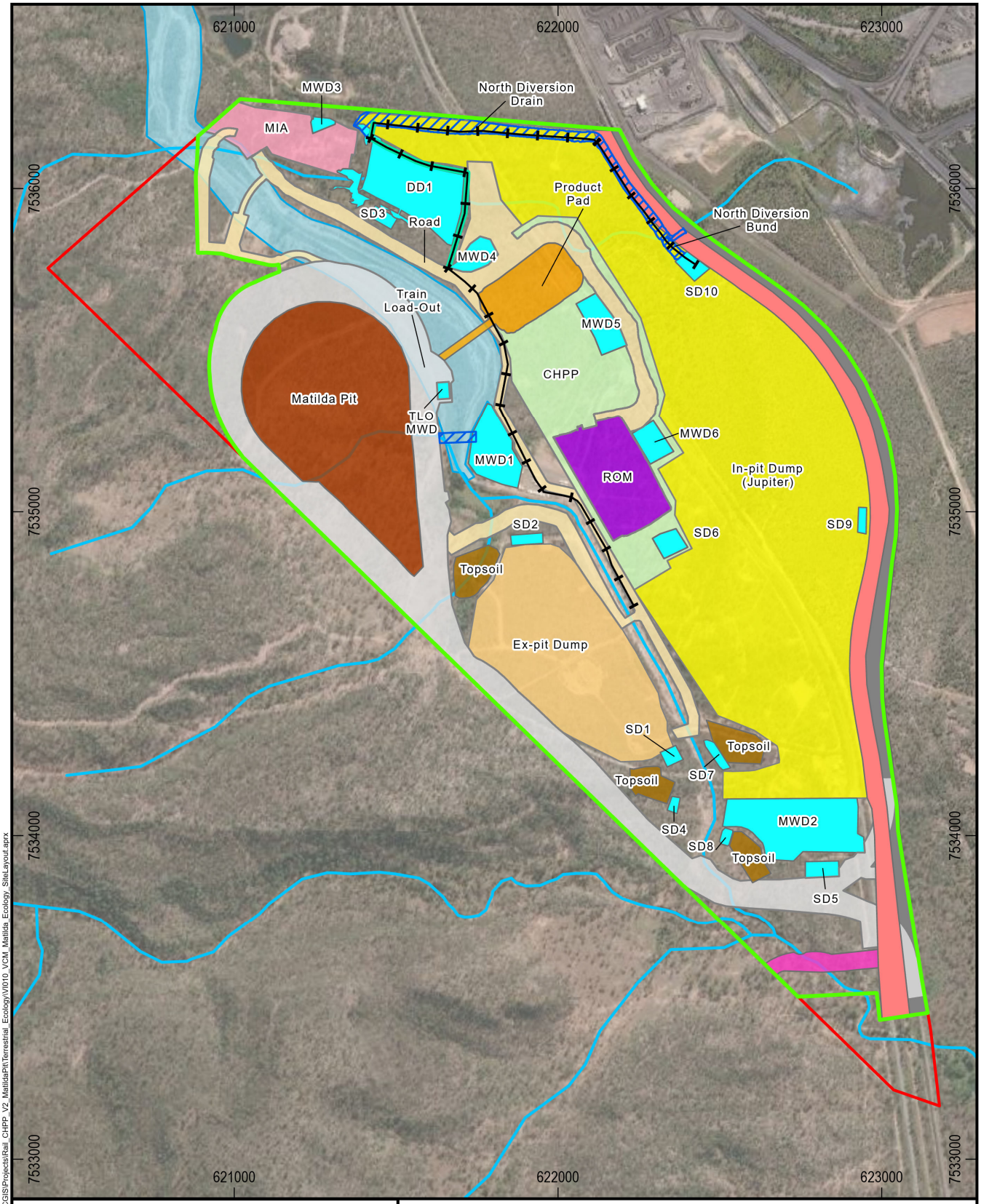
2.4.1 Queensland

Environmental Protection Act 1994

The *Environmental Protection Act 1994* (EP Act) regulates environmental management and aims to achieve ecologically sustainable development. The EP Act outlines legal obligations and the duty of care all persons have to the environment and directions for preparing environmental protection policies. The VCM operates under environmental authority (EA) EA0002912, issued by the Queensland Government under the EP Act. As the proposed changes to the VCM are not in accordance with the current EA conditions, the Queensland Government must assess and approve these changes through an EA amendment application.

Nature Conservation Act 1992

The *Nature Conservation Act 1992* (NC Act) regulates native flora, fauna and habitat conservation within Queensland.



Legend

- Drainage Lines
- ML 700060
- VCM Revised Maximum Disturbance Footprint
- Dam Wall
- Proposed Flood Levee
- Water Pipeline Corridor
- Water Management

Infrastructure

- CHPP
- Ex-pit Dump
- In-pit Dump
- MIA
- Dam
- Rail
- ROM
- Rail Loop
- Road
- Saraji Road
- Stockpile
- Train Load-Out Product Pad
- Open Pit
- Magazine Road

Source: State of Queensland (Department of Resources) 2022, Vitrinite 2021-2022, METServe 2022, Maxar.

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\Terrestrial_Ecology\VI010_VCM_Matilda_Ecology_SiteLayout.aprx

Vulcan Coal Mine Amendment

Proposed Layout of the Amended Vulcan Coal Mine

0 150 300 600

Meters

Scale: 1:17,000 (A4)

14/06/2022

Datum: GDA2020
Projection: MGA55

FIGURE 2-2

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Nature Conservation (Wildlife) Regulation 2006

The *Nature Conservation (Wildlife) Regulation 2006* prescribes the conservation status of Queensland wildlife, following provisions of the NC Act.

Vegetation Management Act 1999

The *Vegetation Management Act 1999* (VM Act) provides a planning framework for the management of native vegetation across Queensland. It regulates clearing of vegetation and aims to conserve Queensland's biodiversity through vegetation management.

Environmental Offsets Act 2014

The *Environmental Offsets Act 2014* (EO Act) provides for environmental offsets to counterbalance significant residual impacts of activities on particular matters of state or local environmental significance.

Biosecurity Act 2014

The *Biosecurity Act 2014* lists weeds and pest animals that constitute prohibited or restricted matters, and obligations pertaining to these matters.

2.4.2 Commonwealth

Environmental Protection and Biodiversity Act 1999

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) provides for the identification and management of Matters of National Environmental Significance, including threatened flora and fauna species, ecological communities, migratory species protected under international treaties, internationally recognised significant wetlands and critical habitat areas. Under the EPBC Act, an action requires approval from the Federal Environment Minister if the action has, will have, or is likely to have a significant impact on a Matter of National Environmental Significance.

Two previous EPBC Act approvals were obtained prior to undertaking actions within the project area. The first (2019/8504) was for extracting a coal bulk sample. The second (2020/8676) was for the Vulcan Coal Mine, as it was originally proposed. Any proposed actions not previously approved must be referred to the Commonwealth Government under the EPBC Act.

EPBC Act Environmental Offsets Policy 2012

The *EPBC Act Environmental Offsets Policy* (EOP) provides guidance on how the federal government considers the suitability of a proposed offset, when there are residual impacts of a project on matters of national environmental significance.

3 METHODS

3.1 LITERATURE REVIEW

A desktop-based assessment was undertaken using publicly available databases to determine the ecological values potentially occurring in the vicinity of the project. The following databases were consulted:

1) Queensland Government's Wildlife Online search tool (records within a 20 km buffer from the central point –22.3678, 148.2352);
2) Department of Environment and Energy's Protected Matters Search Tool (records within a 20 km buffer from central point: -22.3678, 148.2352);
3) Atlas of Living Australia;
4) eBird;
5) the Australasian Virtual Herbarium Search tool; and
6) the Department of Environment and Science's regulated vegetation management mapping.

For each species flagged during the literature review, but not recorded on site during field surveys, an assessment of the likelihoods of their presence within the survey area and project area was undertaken based on the reliability and recentness of the record(s) and whether suitable habitat—as described by the Australian Government's Species Profiles and Threats Database, species recovery plans, referral guidelines, and/or primary scientific literature—is present.

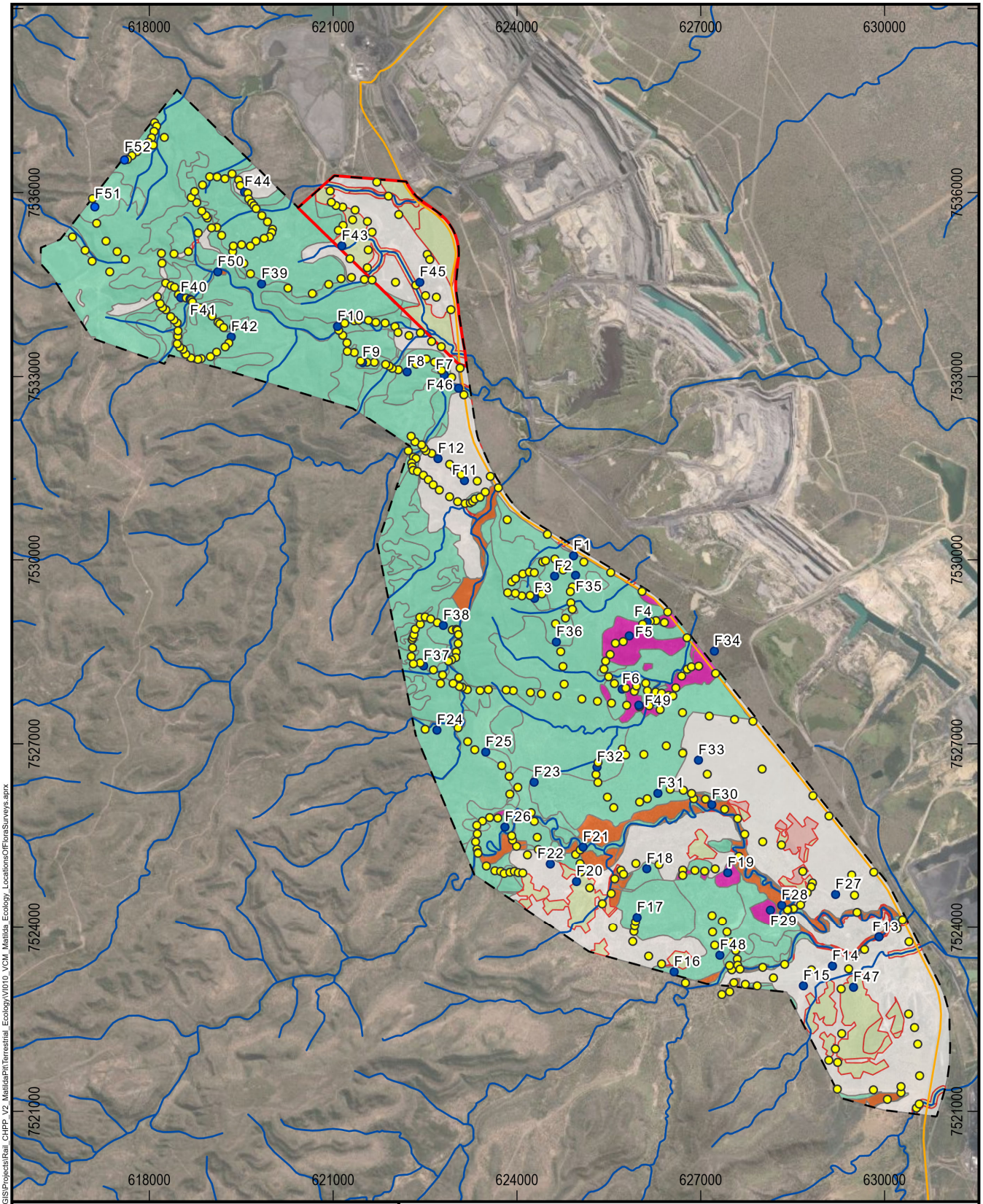
3.2 FIELD SURVEYS

3.2.1 Flora

The principal flora survey was undertaken between 4 February and 15 February 2019 by Dr Chris Wiley (Principal Consultant – Ecology) and Jacob Rolley (Consultant – Ecology). The approach taken followed that prescribed by Neldner *et al*. (2019) in *Methodology for Survey and Mapping of Regional Ecosystems and Vegetation Communities in Queensland, Version 5.0*. Survey timing coincided with maximum plant growth in the mid- to late-wet season, and was optimal for detecting threatened species as well as describing overall diversity.

Additional surveys for supplementary vegetation mapping were undertaken on 1-2 October 2019 in the far south of the survey area, and between 27 March and 5 April 2020 in the far north-west of the survey area. Both of these supplementary vegetation mapping surveys were outside the project area.

For all flora surveys, the survey area was traversed by car and (mostly) on foot, and routes were pre-selected to maximise coverage of the site and the number of mapped vegetation units visited. The aim of the field surveys was to ground-truth a sufficient sample of sites to enable interpolation of regional ecosystems across the survey area using detailed satellite imagery. In total, 485 sites were ground-truthed across the survey area (**Figure 3-1**). These comprised 433 quaternary sites and 52 secondary sites, as per Neldner *et al*. (2019). Secondary sites are detailed floristic and structural assessments of the vegetation communities present. These were only assessed during optimal conditions in February 2019 and March 2020. Quaternary sites are simple descriptions of the dominant species present and their corresponding regional ecosystem. A small subset (3.5%) of quaternary sites was assessed in October 2019, while the remainder were assessed under optimal conditions in February 2019 and March 2020. Field data were then used in conjunction with satellite imagery to produce a field-verified regional ecosystem map of the entire survey area. This field-verified map corrects numerous errors in certified mapping, as well as provides greater resolution due to its finer scale. The certified mapping was amended through a property map of assessable vegetation to better reflect the regional ecosystems present on site.



Legend

Regulated Vegetation Management Map

- Category A or B area containing endangered regional ecosystems
- Category A or B area containing of concern regional ecosystems
- Category A or B area that is a least concern regional ecosystems
- Category C or R area containing endangered regional ecosystems
- Category C or R area containing of concern regional ecosystems
- Category C or R area that is a least concern regional ecosystems
- Category X area

- Road
- Vegetation Management Watercourse/Drainage Feature Map (Stream Order Labelled)
- Survey Area
- ML 700060

Survey Points

- Quaternary
- Secondary

Source: State of Queensland (Department of Resources) 2022, Vitrinite 2022, METServe 2020-2022, Earthstar Geographics.

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\Terrestrial_Ecology\VI010_VCM_Matilda_Ecology_LocationsOfFloraSurveys.aprx

Vulcan Coal Mine Amendment

Locations of Flora Surveys

0 1.5 3

Kilometers

Scale: 1:90,000 (A4)

2/06/2022

Datum: GDA2020
Projection: MGA55

FIGURE 3-1

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Neldner *et al*. (2019) recommend sampling a minimum of three secondary sites per regional ecosystem. An average of 3.25 secondary sites per regional ecosystem was sampled during field surveys. One quarter of the regional ecosystems present on site were represented by single, small patches less than 10 ha in extent, preventing them being sampled over three sites. The remaining regional ecosystems were sampled at an average of 4.3 secondary sites, surpassing guideline requirements.

In addition to plant lists generated at each secondary site, additional plant species were noted during timed meander searches while walking between sites. These searches had the primary goal of targeting species of conservation significance in accordance with the *Flora Survey Guidelines – Protected Plants version 2.01* (Department of Environment and Science 2020). They also allowed for a comprehensive inventory of floral diversity across the survey area.

Supplementary information about the vegetation communities within the project area were also obtained via habitat quality assessments undertaken in 2021 at 13 sites within the disturbance footprint of the VCM, as part of providing environmental offsets for the original mine. An additional 42 sites spanning the entire mining lease were surveyed for weeds in 2022. Any flora detected during these supplementary surveys that were not recorded during the original ecological surveys are included in this report.

3.2.2 Fauna

3.2.2.1 Seasonal Conditions

The following fauna surveys were undertaken across the survey area in order to encompass seasonal variation in faunal movements and detectability:

1) 24 October 2018 to 2 November 2018;
2) 4 February 2019 to 15 February 2019 (bird surveys and spotlighting were undertaken during the flora survey);
3) 25 March 2019 to 29 March 2019 (abandoned prematurely due to heavy rain);
4) 8 April 2019 to 17 April 2019;
5) 1 May 2019 to 9 May 2019; and
6) 23 September to 4 October 2019.

All of the above surveys fell within the two seasons recommended by the *Terrestrial Vertebrate Fauna Survey Guidelines for Queensland version 3.0* (Eyre *et al*. 2018) for the Brigalow Belt bioregion.

Heavy rain events (>100 mm within 24 h) occurred during the first and third surveys, leading to flash-flooding of creeks and the filling of temporary pools and gilgais. This provided optimal conditions for the detection of frogs and burrowing snakes. Light rain events (~15 mm) also occurred during the second and fourth surveys, stimulating moderate frog activity. A light shower (<5 mm) during the sixth survey was the first rain received by the site in many months and also stimulated moderate frog activity.

The mean maximum temperature across all surveys was 33.4°C (range = 24.3°C–41.4°C). The mean minimum temperature across all surveyed was 16.8°C (range = 6.6°C–22.9°C). With the possible exception of three nights that fell below 10°C in May 2019, conditions were optimal for detecting ectothermic fauna.

3.2.2.2 General Approach

In accordance with the *Terrestrial Vertebrate Fauna Survey Guidelines for Queensland version 3.0* (Eyre *et al*. 2018), the entire survey area was divided into assessment units based on broad vegetation groups and age (remnant versus regrowth). These guidelines stipulate that each assessment unit is to be sampled at a minimum of three trap sites. This sampling intensity was achieved for most of the broad vegetation groups present on site, and all broad vegetation groups contained within the project area (**Table 3-1**). Two of the broad vegetation groups present on site (7a and 34d) were not amenable to sampling via traps; 7a was too small, rocky and remote, while 34d was primarily open water. These were sampled via targeted searches (day and night), instead. A remote-sensory camera was also installed in broad vegetation group 7a. These broad vegetation units occurred outside the project area.

Where broad vegetation groups were represented on site by both remnant vegetation and high-value regrowth, sampling effort was focused on the former, but the latter was also sampled if it comprised more than 5% of the total area of the broad vegetation group. In total, 34 comprehensive trap sites were sampled. A list of sites and photographs of each are provided in **Appendix A**.

Table 3-1 Summary of sampling effort per broad vegetation group (BVG)

BVG	Constituent regional ecosystems	Short description	Area (hectares)		$N_{trap\ sites}$	
			Remnant	Regrowth	Remnant	Regrowth
10a	11.10.1	*Corymbia citriodora* woodland on hilly terrain.	244.6	0	3	0
12a†	11.10.7, 11.10.1x1	Ironbark (*Eucalyptus* spp.) and/or bloodwood (*Corymbia* spp.) woodland on scarps and sandstone tablelands.	836.7	59.6	3	2
16a/9e*†	11.3.25/11.3.7	*E. camaldulensis* forest fringing drainage lines/*Corymbia* spp. woodland on alluvial terraces	147.7/86.1	5.3/0	3	0
17a	11.3.2, 11.5.3	*Eucalyptus populnea* woodland on sandplains or alluvium.	406.4	385.6	3	1
17b	11.9.2	*Eucalyptus orgadophila* woodland on fine-grained sedimentary rocks.	325.5	0	3	0
18b†	11.5.9	*Eucalyptus crebra* woodland on flat to undulating plains.	877.7	271.4	3	2
24a†	11.10.3	*Acacia shirleyi* or *A. rhodoxylon* open forest on residual surfaces.	1,589.0	68.8	3	1
25a	11.3.1, 11.4.8, 11.4.9	*Acacia harpophylla* woodland to open forest on clay soils	145.2	4.0	3	0
34d	11.3.27c, 11.3.27e	Freshwater swamps and billabongs on floodplains.	8.5	0	0	0
7a	11.10.8	Semi-evergreen vine thicket in sheltered habitats on medium to coarse-grained sedimentary rocks.	1.3	0	0	0
Non-remnant pasture†		Cleared pasture, +/- scattered trees or young regrowth	1,519.2		4	

*Broad vegetation groups 16a and 9e occur as parallel, narrow bands along waterways. Due to the narrow width of these vegetation units relative to the area of the standard trapping array, trap sites placed on creek banks invariably spanned both broad vegetation groups. For this reason, they were treated as a single assessment unit.

†Broad vegetation groups present within the project area.

3.2.2.3 Comprehensive Trap Sites

Each of the 34 comprehensive trap sites was sampled using methodology described in the *Terrestrial Vertebrate Fauna Survey Guidelines for Queensland version 3.0* (Eyre *et al*. 2018). The following traps were installed and monitored twice daily over four days and nights per site:

1) 45 m of 40-cm-high aluminium fly-screen drift fence was installed flush with the ground in a T-arrangement (**Figure 3-2**);
2) four 20-L buckets were installed as pitfall traps beneath this drift fence;
3) three pairs of funnel traps were installed along the drift fence;
4) 20 Elliott traps (baited with an oat-and-peanut-butter mix) were placed at 10-m spacing parallel to the drift fence; and
5) one Reconyx HC550 Hyperfire White Flash remote-sensory camera (baited with an oat-and-peanut-butter mix) was installed approximately 50 m from the drift fence.

The entire trap array spanned approximately 120 m × 50 m. Note that the survey guidelines suggest the use of one cage trap per site, instead of the camera. This recommended approach was adopted during the October 2018 survey, but abandoned in favour of cameras in all other survey rounds. Remote-sensory cameras are able to detect all species potentially caught by a cage trap, but have

several advantages. They are (i) easier to transport, (ii) able to 'catch' more than one individual/species per night, and (iii) able to detect a broader range of species that are too large (macropods, dingos, pigs) or small (birds, rodents) to be caught in a cage trap.

In addition to the four days of trapping, each trap site was also subjected to the following targeted surveys:

1) 40 person-minutes of spotlighting;
2) 40 person-minutes of diurnal active searches;
3) 80 minutes of bird surveys (10 minutes during each check of the traps); and
4) one night of recording with an AnaBat Express bat-call detector.

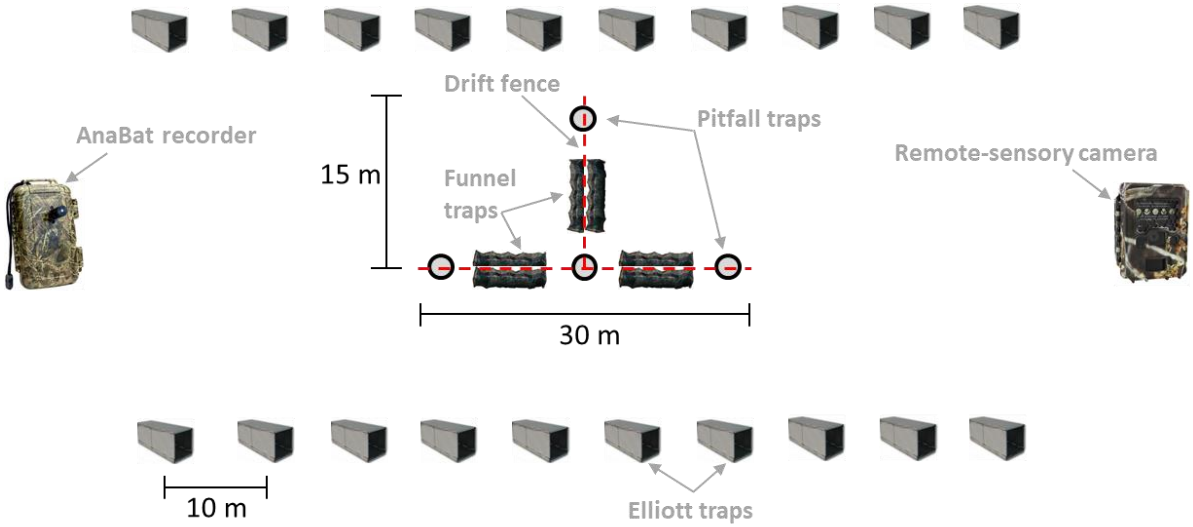


Figure 3-2 Schematic diagram of the trapping array at each comprehensive trap site

3.2.2.4 Supplementary Targeted Surveys

In addition to the sampling at comprehensive trap sites, further targeted searches were undertaken in a range of habitats that are difficult to sample using conventional trapping (e.g., rock outcrops, dams, wetlands, wood piles). Furthermore, targeted searches were undertaken to fill spatial gaps in assessment units that were very extensive and/or spatially heterogenous.

The following surveys were undertaken at additional sites away from the comprehensive trap sites:

1) Diurnal active searches of at least 40 person-minutes' duration were undertaken at 28 sites. This involved turning over logs and rocks, raking through leaf litter, searching for signs of Koalas, and recording all birds seen or heard;
2) Spotlighting for at least 40 person-minutes was undertaken at 28 sites;
3) Bird surveys of at least 20 minutes' duration were undertaken at 24 sites, in addition to diurnal active search sites. All birds heard or seen during flora surveys (10 days of survey effort in February 2019) were also recorded;
4) AnaBat recordings were carried out at 10 sites that represented likely flyways for bats: tracks through forest, creek lines and around dams. Recordings were made across a single night (12 hours) per site; and
5) Remote-sensory cameras were installed at three sites (a total of 12 trap-nights) along creek lines, which are favoured movement pathways for fauna.

In addition to the above surveys, anecdotal fauna sightings were recorded when visiting the project area for habitat quality surveys (in July 2021) and weed surveys (in April 2022).

3.2.2.5 Total Survey Effort

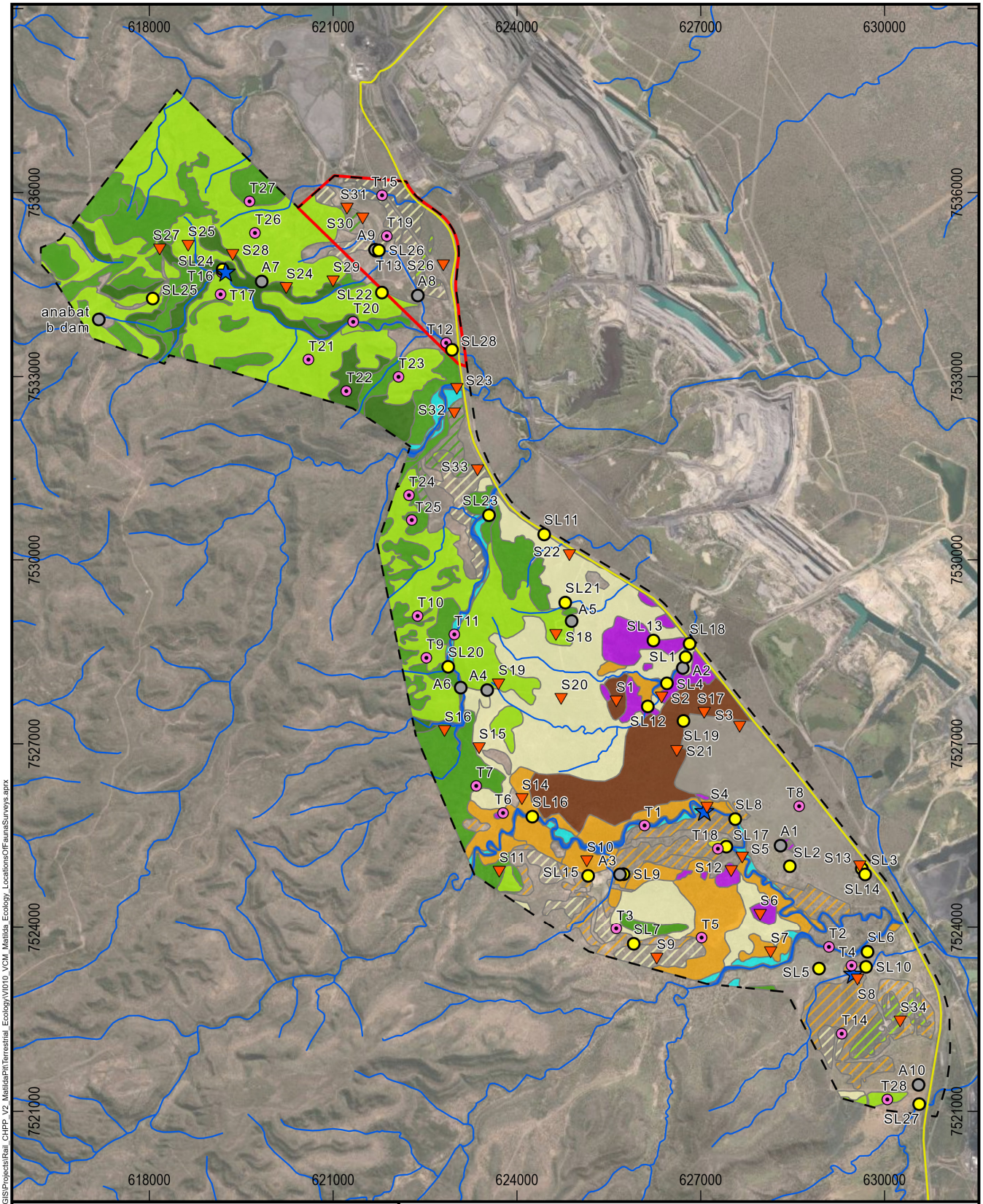
The total amount of survey effort expended for faunal surveys of the survey area is summarised in **Table 3-2** and the locations of surveys are shown on **Figure 3-3**.

Table 3-2 Fauna survey effort across the survey area between October 2018 and October 2019

Survey Method	Targeted Species	Potential EVNT Species*	Total Effort†	Unit
Pitfall trap	Frogs, small reptiles, small mammals	Ornamental Snake, Common Death Adder, Dunmall's Snake, Allan's Lerista	588	Trap-nights
Funnel trap	Lizards, snakes	Ornamental Snake, Common Death Adder, Yakka Skink, Dunmall's Snake, Allan's Lerista	882	Trap-nights
Elliott trap	Small mammals	n/a	2,860	Trap-nights
Cage trap	Medium-sized mammals	Northern Quoll	31	Trap-nights
Remote-sensory camera	Mammals, birds	Short-beaked Echidna, Northern Quoll, Squatter Pigeon	122	Trap-nights
AnaBat	Microchiropteran bats	Ghost Bat, Large Pied Bat	45	AnaBat-nights
Bird survey	Birds	Squatter Pigeon, Red Goshawk, Painted Honeyeater, Australian Painted-snipe, Black-throated Finch, migratory birds	288	Person-hours
Diurnal targeted search	Reptiles, larger mammals	Allan's Lerista, Yakka Skink, Dunmall's Snake, Common Death Adder, Short-beaked Echidna, Koala	45.3	Person-hours
Spotlighting	Frogs, reptiles, mammals, birds	Ornamental Snake, Common Death Adder, Short-beaked Echidna, Central Greater Glider, Koala	52.5	Person-hours

*Potential EVNT species are those listed as endangered, vulnerable, near threatened or special least concern within Queensland and/or nationally that have been historically recorded within the region.

†Note that not all sites were surveyed over four nights, as heavy rain necessitated the early closure of five sites. Four of these were re-surveyed on a later date, resulting in >4 survey nights for these sites.



Legend

- Drainage Lines
- Road
- Survey Area
- ML 700060

Survey Points

- Trap Site
- Camera
- AnaBat
- Spotlight
- Target

Field-verified Broad Vegetation Group

- 10a
- 12a
- 16a
- 17a
- 17b
- 18b
- 24a
- 25a
- 34d
- 7a
- 9e
- H12a
- H16a
- H17a
- H18b
- H24a
- H25a

Source: Vitrinite 2022, METServe 2022, Earthstar Geographics.

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\Terrestrial_Ecology\VI010_VCM_Matilda_Ecology_LocationsOfFaunaSurveys.aprx

Vulcan Coal Mine Amendment

Locations of Fauna Surveys

0 1.5 3

Kilometers

Scale: 1:90,000 (A4)

2/06/2022

Datum: GDA2020
Projection: MGA55

FIGURE 3-3

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

3.3 GROUNDWATER-DEPENDENT ECOSYSTEMS

The Queensland Government has undertaken mapping of groundwater-dependent ecosystems (GDEs) across most of the State (Department of Science, Information Technology and Innovation 2015). The survey area has, however, not been mapped in the most recent version (version 1.5) of this GDE mapping.

Instead, the *National Atlas of Groundwater Dependent Ecosystems* (BOM 2019) was consulted to identify locations where there is a moderate to high potential for vegetation communities to be dependent on groundwater. This dataset was compared to the field-verified regional ecosystem mapping undertaken as per **Section 3.2.1**. Regional ecosystems present within areas mapped as potentially groundwater-dependent ecosystems were assessed for their likelihood of groundwater dependence by examining:

1) Published literature on the ecology of the dominant tree species in each regional ecosystem;
2) landscape position;
3) water-holding capacity of the soil; and
4) site-specific data on the depth to groundwater (where available).

For regional ecosystems considered likely to be groundwater-dependent, their mapped boundaries were taken from field-verified regional ecosystem mapping, rather than the coarser-scale *National Atlas of Groundwater Dependent Ecosystems.* This integration of GDE mapping with regional ecosystem mapping is a core principle of the Queensland GDE Mapping Project (Department of Science, Information Technology and Innovation 2015).

4 ENVIRONMENTAL VALUES

4.1 OVERVIEW OF THE REGION'S ECOLOGY

4.1.1 Habitat Features

The survey area contains a variety of remnant, regrowth and cleared habitats. The western half of the survey area is dominated by low sandstone ridges and escarpments of the Cherwell/Harrow Range. These escarpments rise 100-170 m above the surrounding plains, and mostly support remnant vegetation. Dominant tree species across the Cherwell/Harrow Range include *Corymbia citriodora, Corymbia aureola, Eucalyptus crebra, Corymbia trachyphloia, Eucalyptus melanophloia* and *Acacia shirleyi.* The sandstone escarpments contain an abundance of boulders and rock outcrops (**Figure 4-1**) which provide shelter for reptiles and rock-wallabies. Rock overhangs and small caves are also present, primarily in the northwest, and these provide potential shelter sites for bats and other fauna. These ranges lie immediately west of the project area.

The eastern half of the survey area predominantly comprises a sandy plain supporting woodlands of *Eucalyptus crebra, Eucalyptus melanophloia, Eucalyptus populnea* and/or *Corymbia clarksoniana* (**Figure 4-1**). South of the project area, this plain also contains sections of heavy clay, supporting *Acacia harpophylla, Casuarina cristata* and/or *Eucalyptus cambageana.* These heavier soils have mostly been cleared of their remnant vegetation, although small fragments still remain, especially near Saraji Road. The clay soils support minor gilgai formation. These gilgais tended to be less than 30 cm deep, and held water for less than one month after heavy rain. They provide marginal breeding habitat for frogs, and frog densities tended to be low, even after heavy rain.

A low rise (~10 m above the surrounding plain) running northeast-southwest through the southern half of the survey area (6.7 km south-east of the project area) supported open woodland of *Eucalyptus orgadophila*. The cracking clay soil provided potential shelter for some reptiles and mammals; however, the understorey had been markedly affected by prolonged heavy grazing by livestock. This understorey was dominated by the exotic pasture grass, *Bothriochloa pertusa*, which was grazed to a lawn during dry periods, affording little protection for ground-dwelling fauna.

Heavy grazing pressure was also a notable feature of the sand plains across the survey area. This manifested through the altered composition of the understorey vegetation (Fensham *et al.* 1999; Walker *et al.* 2006). Native perennial grasses, an important food source for a variety of granivorous animals (Lewis 2007; Crowley 2008), were scarce, while introduced pasture grasses (especially *Cenchrus ciliaris, Bothriochloa pertusa, Melinis repens* and *Urochloa mosambicensis*) and native annual species (e.g., *Alloteropsis cimicina, Setaria surgens, Dactyloctenium radulans, Perotis rara*) dominated all remnant and non-remnant habitats away from the sandstone ridges.

The survey area is bisected by numerous first- to fourth-order watercourses that flow in an easterly direction. All of these are tributaries of the Isaac River. All watercourses on site are ephemeral, and sustain flows for short periods (less than one week) following heavy rain. Sub-surface flows (beneath the sandy creek beds) occur for longer periods, and third- and fourth-order watercourses support a dense fringe of *Eucalyptus camaldulensis, Melaleuca leucadendra* and/or *Melaleuca fluviatilis,* trees that can access this water supply. These sandy-bedded watercourses do not provide an important water source for fauna, due to a lack of pools and the short duration of surface flows. The only watercourse within the survey area that retained pooled water for extended periods (i.e., months) after rain was the northern tributary of Boomerang Creek, but only in its upper reaches (upstream of the project area). Where it passes through gorges within sandstone escarpments, the boulder-strewn bed of this tributary (**Figure 4-1**) contains numerous small pools, which provide a drinking source for fauna. These pools were dry in the late dry season (September-October).

Other surface water features that provide important water sources for fauna include farm dams and natural wetlands. The latter are represented on site by two billabongs formed in the former channel of Hughes Creek (**Figure 4-1** and **Figure 4-2)**, 9.2 km south of the project area. The western one is a mapped wetland under the *Vegetation Management Act 1999*.

Both of these billabongs had heavily grazed margins and supported few waterfowl. Among the farm dams, two areas provided particularly important habitat for waterfowl and other aquatic wildlife: 1) a chain of dams in the far southeast of the survey area (along a drainage line), and 2) a large dam beside cattle yards in the southwest of the survey area. Both sites supported a diversity of sedges and rushes, providing refuge for waterfowl and other fauna. A smaller, but equally well vegetated dam occurred within the project area (**Figure 4-1** and **Figure 4-2**).

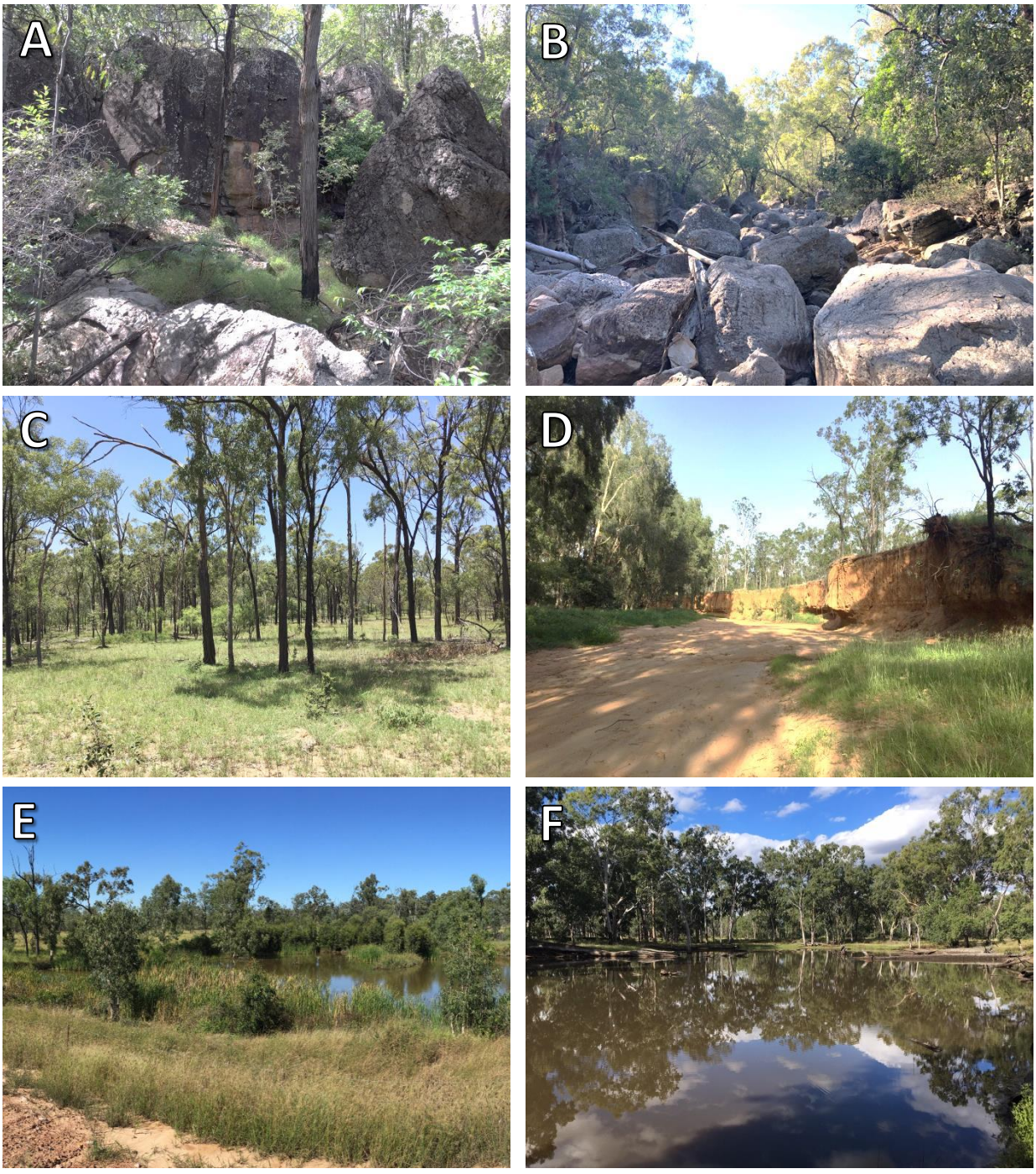
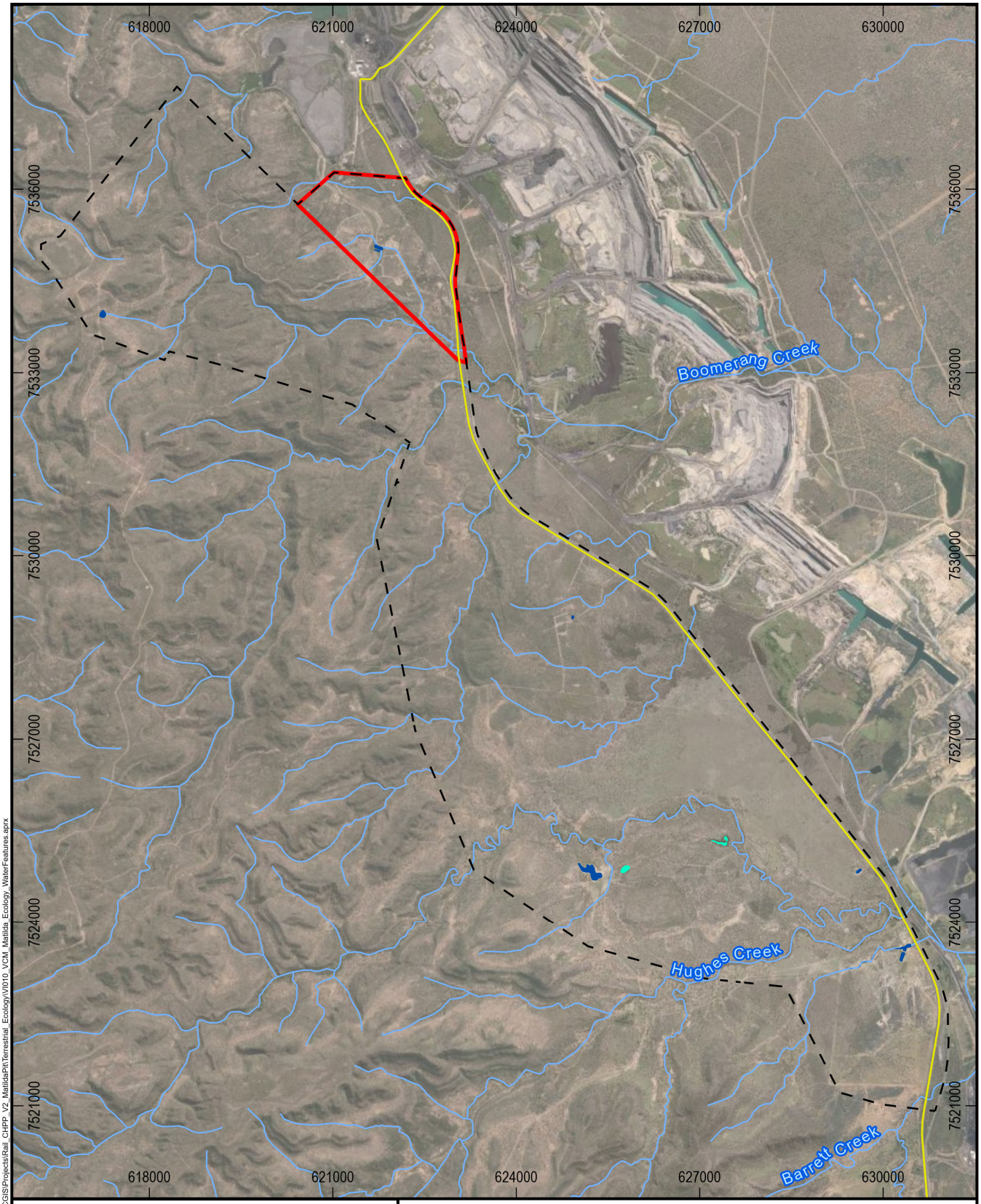


Figure 4-1 Habitat features of the survey area

A) sandstone outcrops, B) headwaters of North Creek, C) sand plain woodland dominated by *Eucalyptus crebra* (RE 11.5.9), D) middle reaches of Hughes Creek showing sandy watercourse bed, E) dam in project area, from which cattle are excluded, and F) natural billabong beside Hughes Creek.



Legend

- Drainage Lines
- Road
- Survey Area
- ML 700060
- Dam
- Natural Wetland

Source: Geoscience Australia 2015, State of Queensland (Department of Resources) 2021, Vitrinite 2022, METServe 2020-2022, Earthstar Geographics.

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\Terrestrial_Ecology\VI010_VCM_Matilda_Ecology_WaterFeatures.aprx

Vulcan Coal Mine Amendment

Water Features

0 1.5 3

Kilometers

Scale: 1:90,000 (A4)

2/06/2022

Datum: GDA2020
Projection: MGA55

FIGURE 4-2

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

4.1.2 Vegetation Communities

Sixteen regional ecosystems were recorded within the survey area (**Table 4-1, Figure 4-3**). Of these, four were present within the project area. Widespread errors in the original regulated vegetation map of the site have since been corrected (for the regulated vegetation map, refer to **Figure 4-17**). However, some variation in vegetation communities is not fully reflected by the amended regional ecosystem mapping:

1) The dominant unit in the western part of the survey area (immediately west of the project area) was mapped as a mixed mosaic containing 11.10.1, 11.10.3 and 11.10.8. While 11.10.3 is widespread in this unit, 11.10.8 is confined to a single, tiny patch (secondary site 50). Regional ecosystem 11.10.1 is represented by two distinctly different subtypes. The classic subtype (dominated by *Corymbia citriodora, Corymbia trachyphloia* and *Eucalyptus crebra*) is limited in extent, primarily occurring in sheltered gorges and south-facing slopes. The more widespread subtype was an open forest dominated by *Corymbia aureola* and *Eucalyptus melanophloia*, which usually grew on plateaux and other exposed sites with shallow, rocky soil. This vegetation unit did not match any of the described regional ecosystems in Queensland, but bore some similarity to 11.10.4a and 11.10.13b (both belong to the broad vegetation group 12a, unlike classical 11.10.1, which belongs to 10a). The Queensland Herbarium has opted to combine both subtypes under 11.10.1 in the updated regulated vegetation map. However, these subunits are mapped separately in this report, in light of their different habitat values to threatened fauna. The subtype dominated by *C. aureola* and *E. melanophloia* is assigned the code 11.10.1x1, as per Nelder *et al.* (2019). Secondary sites assessing 11.10.1x1 include 3, 24, 37 and 44 (**Appendix B**).
2) Large parts of the survey area are mapped as the regional ecosystem 11.5.9. These areas vary spatially in their composition. While *Eucalyptus crebra* and *Corymbia clarksoniana* are usually dominant species, in some areas (e.g., secondary sites 2 and 17: **Appendix B**) these are replaced by *Eucalyptus melanophloia, Alphitonia excelsa, Acacia* spp. And/or *Melaleuca nervosa*. In some places (e.g., secondary sites 1, 4 and 35), the *Eucalyptus* stratum is missing, resulting in a dense shrub layer of *Melaleuca nervosa, Acacia burdekensis* and/or *Allocasuarina luehmannii*. Presumably this occurs where drainage is impeded by shallow bedrock or texture contrast soils. Such areas may constitute 11.5.2, specifically 11.5.2a where *A. luehmannii* is dominant. However, this designation is not perfect, given the frequent presence of *E. melanophloia,* a species not listed in the description of 11.5.2. Due to a lack of suitable alternatives for these communities, they are retained as subtypes of 11.5.9, despite the localised absence of a *Eucalyptus* stratum.
3) Some areas mapped as regional ecosystem 11.5.9 were located on the foot slopes of sandstone outcrops. In many instances, there was substantial outcropping of sandstone present. Based on gully erosion present at some of these sites, the sandy layer was only approximately 0.5 m thick above sandstone. These areas were more appropriately considered 11.10.7, which is the equivalent *E. crebra* and/or *E. melanophloia* community on land zone 10. This is supported by secondary sites 7, 38 and 40 (**Appendix B**). In their revised mapping, the Queensland Herbarium has opted to map these as a mixture of 11.5.9 or 11.10.1, instead of the suggested 11.10.7. Given that the structure and/or floristics of these units vary from other 11.5.9 and 11.10.1 within the survey area, these have been retained as 11.10.7 in field-verified mapping.

Table 4-1 Field-verified regional ecosystems recorded in the survey and project areas

Regional Ecosystem	BVG*	Short description	VM class†	Biodiv. Status‡	Hectares within survey area		Hectares within project area	
					Remnant	Regrowth	Remnant	Regrowth
11.3.1	25a	*Acacia harpophylla* and/or *Casuarina cristata* open forest on alluvial plains	E	E	1.6	0	0	0
11.3.2	17a	*Eucalyptus populnea* woodland on alluvial plains	OC	OC	127.7	148.2	0	0
11.3.7	9e	*Corymbia* spp. woodland on alluvial terraces	LC	OC	86.1	0	0	0
11.3.25	16a	*E. camaldulensis* forest fringing drainage lines.	LC	OC	147.7	5.3	2.1	2.6
11.3.27c	34d	Mixed sedgeland in freshwater wetland	LC	OC	2.0	0	0	0
11.3.27e	34d	Open water freshwater wetland with fringing trees	LC	OC	6.5	0	0	0
11.4.8	25a	*Eucalyptus cambageana* woodland to open forest with *Acacia harpophylla* on Cainozoic clay plains.	E	E	127.4	4.0	0	0
11.4.9	25a	*Acacia harpophylla* shrubby woodland with *Terminalia oblongata* on Cainozoic clay plains.	E	E	16.2	0	0	0
11.5.3	17a	*Eucalyptus populnea* woodland on Cainozoic sand plains and/or remnant surfaces.	LC	NC	278.7	237.4	0	0
11.5.9	18b	*Eucalyptus crebra* and other *Eucalyptus* spp. and *Corymbia* spp. woodland on Cainozoic sand plains and/or remnant surfaces.	LC	NC	877.7	271.4	0	103.7
11.9.2	17b	*Eucalyptus orgadophila* woodland on fine-grained sedimentary rocks.	LC	NC	325.5	0	0	0
11.10.1	10a	*Corymbia citriodora* woodland on coarse-grained sedimentary rocks.	LC	NC	244.6	0	0	0
11.10.1x1	12a	*Corymbia aureola* and *Eucalyptus melanophloia* open forest on scarps and sandstone tablelands.	LC	NC	474.0	11.3	0	0
11.10.3	24a	*Acacia shirleyi* open forest on coarse-grained sedimentary rocks. Crests and scarps.	LC	NC	1,589.0	68.8	32.8	14.3
11.10.7	12a	*Eucalyptus crebra* woodland on coarse-grained sedimentary rocks.	LC	NC	362.7	48.3	0.9	9.2
11.10.8	7a	Semi-evergreen vine thicket in sheltered habitats on medium to coarse-grained sedimentary rocks.	OC	OC	1.3	0	0	0
Non-remnant	-	Cleared pasture, +/- scattered trees or young regrowth	-	-	1,519.2		240.7	

*BVG = broad vegetation group

†VM class = classification under the *Vegetation Management Act 1999*: E = endangered, OC = of concern. LC = least concern.

‡Biodiversity status relates to environmentally sensitive areas under the *Environmental Protection Act 1994*: E = endangered, OC = of concern, NC = no concern at present.

618000
621000
624000
627000
630000
7539000
7536000
7533000
7530000
7527000
7524000
7521000

Legend

- Survey Area
- ML 700060

Field-verified RE mapping

- 11.10.1
- 11.10.1x1
- 11.10.3
- 11.10.7
- 11.10.7/11.5.9
- 11.10.8
- 11.3.1
- 11.3.2
- 11.3.2/11.3.7
- 11.3.25
- 11.3.27c
- 11.3.27e
- 11.3.7
- 11.3.7/11.3.2
- 11.4.8
- 11.4.9
- 11.5.3
- 11.5.9
- 11.5.9/11.10.13
- 11.9.2
- HVR 11.10.13
- HVR 11.10.3
- HVR 11.10.7
- HVR 11.10.7/11.10.3
- HVR 11.3.2
- HVR 11.3.25
- HVR 11.4.8
- HVR 11.5.3
- HVR 11.5.3/11.3.2
- HVR 11.5.9

Source: Vitrinite 2022, METServe 2020-2022, Earthstar Geographics.

Vulcan Coal Mine Amendment

Field-verified Regional Ecosystem Map

0 1 2

Kilometers

Scale: 1:60,000 (A3)

2/06/2022

Datum: GDA2020
Projection: MGA55

FIGURE 4-3

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\V1010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\Terrestrial_Ecology\V1010_VCM_Matilda_Ecology_FV_RegionalEcosystems.aprx

4.1.3 Groundwater-dependent Ecosystems

There are three main categories of groundwater-dependent ecosystems (Department of Science, Information Technology and Innovation 2015):

1) vegetation that accesses sub-surface groundwater through its roots;
2) wetlands that receive groundwater discharge (e.g., springs); and
3) subterranean aquatic ecosystems, and marine systems that receive sub-marine discharge of groundwater.

Of these, categories 2 and 3 are aquatic ecosystems assessed elsewhere through an aquatic ecological assessment. Category 1, however, refers to terrestrial ecosystems that are dependent on access to groundwater on a permanent or intermittent basis to meet all or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services.

For vegetation to access groundwater in the sub-surface, the roots must be able to reach the capillary zone above the water table and the water quality of groundwater must be adequate. In order to assess and map potential terrestrial groundwater-dependent ecosystems across the survey area, the following data sources were considered:

- *National Atlas of Groundwater Dependent Ecosystems version 2.0* (BOM 2019);
- published literature on root depths and groundwater usage among local vegetation types;
- depth-to-groundwater mapping of part of the project area (provided by hydrogeologist.com.au); and
- groundwater quality (hydrogeologist.com.au 2022).

4.1.3.1 Review of Groundwater Use by Terrestrial Vegetation

There has been much recent worldwide research into groundwater-dependent ecosystems, combining tools such as stable isotope analysis, measurement of pre-dawn leaf water potential, and seasonal tracking of transpiration rates and "greenness" indices. One of the key findings of this research is that the use of groundwater by terrestrial vegetation depends greatly on the depth of this groundwater, and the influence of depth is largely consistent across continents and vegetation communities:

- In arid regions of China, groundwater up to 4–10 m below the surface is used by vegetation (Jin *et al.* 2011; Lv *et al*. 2012; Liu *et al*. 2017).
- In California, groundwater up to a depth of 6–8 m is used by vegetation (McLendon *et al*. 2008).
- Various studies in Australia have identified lower limits to the root extraction of groundwater of 7.5 m (Benyon *et al*. 2006), 5–11 m (O'Grady *et al*. 2006a), 8–10 m (Robinson *et al*. 2006), and 9 m (Zolfaghar *et al*. 2017).

Despite these relatively consistent average patterns, not all tree species access groundwater equally. For example, based on spatial patterns in declining canopy conditions during drought, Kath *et al.* (2014) inferred that *Eucalyptus populnea* (a species native to the survey area) regularly accessed groundwater to a depth of 13 m and, to far lesser extent, up to 26 m. To explore this variation between species in their propensity to access groundwater, published data on local vegetation types were reviewed and summarised in **Table 4-2**. Note that this assessment is limited to regional ecosystems within the project area, as the accuracy of depth-to-groundwater mapping far beyond this is limited by a lack of survey data.

Where data is lacking, it is practical to use the widely adopted rule-of-thumb (e.g., Eamus *et al*. 2006a; Department of Natural Resources, Mines and Energy (DNRME) 2019a), that vegetation is likely to use groundwater where it is up to a depth of 10 m, may possibly use groundwater at depths of 10-20 m, but is unlikely to access water deeper than 20 m.

Table 4-2 Published groundwater usage by local tree species

Regional Ecosystem	Rooting depths of dominant species	Depth-to-groundwater within the project area: mean (range)*	Likelihood of groundwater-dependence
11.3.25	*Eucalyptus camaldulensis* is often dependent on shallow aquifers and watercourses (Bacon *et al.* 1993). Isotope studies indicate that *E. camaldulensis* accesses groundwater up to a depth of 9.4–11.2 m, but not deeper (Rumman *et al.* 2018).A similar finding—that *E. camaldulensis* commonly accesses groundwater to a depth of 12.5 m—was revealed by studies of tree condition (Kath *et al.* 2014). The latter study revealed that groundwater may also be accessed to a limited extent up to 20 m, but not deeper. *Melaleuca leucadendra* and other riparian *Melaleuca* spp. are reliant on river water and/or shallow groundwater, up to 9 m deep (O'Grady *et al.* 2005, 2006a, 2006b).	9.2 m (2.6 m to 14.5 m)	**High:** Water tables are within reach of this vegetation, and the constituent species are regularly groundwater-dependent elsewhere.
11.5.9	Ironbarks (*Eucalyptus crebra* and *E. melanophloia*) are sensitive to die-back during drought and exhibit xylem flows and root depths consistent with a lack of access to groundwater (Rice *et al.* 2004; Fensham and Fairfax 2007). *Corymbia clarksoniana* is highly dependent on groundwater between 6.5 and 10 m deep during the dry season (Cook and O'Grady 2006; O'Grady *et al.* 2006b). Gow *et al.* (2016) found that *Eucalyptus crebra*, *E. decorticans* and *Corymbia* spp. woodlands on rocky hill slopes exhibited temperature radiation patterns consistent with the use of deep soil water. As the water table was generally between 10 m and 60 m, the authors hypothesised that most of the water used was intercepted while draining through the unsaturated zones of the soil profile, rather than originating from groundwater per se.	13.6 m (1.2 m to 41.9 m)	**Moderate:** In places where the water table is within 10 m of the ground surface, sub-dominant components of this RE are likely to be groundwater-dependent.
11.10.3	There are no published data on the groundwater-dependence or rooting depths of *Acacia shirleyi* or *Acacia rhodoxylon*. However, other *Acacia* spp. that grow on similar rocky substrates (e.g., *A. aneura, A. aptaneura* and *A. kempeana*) do not access groundwater, but instead have reinforced xylem vessels that are able to cope with strong water deficiencies (Anderson and Hodgkinson 1997; Nolan *et al.* 2017).	14.8 m (4.7 m to 31.1 m)	**Low:** Dominant species are unlikely to utilise groundwater.
11.10.7	Ironbarks (*Eucalyptus crebra* and *E. melanophloia*) are sensitive to die-back during drought and exhibit xylem flows and root depths consistent with a lack of access to groundwater (Rice *et al.* 2004; Fensham and Fairfax 2007). Gow *et al.* (2016) found that *Eucalyptus crebra*, *E. decorticans* and *Corymbia* spp. woodlands on rocky hill slopes exhibited temperature radiation patterns consistent with the use of deep soil water. As the water table was generally between 10 m and 60 m, the authors hypothesised that most of the water used was intercepted while draining through the unsaturated zones of the soil profile, rather than originating from groundwater per se.	10.0 m (6.2m to 18.2 m)	**Low:** Dominant species are unlikely to utilise groundwater.

*Depth-to-groundwater data for the survey area was sourced from hydrogeologist.com.au as per **Section 4.1.3.2**.

4.1.3.2 Depth to Groundwater

Hydrogeologist.com.au (2022) developed a calibrated, numerical groundwater model of all relevant aquifers within the vicinity of the Matilda Pit and existing pit. This was based on a range of data sources, including an on-site groundwater monitoring network, groundwater assessments from nearby mines, and the *Queensland Groundwater and Surface Water Monitoring* database (DNRME 2019b).

An aquifer is generally defined as a geological unit that can transmit and store significant quantities of groundwater. In the vicinity of the project area, some geological units yield low volumes of groundwater and would not typically be classified as aquifers in most hydrogeological settings. However, as these could provide a small and/or temporary source of groundwater for vegetation, they are referred to as aquifers for the purposes of this assessment.

Groundwater may be stored, even if only temporarily, in three hydro-stratigraphic units present on site:

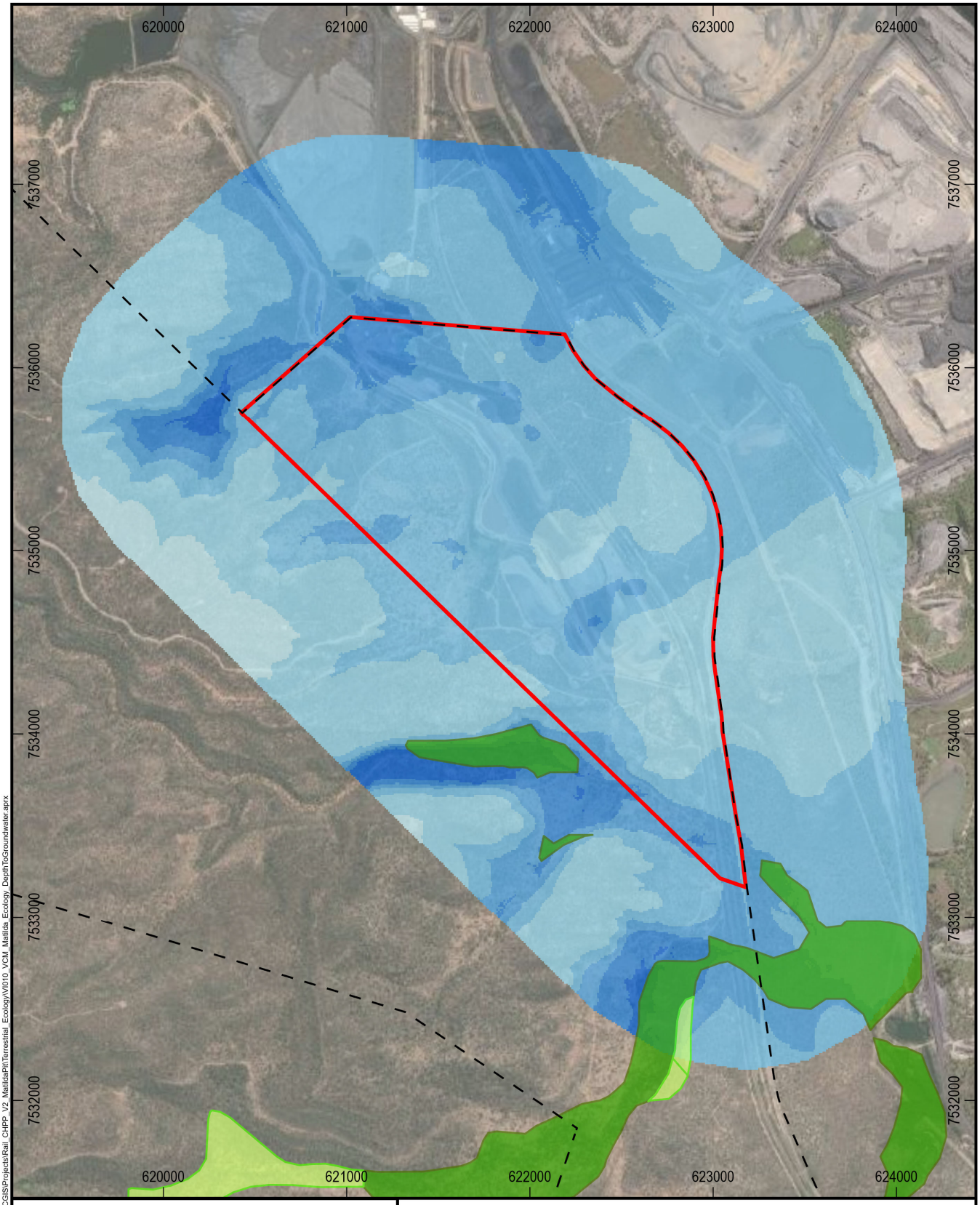
1) Quaternary Alluvium: The silted-up stream channels of ephemeral creeks support small, localised, temporary unconfined "aquifers". The alluvium saturates following flow events within the creeks. As the watercourses are highly ephemeral, some component of sub-surface flow through the alluvium persists after the surface water flow ceases.
2) Tertiary Sediments: This is a mix of Tertiary sediments (lenses of palaeochannel gravels and sands separated by dry, densely compacted sandy silts, sandy clays and clays) and weathered Permian regolith. These aquifers tend to be of limited lateral and vertical extent and consequently have low hydraulic conductivity. This layer was generally unsaturated in the survey area.
3) Permian Coal Measures: The coal seam aquifers are generally confined above and below by the low-permeability inter- and overburden. The coal seam aquifers present on site are regarded as poor aquifers because of their limited thickness and the presence of low-permeability interburden. Across most of the survey area, these aquifers represent the shallowest source of groundwater for vegetation.

Although Quaternary alluvium can provide a temporary source of shallow, fresh groundwater for terrestrial vegetation, this is recharged exclusively via rain and surface flows, and is therefore unaffected by any drawdown that may result from the VCM amendment. For most of the survey area, the Permian Coal Measures and, occasionally, the Tertiary sediments contain the uppermost groundwater.

A map of groundwater elevation contours, within a buffer of 1 km out from the proposed mining pit edge, was developed by Hydrogeologist.com.au (2022). This was converted to a depth-to-groundwater map based on surface topography obtained from aerial LiDAR data. This map revealed that in much of the project area water tables were within 20 m of the ground surface (**Figure 4-4**), and were therefore potentially within reach of vegetation. In some areas, the groundwater was within 10 m, of the ground surface, where it is likely to be utilised by vegetation. The chief locations where this occurs are along the tributaries of Boomerang Creek and Ripstone Creek.

4.1.3.3 National Atlas of Groundwater Dependent Ecosystems

According to the *National Atlas of Groundwater Dependent Ecosystems*, there is a high potential for terrestrial groundwater-dependent ecosystems along the lower reaches of Boomerang Creek and its larger tributaries, including the one passing through the southern corner of the project area (**Figure 4-4**). The un-named tributary of Ripstone Creek in the far north of the project area is also mapped as having a high potential for terrestrial groundwater-dependent ecosystems.



Legend

- Survey Area
- ML 700060

National Groundwater Dependent Ecosystems Atlas

- High Potential Terrestrial GDE
- Moderate Potential Terrestrial GDE

Depth to groundwater (m)

- ≤ 0
- 0 - 5
- 5 - 10
- 10 - 20
- 20 - 50
- > 50

Source: Bureau of Meteorology 2012, Hydrogeologist.com.au 2020-2022, Vitrinite 2022, METServe 2022, Maxar.

Vulcan Coal Mine Amendment

Depth to Groundwater in Relation to the GDE Atlas

0 0.5 1

Kilometers

Scale: 1:30,000 (A4)

8/08/2022

Datum: GDA2020
Projection: MGA55

FIGURE 4-4

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\Terrestrial_Ecology\VI010_VCM_Matilda_Ecology_DepthToGroundwater.aprx

There was reasonable accordance between the *National Atlas of Groundwater Dependent Ecosystems* and depth-to-groundwater mapping. Areas mapped as likely GDEs along the tributary of Boomerang Creek that passes through the south of the ML had a depth to groundwater of less than 10 m. Likewise, riparian vegetation along the northern unnamed tributary is within 6-14 m of groundwater, which it is likely to utilise. However, there were large additional parts of the project area (not mapped as GDEs) where the groundwater was 10-20 m beneath the ground's surface. Such depths can be reached by some species of tree. Given that the vegetation communities present in these areas are dominated by species (e.g., *Eucalyptus melanophloia, Eucalyptus crebra, Corymbia clarksoniana* and *Acacia shirleyi*) that do not typically access groundwater as such depth, it is assumed that these communities are unlikely to represent GDEs. An exception is regional ecosystem 11.5.9, where this occurs in the far north of the MLA area, where groundwater is less than 10 m below the ground surface. This regional ecosystem is likely to be partly groundwater-dependent; that is, dominant species (e.g., *E. crebra* and *E. melanophloia*) are unlikely to utilise groundwater but sub-dominant species (e.g., *C. clarksoniana* and *Melaleuca viridiflora*) are likely to.

4.1.3.4 Water Quality

All groundwater sampled to date within the project area is saline to highly saline. Electrical conductivity ranges between 2.6 and 22.8 dS/m, with a mean value of 9.5 dS/m (Hydrogeologist.com.au 2022). For context, sea water has an electrical conductivity of approximately 50 dS/m, while drinking water has 0.05–0.5 dS/m. The pH of groundwater on site is generally close to neutral (Hydrogeologist.com.au 2022). Electrical conductivity greater than 3–4 dS/m inhibits the growth of most plants (Katerji *et al.* 2003), although tolerance to salt varies between species. As the water table within the project area is beyond the reach of most local plant communities, the most relevant plant species are those inhabiting regional ecosystems 11.3.25 and 11.5.9.

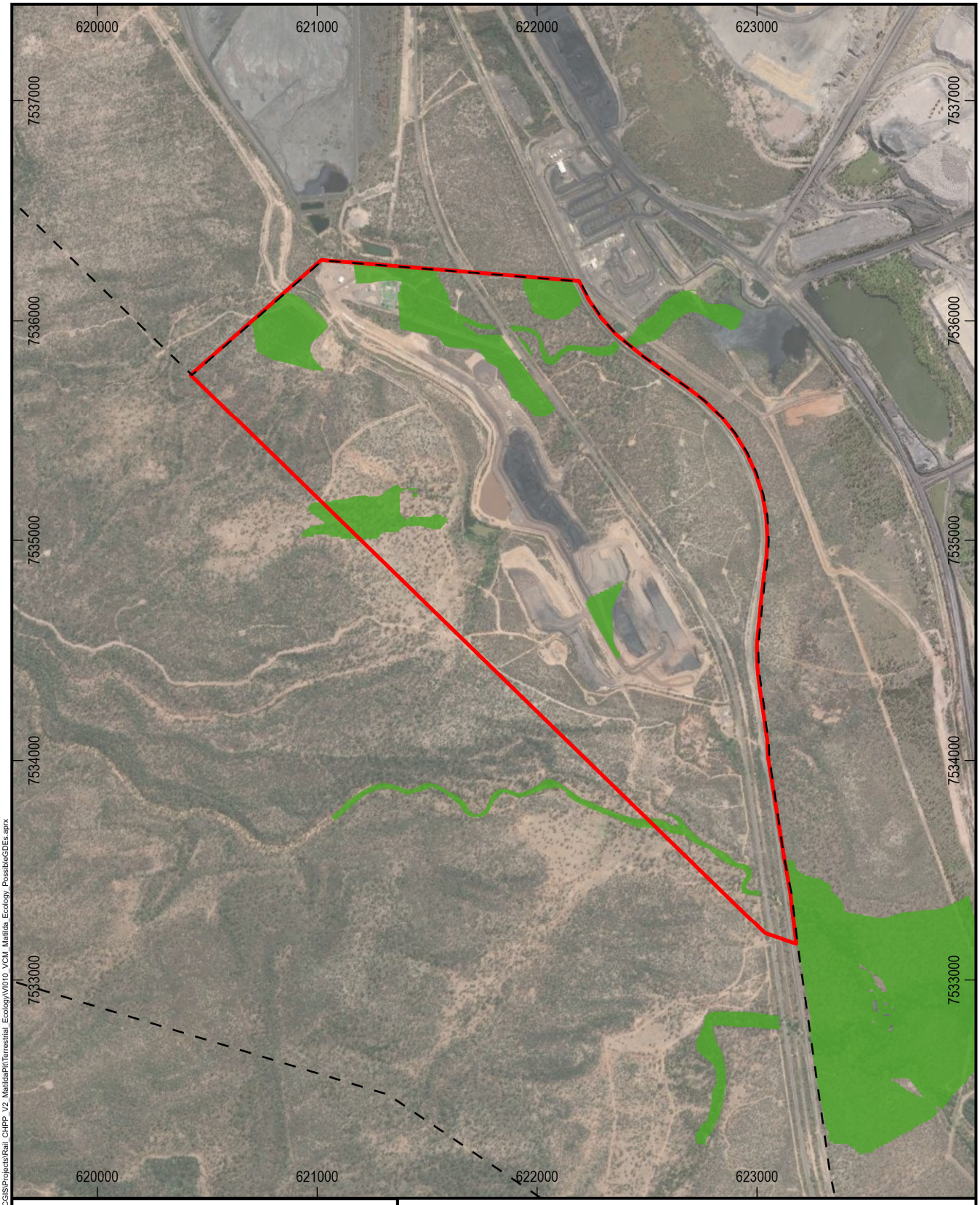
Some local tree species have high salt tolerance. *Eucalyptus camaldulensis*, a dominant tree along local waterways (RE 11.3.25), is one such species. Salinity comparable to the lower levels recorded on site impairs the growth of *E. camaldulensis* seedlings, but has no effect on survival (Sun and Dickinson 1995; Farrell *et al.* 1996). Furthermore, isotope analyses revealed that trees growing above a 2–3 m deep, highly saline (30–50 dS/m) water table were able to use this groundwater, despite severe water stress as a result (Mensforth *et al.* 1994). While saline groundwater can potentially sustain *E. camaldulensis* during dry periods, most growth occurs in response to the flooding of the upper soil profile with freshwater. These intermittent flooding events provide half to two-thirds of the species' water requirements and are vital for maintaining their health (Eamus *et al.* 2006b; Wen *et al.* 2009).

Melaleuca leucadendra, the other dominant riparian species in regional ecosystem 11.3.25 is known to be variously salt-sensitive (van der Moezel *et al.* 1991) to salt-tolerant (Sun and Dickinson 1995). This species may be able to use groundwater at the lower end of local salinity levels (equivalent to electrical conductivity up to 5 dS/m), even though such concentrations of salt greatly impair growth (Nguyen *et al.* 2009). It is likely that *M. leucadendra* is dependent on shallow, sub-surface flows through Quaternary alluvium along watercourses following rain events, but is not likely to be able to utilise saline groundwater within Tertiary sediment and Permian Coal Measures.

In summary, regional ecosystem 11.3.25 is capable of using saline groundwater within the reach of roots; however, the quality of the groundwater within the project area is near the limits of tolerance of 11.5.9.

4.1.3.5 Potential Groundwater-dependent Ecosystems

Based on literature reviews (see **Section 4.1.3.1**), depth-to-groundwater data (see **Section 4.1.3.2**), national GDE mapping (see **Section 4.1.3.3**) and water quality data (see **Section 4.1.3.4**), there are likely to be some GDEs contained within the project area. The locations of these likely GDEs closely match that mapped within the *National Atlas of Groundwater Dependent Ecosystems*. An additional partly groundwater-dependent ecosystem is located in the far north of the project area. The location of these GDEs, based on depth-to-groundwater and field-verified regional ecosystem mapping, is presented in **Figure 4-5**.



Legend

- Survey Area
- ML 700060
- Potential Terrestrial GDEs

Source: Bureau of Meteorology 2012, Hydrogeologist.com.au 2020-2022, Vitrinite 2022, METServe 2022, Earthstar Geographics.

Vulcan Coal Mine Amendment

Possible Groundwater Dependent Terrestrial Ecosystems

0 0.5 1

Kilometers

Scale: 1:25,000 (A4)

9/08/2022

Datum: GDA2020
Projection: MGA55

FIGURE 4-5

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\Terrestrial_Ecology\VI010_VCM_Matilda_Ecology_PossibleGDEs.aprx

4.1.4 Biodiversity

Field surveys detected 41 species of mammal, 135 species of bird, 36 species of reptile, 14 species of frog and 432 species of vascular plant (**Appendix C**). Not all bat calls could be identified to unique species, and unresolved calls may have arisen from an additional species of bat not included in the above tally (**Appendix D**).

4.1.4.1 Thoroughness of Surveys

The nature of ecological surveys means that it is inevitable that some species present remain undetected. To estimate the extent to which this occurred, species accumulation curves were fitted to the fauna and flora data using EstimateS 9.1.0. The total numbers of species that occur within the survey area were estimated using the Chao2 richness estimator. These analyses suggested that, of the species that could have been detected using the methodology employed, the surveys to date have detected:

1) 88% of the floral diversity;
2) 100% of reptiles;
3) 97% of amphibians;
4) 100% of birds;
5) 92% of non-bat mammals; and
6) 100% of bats.

Note that the above are estimates generated from a statistical analysis of the detection rate per sampling unit (e.g., per trap site). It only takes into account species that *could* be detected by the surveys. Species that were inactive at the time of surveys, or which are visitors that did not occur during the sampling periods are not incorporated into these estimates. Sampling across a broad range of seasons and climatic conditions, as was done for this study, limits the number of species considered undetectable. Nevertheless, it is possible that even for taxonomic groups with total detection, additional species could be detected with additional effort. Still, the number missed is expected to be very low. Overall, the species accumulation curves indicate that the data gathered on the area's ecology is relatively thorough. The incomplete knowledge of mammals reflects the cryptic behaviour (shy, difficult to trap) and low density of many species. The incomplete knowledge of amphibians is due to the highly patchy distribution of populations and the narrow windows of time (immediately after heavy rain) that these are detectable. The incomplete knowledge of plants in part owes to the high diversity present (almost 430 species already recorded), and the observation that many are restricted to patchily distributed micro-habitats within the sandstone ridges and gorges within the survey area.

4.1.4.2 Species at their Distributional Limit

In general, the faunal and floral communities of the survey area were typical of the dry *Acacia* and *Eucalyptus* woodlands of the northern Brigalow Belt.

The location of the VCM, midway between mesic coastal regions and the arid interior, results in a mixture of species from wetter and drier environments. The following species widespread in coastal regions reach their western distributional limits in the vicinity of the project: Little Lorikeet (*Glossopsitta pusilla*), Scarlet Honeyeater (*Myzomela sanguinolenta*), Golden Whistler (*Pachycephala pectoralis*), Rufous Fantail (*Rhipidura rufifrons*) and the plants, *Deeringia amaranthoides, Euroschinus falcatus, Aristolochia thozetii, Desmodium rhytidophyllum, Pycnospora lutescens, Trophis scandens, Gossia bidwillii, Lophostemon grandiflorus, Sorghum leiocladum, Persoonia amaliae, Cheilanthes nudiuscula, Cyclophyllum coprosmoides, Pavetta granitica, Acronychia laevis, Flindersia australis, Planchonella pohlmanniana* and *Tetrastigma nitens.* Most of these species were recorded in sheltered pockets within sandstone gorges.

The survey area also represents the eastern distributional limit for the following species typical of more arid environments: Inland Forest Bat (*Vespadelus baverstocki*) and the plants, *Heliotropium cuninghamii, Cleome tetrandra* and *Cyperus betchei.*

Only one species (the plant, *Heliotropium peninsulare*) reaches its southern distributional limit near the survey area, and one species (Speckled Warbler, *Pyrrholaemus sagittatus*) is near its northern distributional limit.

None of the above species are threatened or near threatened.

The survey area lies within the contact zone between two species of near-identical rock-wallabies, the Unadorned Rock-wallaby (*Petrogale inornata*) and Herbert's Rock-wallaby (*Petrogale herberti*). These species are not possible to distinguish in the field without genetic testing or chromosomal analysis. In coastal areas, the Fitzroy River is a dispersal barrier that marks the boundary between the two species. However, it is not known if the two species meet further inland. The project occurs closest to known populations of Unadorned Rock-wallabies, just north of Moranbah. However, the Isaac River lies in between. In contrast, there are no major rivers between the Harrow Range (adjacent to the VCM) and Herbert's Rock-wallaby populations near Clermont. Neither species is listed as threatened and, therefore, the identity of the local rock-wallaby species is inconsequential to assessing the environmental impacts of the project.

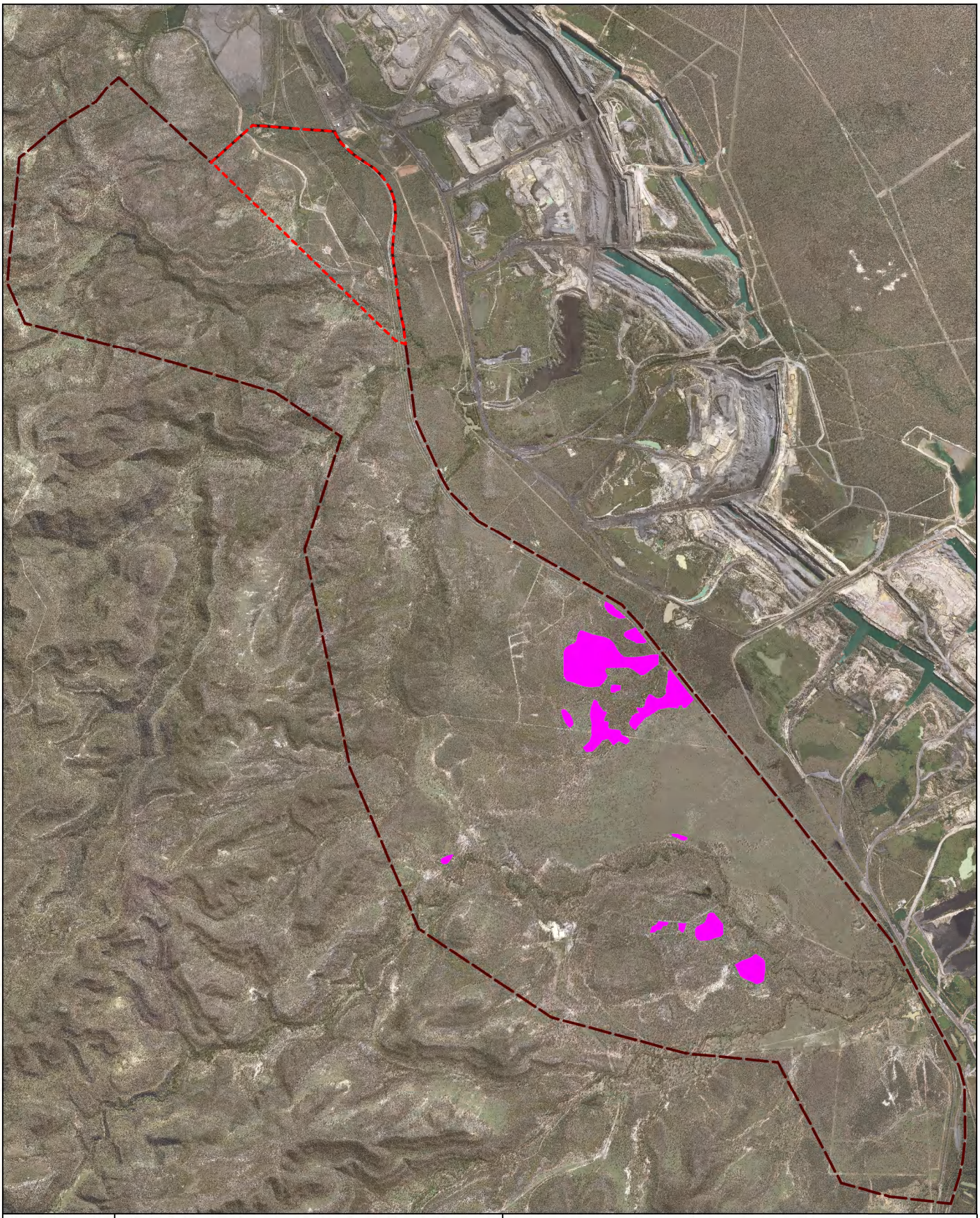
All of the above species occupy relatively broad ranges, and it is unexceptional that a small subset of the 656 species recorded on site occurs near the edge of their distribution. However, one species recorded on site occurs within a very narrow geographic range. The Ornate Velvet Gecko (*Oedura picta*) is a newly described species of reptile (Hoskin 2019) confined to sandstone outcrops within the Cherwell-Harrow Range between Moranbah and Tieri. The project area lies midway along the eastern edge of this very small distribution. The project avoids disturbance to the habitat of this gecko. Despite its limited range, the Ornate Velvet Gecko is not listed as a threatened or near threatened species.

4.2 ENVIRONMENTALLY SENSITIVE AREAS

Category A and B environmentally sensitive areas are defined under Schedule 12 of the *Environmental Protection Regulation 2008*, while category C environmentally sensitive areas are defined in the *Eligibility Criteria and Standard Conditions for Mining Lease Activities* (Department of Environment and Heritage Protection 2016).

No category A or C environmentally sensitive areas occur in or near the survey area.

The only category B environmentally sensitive areas within the survey area are "endangered regional ecosystems identified in the database known as the 'Regional ecosystem description database'". A total of 145.2 ha of endangered regional ecosystems occur within the survey area, but none occur within the project area. The locations of these category B environmentally sensitive areas are shown in **Figure 4-6**.



METSERVE
Mining & Energy Technical Services Pty Ltd

LEGEND

Vulcan Complex Survey Area

Project Area

Category B Environmentally Sensitive Areas

Endangered Regional Ecosystem

Data Source: Field-verified RE Mapping - METServe (2019); Survey Boundary - Vitrinite (2019); Imagery - ESRI, DigitalGlobe, GeoEye, Easrthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

Vitrinite

Vulcan Complex Project
Environmentally Sensitive Areas

1 0 1 2 3

Kilometres

Scale: 1:75,000 (A4)

21/02/2020

Datum: GDA94
Projection: MGA55

FIGURE 4-6

S:\Projects\V1002 Saraji West_MapInfo\Workspaces\Vulcan_Ecology_Report\V1002_Fig4-4_EnvironmentallySensitiveAreas_RevB.WOR

4.3 MATTERS OF NATIONAL ENVIRONMENTAL SIGNIFICANCE

Matters of national environmental significance (MNES) are those protected under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). These include:

1. World heritage places;
2. National heritage places;
3. Wetlands of international importance;
4. Listed threatened species and ecological communities;
5. Migratory species protected under international agreements;
6. Commonwealth marine areas;
7. The Great Barrier Reef Marine Park;
8. Nuclear actions; and
9. A water resource, in relation to coal seam gas development and large coal mining development.

The last two matters on the list are not ecological matters, and are assessed elsewhere. Of the remainder, the only MNES present in the vicinity of the project are 4 and 5.

4.3.1 Threatened Ecological Communities

One threatened ecological community was confirmed to be present within the survey area. Two other vegetation communities present possessed attributes similar to listed threatened ecological communities, but did not meet the criteria for these listed communities. Each of these three ecological communities is discussed below. None of these threatened ecological communities were located within the project area.

4.3.1.1 Brigalow

A total of 149.2 ha of the threatened ecological community listed as "Brigalow (*Acacia harpophylla* dominant and co-dominant)" are contained within the survey area. This includes remnants and high-quality regrowth of the constituent regional ecosystems, 11.3.1, 11.4.8 and 11.4.9 (see **Figure 4-3**). None of this occurred within the project area.

4.3.1.2 Poplar Box Woodland on Alluvium

The ecological community listed under the EPBC Act as "Poplar Box Grassy Woodland on Alluvial Plains" broadly corresponds to some remnant and high-value regrowth forms of regional ecosystem 11.3.2, among others not found on site. A total of 127.7 ha of remnant 11.3.2 and 148.2 ha of regrowth 11.3.2 occurs within the survey area, mostly along Hughes Creek. No 11.3.2 occurred within the project area.

4.3.1.3 Semi-evergreen Vine Thicket

A small area (1.3 ha) of semi-evergreen vine thicket is located in a gorge in the upper reaches of North Creek. This patch lies west of the project area. Floristically, this resembles the threatened ecological community listed under the EPBC Act as "Semi-evergreen Vine Thickets of the Brigalow Belt (North and South) and Nandewar Bioregions". However, the particular regional ecosystem assigned to this vine thicket (11.10.8) is not included in the listed threatened ecological community, on the grounds that it occurs on coarse-grained sedimentary rock (Department of Climate Change, Energy, the Environment and Water 2022a). No 11.10.8 occurs within the project area.

4.3.2 Threatened Species

Twenty-seven species of plants and animals listed as threatened species under the EPBC Act were flagged by database searches as being potentially present in the region. Field surveys confirmed that four of these (Koala, Central Greater Glider, Squatter Pigeon and White-throated Needletail) are present within the survey area (**Figure 4-7**). No threatened species of plants were detected within the survey area.

The likelihoods that the remaining species occur within the survey area were assessed by considering the proximity and recentness of records, as well as availability of potential habitat (**Table 4-3**). An additional 11 species were considered likely or possibly occurring within the vicinity of the project. A

detailed description of the habitat requirements of each of the above 15 species is provided in the following subsections.



Figure 4-7 **Photographs of threatened wildlife taken during surveys:** A) Central Greater Glider, B) Koala, and C) Squatter Pigeons

Table 4-3 Threatened species of national environmental significance flagged by databases as being potentially present in the local region

Taxon	Species	Common Name	EPBC status*	NC status†	Habitat requirements	Presence in survey area#	Presence in project area#
Bird	*Geophaps scripta scripta*	Squatter Pigeon	V	V	Open grassy woodland near water, with areas of bare ground, on land zones 3, 5 and 7.	C	C
Mammal	*Phascolarctos cinereus*	Koala	E	E	Vegetation communities containing food trees (*Eucalyptus* spp.), especially near watercourses.	C	C
Bird	*Hirundapus caudacutus*	White-throated Needletail	V	V	Airspace containing flying insects, above a diversity of landscapes.	C	C
Mammal	*Petauroides armillatus*§	Central Greater Glider	E	E	Tall, old-growth eucalypt forest with tree hollows, especially near watercourses.	C	L
Reptile	*Denisonia maculata*	Ornamental Snake	V	V	Gilgais on heavy clay soil, especially where *Acacia harpophylla* grows.	L	P
Reptile	*Egernia rugosa*	Yakka Skink	V	V	Potentially any vegetated habitat with fallen timber or rocks. There are no nearby records, but habitat is available locally.	P	P
Mammal	*Dasyurus hallucatus*	Northern Quoll	E	LC	Rugged escarpments in wetter forested areas.	P	P
Bird	*Rostratula australis*	Australian Painted-snipe	E	V	Freshwater wetlands with well-vegetated muddy edges.	P	P
Bird	*Erythrotriorchis radiatus*	Red Goshawk	V	E	Large tracts of undisturbed forest, especially near the ecotone between rainforests, melaleuca swamps and open eucalypt woodlands. Within the survey area, it is most likely in densely forested riparian habitats.	P	U
Grass	*Aristida annua*	Annual Wiregrass	V	V	Open eucalypt woodlands and pastures on basalt-derived clay. The survey area lies outside the known distribution of the species; the most northern record is 35 km south. No clay soil occurs within the project area.	P	U
Mammal	*Macroderma gigas*	Ghost Bat	V	E	Primarily coastal ranges, where large cave systems occur near extensive forests. The nearest record is 85 km northeast.	P	U
Reptile	*Furina dunmalli*	Dunmall's Snake	V	V	Associated with *Acacia harpophylla* and eucalypt forests. The survey area is outside the known distribution of the species.	P	U
Reptile	*Lerista allanae*	Allan's Lerista	E	E	Inhabits root systems of grass tussocks growing on black clay soils. No clay soil occurs within the project area.	P	U
Grass	*Dicanthium queenslandicum*	King Blue-grass	E	V	Grasslands or open woodland on clay soils, with low grazing pressure. Favourable soils within the survey area were subject to high grazing pressure. No clay soil occurs within the project area.	P	U
Grass	*Dicanthium setosum*	Hairy Bluegrass	V	LC	Grasslands or open woodland on clay soils, with low grazing pressure. No clay soil occurs within the project area.	P	U

Taxon	Species	Common Name	EPBC status*	NC status†	Habitat requirements	Presence in survey area‡	Presence in project area‡
Bird	*Calidris ferruginea*	Curlew Sandpiper	CE	E	Primarily coastal mudflats, but occasionally also uses the muddy margins of large freshwater wetlands.	U	U
Bird	*Grantiella picta*	Painted Honeyeater	V	V	Open woodlands, especially dominated by *Acacia harpophylla* or other *Acacia* species. They are dependent on an abundance of mistletoe, a resource that was scarce in the survey area.	U	U
Bird	*Neochmia ruficauda ruficauda*	Star Finch	E	E	Probably extinct in the Bowen Basin. Formerly inhabited grassy edges of rivers and wetlands.	U	U
Bird	*Poephila cincta cincta*	Southern Black-throated Finch	E	E	Grassy eucalypt forests, especially near water, where the understorey of native perennial grasses has not been compromised by grazing. No records within 100 km.	U	U
Mammal	*Nyctophilus corbeni*	Corben's Long-eared Bat	V	V	Only known from three cave systems, all south of Bundaberg. The survey area lies well outside the known distribution of the species.	U	U
Mammal	*Pteropus poliocephalus*	Grey-headed Flying-fox	V	LC	Rainforests and wet eucalypt forests well south and east of the survey area. No records within 100 km.	U	U
Reptile	*Elseya albagula*	Southern Snapping Turtle	CE	E	Large permanent to semi-permanent river systems. The survey area lies outside the known distribution of the species, and suitable habitat is lacking.	U	U
Reptile	*Rheodytes leukops*	Fitzroy River Turtle	V	V	Inhabits deep pools with fallen timber in rivers with fast-flowing water. Suitable habitat is absent from the survey area.	U	U
Fish	*Maccullochella peelii*	Murray Cod	V	-	Clear, rocky streams, slow-flowing or turbid lowland rivers and billabongs. The survey area lies well outside the natural range of the species.	U	U
Cycad	*Cycas ophiolitica*	Marlborough Blue Cycad	E	E	Grows on steep slopes and hill tops in coastal areas over 100 km east of the survey area.	U	U
Tree	*Cadellia pentastylis*	Ooline	V	V	Edges of sandstone or basalt escarpments within *Acacia harpophylla*, vine-thicket, poplar box and bendee vegetation communities. The survey area lies outside the known distribution of the species. A very small amount of suitable habitat for the species exists on site, and this was thoroughly surveyed.	U	U
Tree	*Samadera bidwillii*	Quassia	V	V	Occurs in lowland rainforest 120 km east of the survey area.	U	U

*Status under the *Environment Protection and Biodiversity Conservation Act 1999*: CE = critically endangered, E = endangered, V = vulnerable, M = migratory.

†Status under the *Nature Conservation Act 1992*: E = endangered, V = vulnerable, LC = least concern, SL = special least concern.

‡Presence within survey area in which the project is contained: C = presence confirmed, L = likely to be present, P = possibly present, U = unlikely to be present.

§Listed under the EPBC Act as *Petauroides volans.*

4.3.2.1 Squatter Pigeon

The southern subspecies of the Squatter Pigeon (*Geophaps scripta scripta*) is listed as vulnerable under the EPBC Act. This species was recorded on numerous occasions throughout the survey area (69 individual records at 29 locations). There is no recovery plan in place for the species. However, the Commonwealth Government has provided advice about the species' ecology and priority actions to mitigate key threats within the conservation advice (Threatened Species Scientific Committee 2015a) and the SPRAT profile for the species (Department of Climate Change, Energy, the Environment and Water 2022b).

The Squatter Pigeon is a ground-dwelling bird that feeds on seeds among sparse and low grass, in improved pastures, and beside railway lines and around settlements (Threatened Species Scientific Committee 2015a). The Squatter Pigeon inhabits the grassy understorey of open eucalypt woodland, and less often savannas. It is nearly always found near permanent water such as rivers, creeks and waterholes (Threatened Species Scientific Committee 2015a). Sandy areas dissected by gravel ridges, which have open and short grass cover, allowing easy movement, are preferred (Threatened Species Scientific Committee 2015a). It is less commonly found on heavier soils with dense grass (Threatened Species Scientific Committee 2015a). It often occurs in burnt areas and is sometimes found on tracks and roadsides (Threatened Species Scientific Committee 2015a).

The species nests on the ground, usually laying two eggs among or under vegetation (Threatened Species Scientific Committee 2015a). One nest was located during recent weed surveys within the project area (**Figure 4-8**), but these are well hidden and likely to be widespread across the survey area.



Figure 4-8 Squatter Pigeon chicks in a nest beneath a grass tussock within the project area

Provided land is not overgrazed, Squatter Pigeons coexist readily with cattle grazing; however, the species has largely disappeared from the southern part of its distribution (e.g., New South Wales and southern Queensland), where sheep grazing is widespread and rabbit densities are high (Threatened Species Scientific Committee 2015a). Squatter Pigeons often favour thinned habitats where grazing

cattle create open patches of ground for foraging. Some introduced pastures also provide a valuable food source for the species (Crome 1976). A moderate amount of land modification probably benefits the species, reflected by long-term population increases (between 1934 and 1999) in grazing properties elsewhere in the Brigalow Belt (Woinarski and Catterall 2004). This is also supported by data comparing undisturbed woodlands near Townsville with areas disturbed by grazing or military activities; the latter two land uses supported ten times more Squatter Pigeons (Woinarski and Ash 2002).

The SPRAT profile defines foraging habitat for the Squatter Pigeon as remnant or regrowth open-forest to sparse, open-woodland or scrub dominated by *Eucalyptus*, *Corymbia*, *Acacia* or *Callitris* species, on sandy or gravelly soils (Queensland land zones 5 and 7), within 3 km of a suitable, permanent or seasonal waterbody (Department of Climate Change, Energy, the Environment and Water 2022b). Breeding habitat occurs on rises occurring on sandy or gravelly soils, within 1 km of a suitable, permanent waterbody (Department of Climate Change, Energy, the Environment and Water 2022b). Typically, the ground-covering vegetation layer in foraging and breeding habitat is considerably patchy, consisting of native, perennial tussock grasses or a mix of perennial tussock grasses and low shrubs or forbs. This patchy, ground layer of vegetation rarely exceeds 33% of the ground area (Department of Climate Change, Energy, the Environment and Water 2022b). The remaining ground comprises bare soil with a light covering of leaf litter (Department of Climate Change, Energy, the Environment and Water 2022b).

Except where this has been cleared, all vegetation within the survey area (with the exception of one small patch of vine-thicket) is dominated by *Eucalyptus, Corymbia* and/or *Acacia* species. Most is located on land zone 5 (sandy plain) favoured by Squatter Pigeons. Here, *Eucalyptus crebra*, *Eucalyptus populnea, Eucalyptus melanophloia* and *Corymbia clarksoniana* are the dominant canopy species. The understorey is usually dominated by the introduced pasture grasses *Bothriochloa pertusa*, *Cenchrus ciliaris* and *Melinis repens*. However, the native grasses *Aristida* spp., *Chrysopogon fallax*, *Eriochloa crebra* and *Alloteropsis cimicina* are occasionally dominant.

Narrow ribbons of land zone 3 (sandy alluvium) occur along creeks, where dense forests of *Eucalyptus camaldulensis* and *Melaleuca leucadendra* grow. Creek terraces support open forests of *Corymbia tessellaris, Eucalyptus populnea, Corymbia dallachiana* and *Corymbia clarksoniana.* In general, land zone 3 contains too thick a grass cover to be favourable for Squatter Pigeons; the mean ground vegetation cover is 58% and four out of five sites sampled exceeded 33% cover. However, most permanent water points (dams and natural wetlands) are located in this land zone, and these provide water resources for Squatter Pigeons. Furthermore, as the ground around these water points is often heavily grazed, patches of suitable foraging habitat exist in an otherwise unfavourable matrix. These "islands" of highly favourable habitat (water with adjacent foraging habitat) were the locations of many Squatter Pigeon sightings (**Table 4-4**).

Land zone 10 (sandstone rises and escarpments) occurs along the western fringe of the project area, and more extensively further west. Steep slopes, extensive rock outcropping, no surface water, and a lack of bare ground patches within this land zone make it largely unsuitable for Squatter Pigeons. Of 17 sites sampled, nine were unsuitable for Squatter Pigeons due to having >33% vegetation cover or <10% bare ground. The eight sites classed as suitable based on understorey composition were primarily in regional ecosystems 11.10.7 or 11.10.3 located on the foot slopes. Squatter Pigeon sightings largely mirrored these habitat assessments. Despite comprising 39% of the total survey area, only 3% of individuals sighted were in land zone 10 (all in regional ecosystem 11.10.7), and all were within 300 m of land zone 3 or 5.

The vast majority of sightings (69.7%) were in land zone 5, a finding that strongly accords with habitat preferences presented in the SPRAT profile.

No Squatter Pigeons were recorded on land zones 4 or 9. The heavy clay soils in land zone 9 support an excessively dense grass cover. In remnant 11.9.2, vegetation covers an average of 63% of the ground, and this increases to 85% in areas where 11.9.2 has been cleared. The clay soils in land zone 4 are similarly unsuitable for Squatter Pigeons. Sites surveyed within this land zone fell into one of two categories. In areas where the canopy was open, vegetation covered far greater than 33% of the

ground. In areas where the canopy was dense, there was very little grass as a source of seed and/or bare ground on which to forage (one or both categories constituted less than 10% of the total ground cover).

In summary, data gathered on site strongly supports the habitat preferences described in the SPRAT profile, in that land zone 5 constitutes the primary foraging and breeding habitat for Squatter Pigeons within the survey area, land zone 3 is utilised in the vicinity of water, and land zone 10 is mostly not utilised, except for regional ecosystem 11.10.7 and possibly 11.10.3 on the foot slopes. There is no local evidence that heavy clays on land zones 4 and 9 are utilised by Squatter Pigeons.

Table 4-4 Squatter Pigeon records per habitat type

Land Zone	Vegetation Age	Percentage of Survey Area	Percentage of Squatter Pigeon Records
3: Alluvium	Remnant	5.5%	21.2%*
	Regrowth	2.3%	4.5%*
	Cleared	4.2%	6.1%*
4: Clay plain	Remnant	2.1%	0%
	Regrowth	0.1%	0%
	Cleared	1.6%	0%
5: Sand plain	Remnant	17.1%	15.2%
	Regrowth	7.5%	6.0%
	Cleared	12.2%	48.5%
9: Clay derived from fine-grained sedimentary rock	Remnant	4.8%	0%
	Regrowth	0%	0%
	Cleared	2.8%	0%
10: Sandstone ranges	Remnant	37.5%	3%
	Regrowth	1.7%	0%
	Cleared	0.8%	0%

*Detection rates of Squatter Pigeons in alluvial areas may overestimate the true value of this habitat for the species, as the high grass density within this land zone means that individuals are more likely to forage on tracks, where they are more detectable.

Many cleared patches of vegetation within the survey area had regrown sufficiently, or a sufficient density of trees was retained during clearing, for some cleared areas to qualify as "sparse open-woodland or scrub" used by Squatter Pigeon for foraging and breeding. Accordingly, as can be seen from **Table 4-4**, many Squatter Pigeon records came from cleared vegetation.

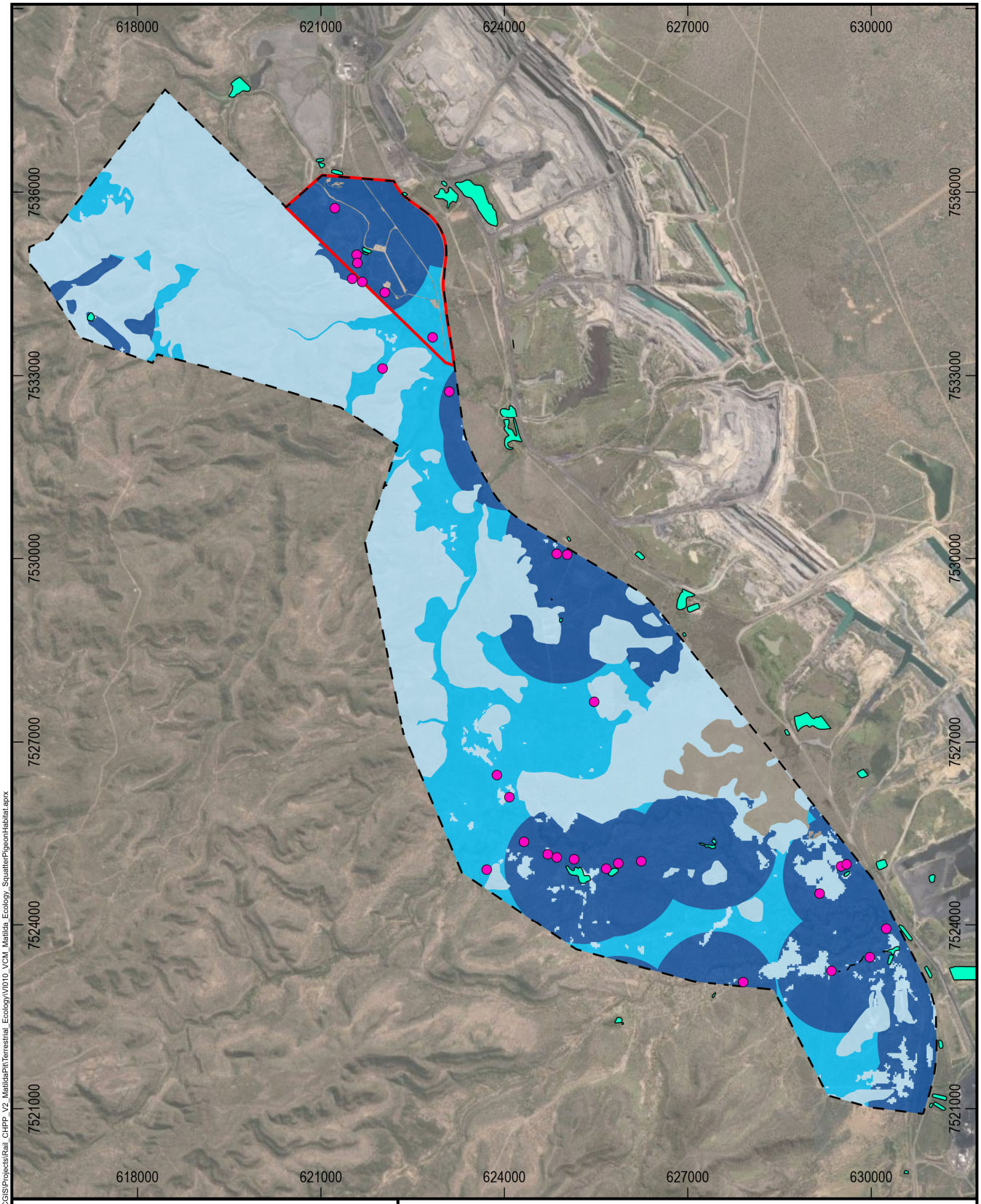
There is no single, standard definition of "sparse" vegetation in Australia. The most widely used vegetation classification system (the Specht classification system: Specht 1970) defines "sparse" vegetation classes as possessing 10-30% foliage projection cover or 20-50% canopy cover (the latter includes gaps between leaves within each canopy). However, in its *National Forest and Sparse Woody Vegetation Data* (Department of Industry, Science, Energy and Resources 2020), the Australian Government adopts a more conservative definition of sparse woody vegetation as having 5-19% canopy cover. Given that the definition of Squatter Pigeon habitat as "open-forest to sparse, open-woodland or scrub" was developed by the Australian Government for their SPRAT profile, the Australian Government's definition of "sparse" as >5% canopy cover was adopted for habitat mapping purposes.

Regardless of the status of vegetation under Queensland's VM Act (non-remnant, regrowth or remnant), any parts of land zones 3 or 5 that qualified as "sparse" vegetation according to *National Forest and Sparse Woody Vegetation Data* were considered Squatter Pigeon foraging habitat and/or breeding

habitat. Likewise any remnant or former regional ecosystem 11.10.7 was considered habitat if this qualified as "sparse" vegetation. Vegetation with less than 5% cover of woody vegetation, vegetation occurring on land zones 4 or 9, and any vegetation on land zone 10 that is not 11.10.7 (or 11.10.3 within the lower 300 m of foot slopes) were not considered appropriate foraging or breeding habitat.

Most habitats within the survey area that did not qualify as foraging or breeding habitat did qualify as dispersal habitat. Dispersal habitat is defined by the SPRAT profile as any vegetation unit on any land zone where trees are at less 100 m apart. Most of the survey area, including areas that do not qualify as "sparse woody vegetation", have trees that are 100 m or less apart. Satellite imagery was used to identify non-remnant patches where trees were further than 100 m apart. Any vegetation outside these bare patches that were not foraging habitat qualified as dispersal habitat.

The distribution of Squatter Pigeon habitat across the survey area is shown in **Figure 4-9.** In total, the survey area contained 3,540.5 ha of foraging habitat (of which 2,146 ha is also breeding habitat) and 3,238.7 ha of dispersal habitat for the Squatter Pigeon. The project area contained 376.9 ha of foraging habitat (of which 310.5 ha is also breeding habitat). Of this, 253.9 ha of foraging habitat (of which 209.8 ha are also breeding habitat) are already approved for clearing for the VCM and bulk sample.



Legend

- Survey Area
- ML 700060
- Waterbodies
- Squatter Pigeon Sighting

Squatter Pigeon Habitat

- Breeding and foraging habitat
- Foraging habitat
- Dispersal habitat

Source: Geoscience Australia 2015, Australian Government (Department of Industry, Science, Energy and Resources) 2021, METServe 2019-2022, Earthstar Geographics. Squatter Pigeon habitat derived from the National Forest and Sparse Woody Vegetation dataset (Version 5.0) and field-verified regional ecosystem data.

Vulcan Coal Mine Amendment

Squatter Pigeon Habitat

0 1.5 3

Kilometers

Scale: 1:90,000 (A4)

14/06/2022

Datum: GDA2020
Projection: MGA55

FIGURE 4-9

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\Terrestrial_Ecology\VI010_VCM_Matilda_Ecology_SquatterPigeonHabitat.aprx

4.3.2.2 Koala

Koalas (*Phascolarctos cinereus*) within Queensland, New South Wales and the Australian Capital Territory are listed as endangered under the EPBC Act. This species was recorded 14 times within the survey area, involving at least 12 individuals. It is highly likely that more individuals were present than were detected. The Threatened Species Scientific Committee (2012) suggests an average Koala density of 0.005 Koalas/ha across the Brigalow Belt. Assuming this same density across the survey area, 33 individuals are likely to occur within the survey area. This estimate has low reliability, given the lack of local data on population densities.

The former Australian Government Department of Agriculture, Water and the Environment (2022a) published the *National Recovery Plan for the Koala* Phascolarctos cinereus *(combined populaitons of Queensland, New South Wales and the Australian Capital Territory)*. The Australian Government has also provided advice about the species' ecology and priority actions to mitigate key threats within the SPRAT profile for the species (Department of Climate Change, Energy, the Environment and Water 2022c).

On the western slopes, tablelands and plains in Queensland, Koalas are found in sub-humid *Eucalyptus*-dominated forests and woodlands in riparian and non-riparian environments, and some *Acacia*-dominated forests and woodlands in non-riparian environments (Department of Climate Change, Energy, the Environment and Water 2022c). The main habitat requirement is availability of suitable food trees and, to a lesser extent, shelter trees, which tend to have shadier foliage, be taller and/or be located in sheltered locations in gullies (Crowther *et al.* 2013). Koala habitat includes forests or woodlands; roadside and railway vegetation and paddock trees; safe intervening ground matrix for travelling between trees and patches to forage and shelter and reproduce; and access to vegetated corridors or paddock trees to facilitate movement between patches (Department of Agriculture, Water and the Environment 2022a).

While Koalas have been observed sitting in or eating up to 600 species of eucalypt (Department of Agriculture, Water and the Environment 2022a), the diet of individual Koalas is usually limited to one or a few species (Moore and Foley 2000). Preferences also vary between regions or seasons (Moore and Foley 2000). Chemical anti-feedants, soil nutrients and leaf water content in semi-arid areas may limit or prevent Koalas feeding on foliage of individual trees even when the species is considered preferred (Lawler *et al.* 1998; Moore *et al*. 2005). In the northwest of their range in Queensland (including the survey area), Koala distribution is limited by heat and water availability, with the highest densities of Koalas occurring along creek lines (Munks *et al.* 1996; Sullivan *et al*. 2003). Variability in leaf nutrition creates patchiness such that species-based assessments of habitat likely overestimate the availability of high-quality habitat (Threatened Species Scientific Committee 2012).

Despite limitations in habitat mapping caused by varying leaf nutrition, a conservative approach to habitat mapping is appropriate, which assumes that any individuals of tree species known to be eaten by Koalas could constitute a potential food tree. Likewise, the SPRAT database defines Koala habitat as "any forest or woodland containing species that are known Koala food trees, or shrubland with emergent food trees" (Department of Climate Change, Energy, the Environment and Water 2022c). This includes remnant, regrowth and modified vegetation communities. Assessment of habitat quality for Koalas therefore relies on the identification of local preferences for species and the quantification of the availability of those species (Department of Climate Change, Energy, the Environment and Water 2022c).

The Australian Koala Foundation (2015) maintains a database of the food trees known to be used by Koalas in each local government area of Australia. This database lists *Eucalyptus camaldulensis* and *Eucalyptus tereticornis* as the primary food trees in the Isaac Regional Council area. Secondary food trees include *Eucalyptus brownii*, *Eucalyptus coolabah*, *Eucalyptus ochrophloia*, *Eucalyptus orgadophila* and *Eucalyptus populnea*. Of these species, *E. camaldulensis*, *E. orgadophila* and *E. populnea* are found within the survey area (**Table 4-5**).

The Australian Koala Foundation (2015) acknowledges that *Eucalyptus crebra* can sometimes constitute an additional secondary food species in localised areas with better soils and nutrient availability. Given that this tree species is eaten by Koalas at nearby sites (Ellis *et al*. 2002; Melzer *et al*. 2014), it is conservatively considered a food tree for the purposes of habitat mapping. This species is widespread across the survey area and surrounding region, being a dominant component of many of the regional ecosystems occurring on site. Given the low fertility of local sandy soils, it is unlikely that most local *E. crebra* is utilised to a significant extent by Koalas. Indeed, no Koalas were recorded anywhere on land zone 5 (sand plains), where soils are least fertile. However, small numbers were observed on land zone 10 (sandstone) where *E. crebra* was growing. In accordance with the SPRAT definition of Koala habitat (i.e., any forest or woodland containing species that are known Koala food trees), any vegetation containing *E. crebra* is included as potential habitat.

Table 4-5 Distribution of Koala food trees across vegetation units

Regional Ecosystem*	Area (ha)*	Primary Food Trees	Secondary Food Trees	Overall Value to Koalas†	N_{Koalas}/100ha‡
11.3.1	1.6	Absent	Absent	Nil	0
11.3.2	276.2	Absent	*E. populnea* dominant	Moderate	0
11.3.7	86.4	*E. camaldulensis* occasionally present	*E. populnea* and/or *E. crebra* sometimes subdominant	Moderate	0
11.3.25	153.0	*E. camaldulensis* dominant	*E. populnea* and/or *E. crebra* sometimes subdominant	High	7.19
11.3.27c	2.0	Absent	Absent	Nil	0
11.3.27e	6.5	*E. camaldulensis* dominant	*E. populnea* and/or *E. crebra* sometimes subdominant	High	0
11.4.8	131.4	Absent	Absent	Nil	0
11.4.9	16.2	Absent	Absent	Nil	0
11.5.3	517.6	Absent	*E. populnea* dominant	Moderate	0
11.5.9	1,152.5	Absent	*E. crebra* sometimes dominant, but some variants of this RE lack secondary food trees.	Moderate	0
11.9.2	326.4	Absent	*E. orgadophila* dominant	Moderate	0
11.10.1	265.9	Absent	*E. crebra* usually subdominant	Moderate	0.38
11.10.1x1	412.3	Absent	*E. crebra* occasionally present in low densities	Low	0
11.10.3	1,642.1	Absent	*E. crebra* occasionally present as a scattered emergents	Nil-Low §	0.06
11.10.7	341.6	Absent	*E. crebra* dominant	Moderate	0.29
11.10.8	1.3	Absent	Absent	Nil	0

*Remnant, regrowth and modified forms of regional ecosystems can all constitute habitat, provided non-juvenile food trees (>4 m tall: Department of Environment and Heritage Protection 2017a) are present. Only remnant and regrowth total area is presented in the table, as no Koalas were recorded in cleared vegetation. However, non-remnant habitat that is sufficiently dense to qualify as "sparse woody vegetation" (see **Section 4.3.2.1**) was also considered Koala habitat in **Figure 4-10** and when assessing potential impacts to the species.

†High, moderate and low value habitats all qualify as Koala habitat under the Australian Government's definition (Department of Climate Change, Energy, the Environment and Water 2022c).

[‡]Refers to the number of Koalas recorded in each regional ecosystem as a function of the total area in hectares of each regional ecosystem within the survey area. Note that this is not the same as population density, as not all Koalas present are likely to have been detected. Nevertheless, it is a useful indicator of relative density.

[§]The small patches of 11.10.3 located within the project area lack *E. crebra* and therefore do not qualify as Koala habitat.

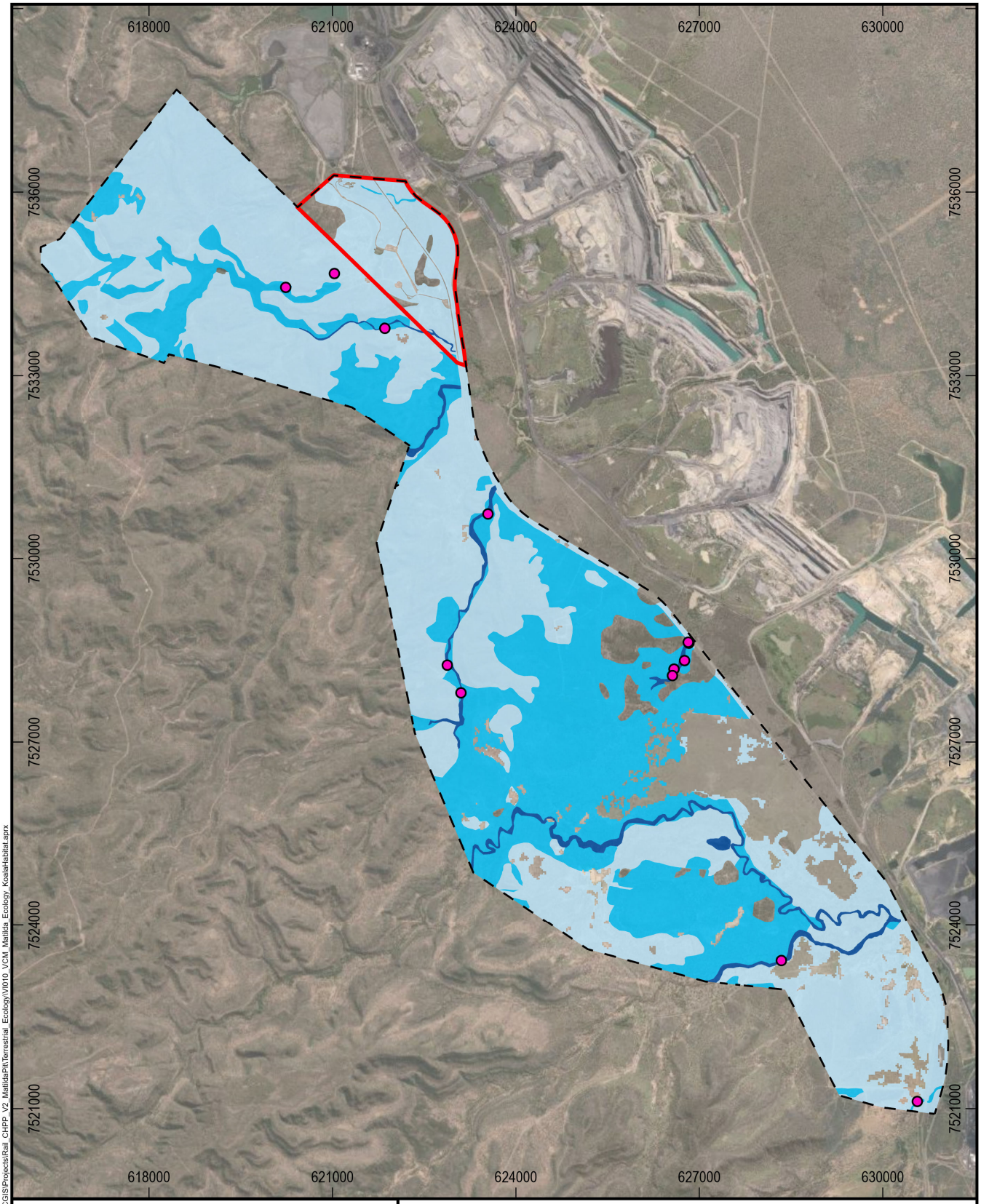
All but one sighting of Koalas occurred in remnant vegetation. The single exception was in regrowth 11.3.25 along Barrett Creek. No Koalas were recorded in cleared vegetation units, despite detectability being higher in smaller trees and open landscapes. This aligns with known preferences of the species for tall trees (Callaghan *et al*. 2011; Smith *et al*. 2013). This finding conflicts with the broad definition of Koala habitat presented in the SPRAT profile (Department of Climate Change, Energy, the Environment and Water 2022c) as any remnant, regrowth and modified vegetation communities containing Koala food trees. As most cleared portions of the survey area contain widely scattered food trees, they therefore qualify as habitat under this definition, despite being of negligible importance to local Koalas. They are therefore mapped as the same low value as remnant units containing low densities of secondary food trees (e.g., 11.10.1x1 or 11.10.3).

Non-remnant regrowth that had a canopy cover less than 5% is considered "non-woody" vegetation by the *National Forest and Sparse Woody Vegetation Data* (Department of Industry, Science, Energy and Resources 2020) and was accordingly mapped as non-habitat.

The Brigalow Belt bioregion contains the largest population of Koalas within Queensland (Department of Climate Change, Energy, the Environment and Water 2022c), owing to its large size and subhumid climate (other large bioregions are in semi-arid climates with low Koala densities). Habitat connectivity is high across the region surrounding the VCM. Habitats containing secondary food trees connect ribbons of important habitat (containing primary food trees) occurring along major watercourses, and provide opportunities for dispersal. The project, however, lies at a habitat edge, as it is bounded to the north and east by existing mining operations that represent an impediment to dispersal. The Koala population present within the survey area is connected to the broader region via extensive tracts of eucalypt forests that cover the Cherwell-Harrow Range, to the west and south.

Habitat clearance and climate change represent the major threats to Koala populations in the Brigalow Belt. The location of primary food trees along watercourses means that they represent important drought refugia. Road-based mortality is another local threat, and multiple fatalities occur along Saraji Road each year. Attacks by domestic dogs, a key threat in densely settled regions of Queensland, is a negligible threat locally, given the low density of houses.

The survey area contained 153.9 ha of high-value habitat, 2,226.6 ha of moderate-value habitat and 3,860.9 ha of low-value habitat for the Koala, while the project area contained 2.1 ha of high-value habitat, 3.5 ha of moderate-value habitat and 328.9 ha of low-value habitat. Of this, 2.6 ha of moderate-quality habitat and 236.5 ha of low-quality habitat are already approved for clearing for the VCM.



Legend

- Survey Area
- ML 700060
- Koala Sighting

Koala Habitat

- High Quality
- Moderate Quality
- Low Quality

Source: Australian Government (Department of Industry, Science, Energy and Resources) 2021, METServe 2020-2022, Vitrinite 2022, Earthstar Geographics. Koala habitat derived from the National Forest and Sparse Woody Vegetation dataset (Version 5.0) and field-verified regional ecosystem data.

Vulcan Coal Mine Amendment

Koala Habitat

0 0.75 1.5 3

Kilometers

Scale: 1:90,000 (A4)

14/06/2022

Datum: GDA2020
Projection: MGA55

FIGURE 4-10

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\Terrestrial_Ecology\VI010_VCM_Matilda_Ecology_KoalaHabitat.aprx

4.3.2.3 Central Greater Glider

The Greater Glider (*Petauroides volans*) is listed as an endangered species under the EPBC Act. Recent studies have suggested that this taxon actually comprises three genetically distinct species, with the Central Greater Glider (*P. armillatus*) being present in the survey area (McGregor *et al.* 2020). Its taxonomy under the EPBC Act is yet to be revised in accordance with this recent study.

A total of 20 Central Greater Gliders were recorded within the survey area, with most of these occurring in riparian forests along watercourses. There is no recovery plan in place for the species. However, the Commonwealth Government has provided advice about the species' ecology and priority actions to mitigate key threats within the conservation advice (Threatened Species Scientific Committee 2016).

All three species of greater glider feed on the young leaves of *Eucalyptus* and *Corymbia* in a broad range of forests across eastern Australia. They have a preference for tall, montane, moist eucalypt forests with abundant hollows and a diversity of tree species present (Threatened Species Scientific Committee 2016), but also occur in drier lowland forests, provided tall, hollow trees are present.

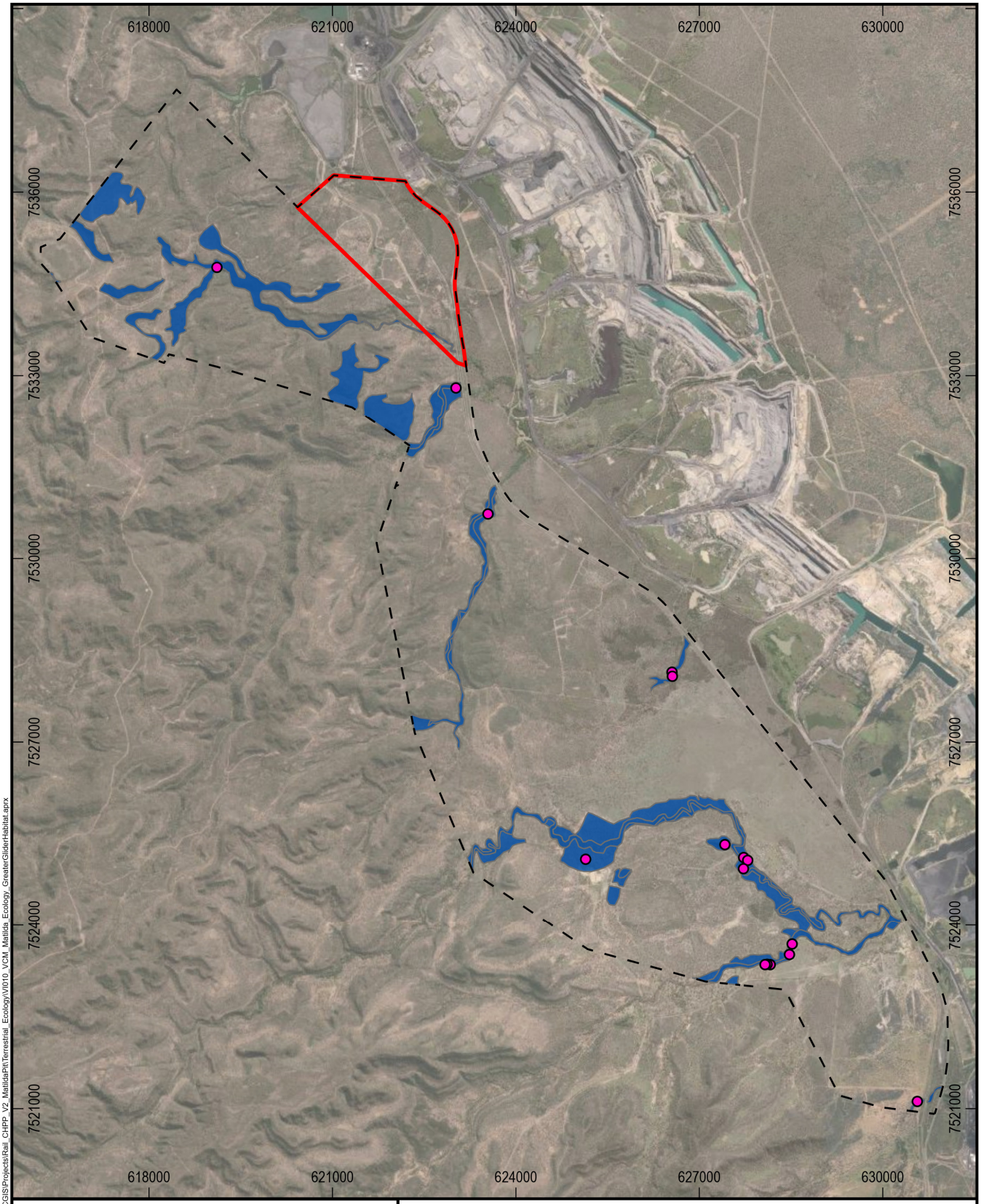
The project lies near the western edge of the distribution of the Central Greater Glider (Kearney *et al.* 2010). Water availability limits the distribution of local populations (Kearney *et al.* 2010). Consequently, local populations are largely restricted to riparian environments, where large, hollow trees are most abundant, and subsoil moisture allows suitable food trees to grow fresh leaves over extended periods of the year.

Each individual requires many large, hollow-bearing trees within its home range of 1-4 ha (Comport *et al*. 1996; Lindenmayer *et al*. 2004). Southern Greater Gliders generally require trees larger than 50 cm (diameter of trunk) (Kehl and Borsboom 1984), and even larger trees may be required in tropical environments, in order for hollows to be buffered against extreme daytime temperatures (Kearney *et al.* 2010). During ecological surveys of the survey area, high densities of trees of this size were very rarely encountered away from riparian zones. Nevertheless, large, hollow *Corymbia citriodora* occasionally grew in sheltered, south-facing slopes of gorges within the Harrow Range. One Central Greater Glider was recorded within such habitat during surveys. For this reason, regional ecosystem 11.10.1 was also considered potential habitat for Central Greater Gliders within the survey area.

With the exception of the single record in regional ecosystem 11.10.1, all other records were in riparian environments (regional ecosystems 11.3.25, 11.3.7, 11.3.27e and regrowth 11.3.25 with many retained large trees), despite these habitats comprising only 3.7% of the survey area. This is clear evidence for the importance of riparian habitats for local populations of the Central Greater Glider. Local populations are likely to be relatively large, as the species was recorded along all major drainage lines surveyed. Conservatively assuming that each pair occupies 16 ha (the home range in lower productivity forests and more open woodlands: Threatened Species Scientific Committee 2016), there is expected to be at least 58 individuals inhabiting the survey area. This population could be larger than 450 individuals if an average home range of 2 ha is assumed (a more typical size: Threatened Species Scientific Committee 2016). The project area contains enough habitat to support up to one home range. The local population is connected to the broader region via extensive tracts of eucalypt forests that cover the Harrow Range, to the west and south (regional ecosystem 11.10.1 is a subdominant community within this range).

Non-remnant habitats (e.g. regrowth) are unlikely to be utilised by Greater Gliders, due to an absence of hollows for shelter. An exception is where many large, hollow trees were retained during clearing. The only part of the survey area where this was observed was in the far south, along Barrett Creek. Here, a pair of Greater Gliders was observed to emerge from one of the retained hollow dead trees. Riparian vegetation along Barrett Creek was therefore mapped as habitat, while regrowth elsewhere within the survey area was considered to be unsuitable for Central Greater Gliders.

In total, 617.2 ha of Central Greater Glider habitat are present within the survey area, while the project area contains 2.1 ha of habitat (**Figure 4-11**). No habitat within the project area was approved for disturbance for the VCM.



Legend

- Survey Area
- ML 700060
- Central Greater Glider Sighting
- Central Greater Glider Habitat

Source: Vitrinite 2022, METServe 2020-2022, Earthstar Geographics.

Vulcan Coal Mine Amendment

Central Greater Glider Habitat

0 1.5 3

Kilometers

Scale: 1:90,000 (A4)

14/06/2022

Datum: GDA2020
Projection: MGA55

FIGURE 4-11

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\Terrestrial_Ecology\VI010_VCM_Matilda_Ecology_GreaterGliderHabitat.aprx

4.3.2.4 White-throated Needletail

The White-throated Needletail is an almost exclusively aerial bird that visits eastern Australia when not breeding (the austral summer). Under the EPBC Act, it is listed both as a threatened species (vulnerable) and a migratory species.

White-throated Needletails feed on flying insects in large, fast-moving flocks that can cover huge distances in a day. In central Queensland, the species is most often recorded in the vicinity of the coast and nearby ranges. It tends to favour forested areas and landforms facilitating updraughts (ranges, cliffs and sand dunes), but can occur over a wide variety of landforms and vegetation types. No White-throated Needletails were recorded in the survey area during the various ecological surveys undertaken on site, despite the species being highly detectable when present. There were also no nearby recent records of the species. However, a flock of approximately 100 White-throated Needletails was observed moving north in airspace above the VCM during weed monitoring undertaken in March 2022.

White-throated Needletails regularly follow the edges of low pressure systems, and the sighting coincided with unstable storm activity. The timing of the sighting and the direction of travel suggest that the flock was likely on its northward passage to breeding grounds in East Asia. It is possible that the storm cells encouraged the flock to move west of the usual migration route along the coast and sub-coastal ranges.

The survey area is unlikely to be of great importance to the White-throated Needletail. It lies west of the species' usual migration route and the species is rarely recorded in the local region. The survey area is most likely to be used for foraging by flocks that are based in the Clarke Range, but which occasionally follow low pressure systems further west.

4.3.2.5 Ornamental Snake

Ornamental Snakes feed on frogs and favour habitats supporting the temporary pooling of water where frogs breed (Department of Climate Change, Energy, the Environment and Water 2022d). Ornamental Snakes primarily inhabit gilgai (melon-hole) mounds and depressions in land zone 4 (deep-cracking clay plains), but also lake margins and wetlands (Department of Climate Change, Energy, the Environment and Water 2022d). Locally, such habitats tend to support vegetation communities dominated by *Acacia harpophylla* (broad vegetation group 25a). Areas with a diversity of gilgai sizes and depths provide optimal habitat (Department of Climate Change, Energy, the Environment and Water 2022d). An abundance of fallen timber is also important for shelter (Department of Climate Change, Energy, the Environment and Water 2022d). Cleared grasslands may also be utilised, provided that gilgais are present and some debris remains for shelter.

The *Draft Referral Guidelines for the Nationally Listed Brigalow Belt Reptiles* (Department of Sustainability, Environment, Water, Population and Communities 2011) defines suitable habitat for Ornamental Snakes as "open-forests to woodlands associated with gilgai formations and wetlands. These are commonly mapped as QLD REs 11.3.3, 11.4.3, 11.4.6, 11.4.8, 11.4.9, 11.5.16 or mapped as cleared but where the above REs formerly occurred". Important habitat is defined by these guidelines as "gilgai depressions and mounds".

Ornamental Snakes are active, and therefore detectable, only when frogs are active (i.e., following heavy rainfall events). For the remainder of the year, most local frogs (especially the genera *Cyclorana, Platyplectrum* and *Limnodynastes*) remain buried underground, and Ornamental Snakes are similarly inactive. At optimal times of the year, Ornamental Snakes are readily detectable by spotlighting around flooded gilgais where frogs are active, or via funnel and pitfall traps installed in favourable habitats (Department of Climate Change, Energy, the Environment and Water 2022d).

Most fauna surveys undertaken on site coincided with ideal conditions for detecting Ornamental Snakes. Heavy rain events occurred midway through the October 2018 and March 2019 surveys, resulting in widespread flash-flooding and the pooling of surface water in gilgais and other depressions. Spotlighting on the nights following these rain events targeted 10 locations potentially supporting Ornamental Snakes (flooded gilgais, dams and billabongs). A total of 8 person-hours were spent spotlighting in possible

habitat under optimal conditions. This represented a disproportionate search effort for this species; it equates to 18.5 % of the total spotlighting effort on site, despite potential Ornamental Snake habitats constituting only 1.8 % of the survey area. In addition, there were three trap sites installed in broad vegetation group 25a, and rain fell midway through the sampling of each of these. Two other trap sites were installed in *Eucalyptus populnea* woodland close to dams with potential to support Ornamental Snakes. Despite all the above search effort, no Ornamental Snakes were recorded on site.

According to the Wildnet database, Ornamental Snakes have been recorded at the adjacent Peak Downs Mine and Saraji Mine (immediately east of the survey area) since 2000. Despite the close proximity, there are several differences between the habitat in the survey area and east of Saraji Road. Firstly, regional ecosystem mapping indicates that land zone 4 is far more widespread to the east. Within the survey area, it was confined to small, isolated patches mostly less than 5 ha in extent. Secondly, most of land zone 4 within the survey area has very minor to no gilgai development. Where gilgais occurred, these tended to be less than 30 cm deep, and held water for less than one month after heavy rain. Consequently, frog diversity and density were very low in gilgais on site. In contrast, large ponds and wetlands (many of which are constructed as part of water management at neighbouring mines) occur east of Saraji Road, and many frogs were heard calling from this direction.

Nevertheless, given that known populations of Ornamental Snakes occur nearby, and some potential habitat occurs within the survey area, it is likely that small numbers of Ornamental Snakes occur locally. Failure to detect the species despite optimal survey conditions, combined with the poor quality of habitat present, suggests that the survey area is of marginal importance to the species.

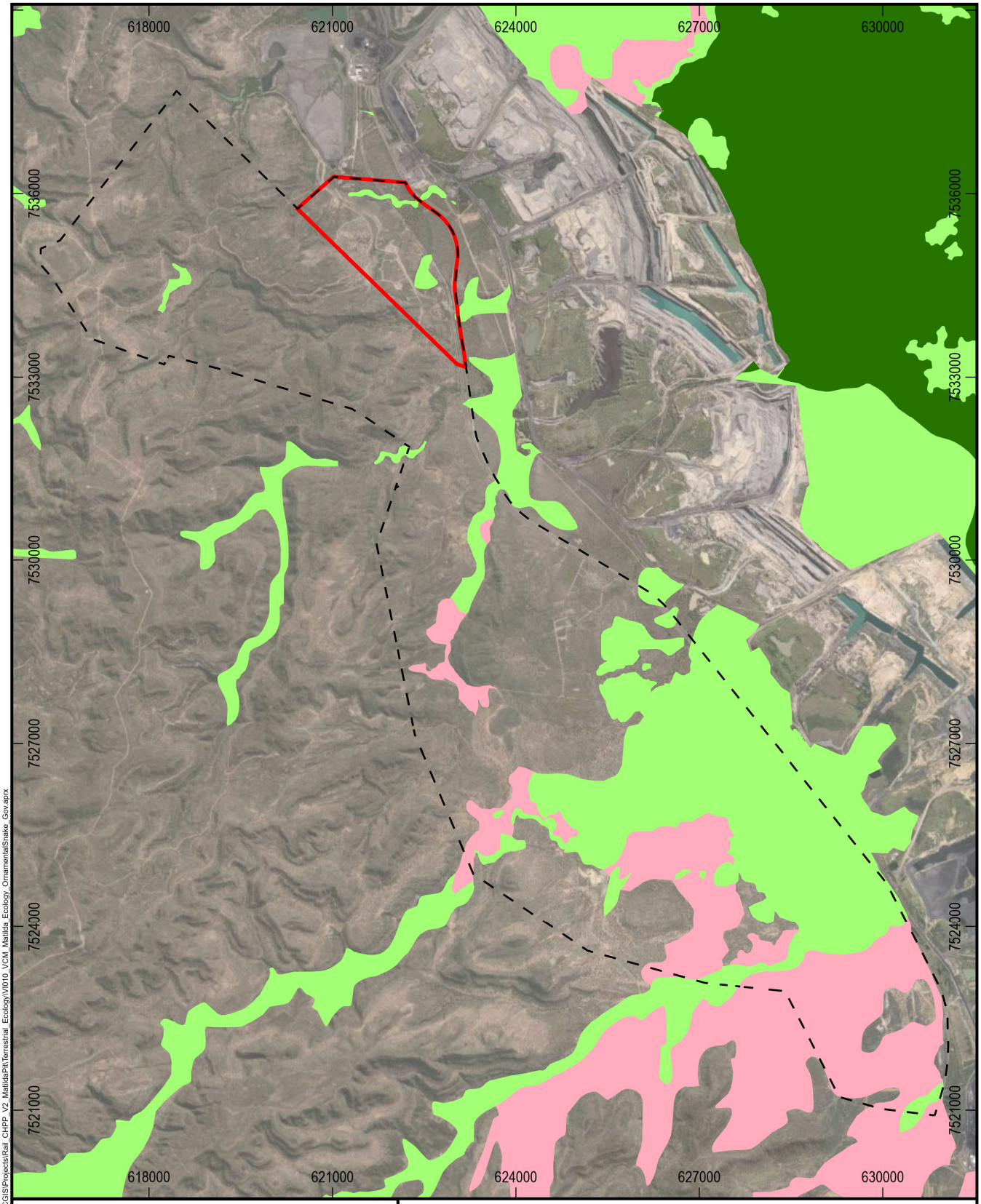
The Queensland Department of Environment and Science published a habitat suitability model for the Ornamental Snake in January 2019. This model shows extensive areas of habitat in the southern half of the survey area (**Figure 4-12**). However, there are several reasons why the mapping generated by this model was not reliable with respect to the survey area. These include:

1) The model was based on former regional ecosystem mapping, which contained widespread errors with regards to the local distribution of *Acacia harpophylla* communities important to Ornamental Snakes;
2) The model assumed that riparian areas represented non-core habitat; however, all watercourses within the survey area had sandy beds with no surface water pools. No breeding habitat for frogs (and therefore Ornamental Snakes) was present along these watercourses; and
3) Some gilgais and well-vegetated dams occurred in areas mapped as non-remnant, which were excluded from the models. Given the high frog densities recorded at such sites, it is appropriate to include these locations as potential habitat for the Ornamental Snake.

For the above reasons, potential habitat for the Ornamental Snake was re-mapped based on the following principles:

1) Any patches of broad vegetation group 25a (remnant and regrowth forms) were assumed to be primary habitat, unless field surveys confirmed that gilgais were lacking;
2) Any natural wetlands with a dense cover of aquatic vegetation were assumed to be primary habitat;
3) Permanent dams supporting a fringe of aquatic vegetation were considered secondary habitat;
4) Gilgais within cleared pasture were considered secondary habitat; and
5) Dams lacking vegetated margins, and all other locations where surface water did not pool after rain (including all creeks on site), were considered non-habitat.

The resulting habitat map (**Figure 4-13**) revealed 93.1 ha of primary habitat and 48.3 ha of secondary habitat contained within the survey area. Of this, 1.3 ha of secondary habitat is contained within the project area.



Legend

- Survey Area
- ML 700060

Ornamental Snake Habitat Value

- Preferred Habitat Known
- Preferred Habitat Possible
- General Habitat Known
- General Habitat Possible

Source: State of Queensland (Department of Environment and Science) 2021, Vitrinite 2022, METServe 2022, Earthstar Geographics.

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\Terrestrial_Ecology\VI010_VCM_Matilda_Ecology_OrnamentalSnake_Gov.aprx

Vulcan Coal Mine Amendment

Ornamental Snake Habitat Suitability Model Predictions (Department of Environment and Science)

0 1.5 3

Kilometers

Scale: 1:90,000 (A4)

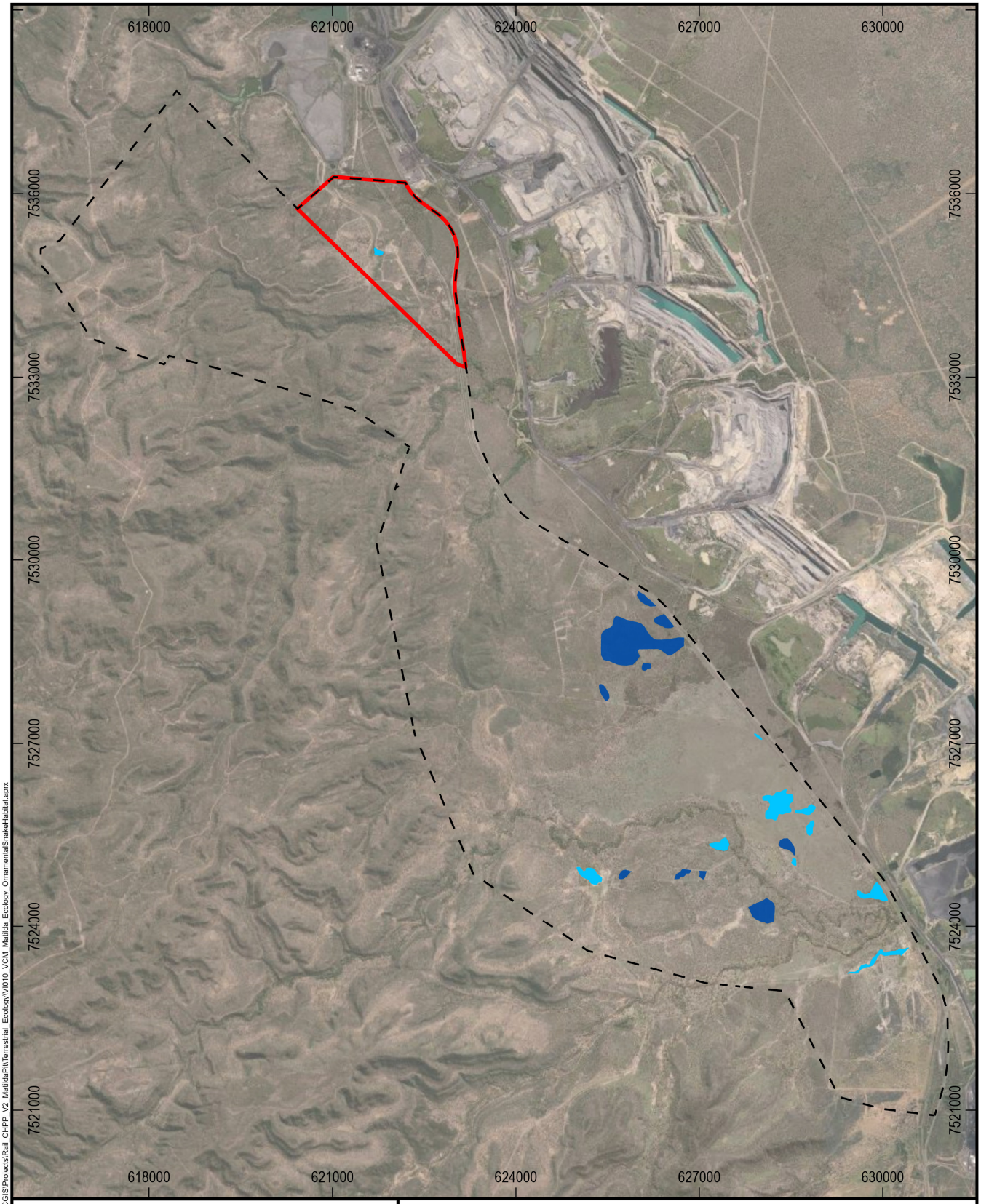
14/06/2022

Datum: GDA2020
Projection: MGA55

FIGURE 4-12

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd



Legend

- Survey Area
- ML 700060

Potential Ornamental Snake Habitat

- Primary
- Secondary

Source: Vitrinite 2022, METServe 2020-2022, Earthstar Geographics.

Vulcan Coal Mine Amendment

Potential Ornamental Snake Habitat

0 1.5 3

Kilometers

Scale: 1:90,000 (A4)

14/06/2022

Datum: GDA2020
Projection: MGA55

FIGURE 4-13

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\Terrestrial_Ecology\VI010_VCM_Matilda_Ecology_OrnamentalSnakeHabitat.aprx

4.3.2.6 Yakka Skink

Yakka Skinks are large, gregarious lizards that inhabit a broad range of woodland and forest communities across sub-coastal and semi-arid Queensland (Department of Climate Change, Energy, the Environment and Water 2022e). The core habitat of this species is within the Mulga Lands and Brigalow Belt South Bioregions (Department of Climate Change, Energy, the Environment and Water 2022e), and there are few records in the Brigalow Belt North Bioregion (where the VCM is located).

Yakka Skinks live in colonies within cavities under and between partly buried rocks, logs or tree stumps, root cavities and abandoned animal burrows (Department of Climate Change, Energy, the Environment and Water 2022e). They remain in close proximity to their burrows, and are only active for brief periods at dawn and dusk (Department of Climate Change, Energy, the Environment and Water 2022e). This, combined with their low density, makes them difficult to detect.

The *Draft Referral Guidelines for the Nationally Listed Brigalow Belt Reptiles* (Department of Sustainability, Environment, Water, Population and Communities 2011) defines suitable habitat for Yakka Skinks as "open-forests to low-woodlands and scrub in QLD RE Land Zones (LZ) 3, 4, 5, 7, 8, 9, 10 and 12 (LZ 8 not considered core habitat; LZ 12 in Wet Tropics bioregion only). Colonies have been found in large hollow logs, cavities or burrows under large fallen trees, tree stumps, logs, stick-raked piles, large rocks and rock piles, dense ground-covering vegetation, and deeply eroded gullies, tunnels and sinkholes". Important habitat is defined as "any contiguous patch of suitable habitat, particularly remnant vegetation, where a colony is known or identified, or any microhabitat where colonies are likely to be found".

The survey area lies outside the Yakka Skink's modelled "known/likely to occur" distribution (Department of Sustainability, Environment, Water, Population and Communities 2011). However, the modelled distribution of the Yakka Skink shows that the species "may occur" with the survey area (Department of Sustainability, Environment, Water, Population and Communities 2011).

No Yakka Skinks were recorded during surveys on site. Detectability is greatest during warm, humid conditions (Department of Climate Change, Energy, the Environment and Water 2022e), and the surveys were therefore under optimal conditions. Nevertheless, given the large size of the survey area, it was not practical to inspect every possible burrow location within it.

The survey area does not contain habitat connected to known populations of the Yakka Skink. The nearest records (Queensland Museum specimens from 1976 and 2000) of this species are from the vicinity of Blackwater, 130 km to the south. Furthermore, as no colonies have ever been recorded in the northern Bowen Basin, despite extensive ecological surveys undertaken across Dysart-Moranbah-Collinsville for various mining projects, colonies are not "likely to be found" in the vicinity of the Project. Consequently, no "important habitat" is located within the survey area.

Nevertheless, there are scattered records of Yakka Skinks as far north as Cape York, and there remains a slight possibility that the species occurs within the survey area. All remnant and regrowth vegetation within the survey area qualifies as "suitable habitat" for the species, as all contain woody debris and/or rocks that provide structural support for burrows.

4.3.2.7 Northern Quoll

The Northern Quoll inhabits a broad range of habitats across eastern and northern Australia. The *EPBC Act Referral Guideline for the Endangered Northern Quoll* (Department of the Environment 2016) defines critical habitat as "habitat within the modelled distribution of the northern quoll which provides shelter for breeding, and refuge from fire, predation and potential poisoning from Cane Toads". These can include rocky habitats, treed creek lines and structurally diverse forest with large trees, termite mounds and hollow logs (Department of the Environment 2016). The survey area occurs within the modelled distribution of the Northern Quoll (Department of the Environment 2016). Within the survey area, critical habitats were found on land zones 3 and 10 (3,043.2 ha within the survey area). Land zone 10, particularly in the northwest of the survey area, contained boulder-strewn escarpments and gorges, which are potentially important for Northern Quolls (Pollock 1999; Woinarski *et al.* 2008; Hill and Ward

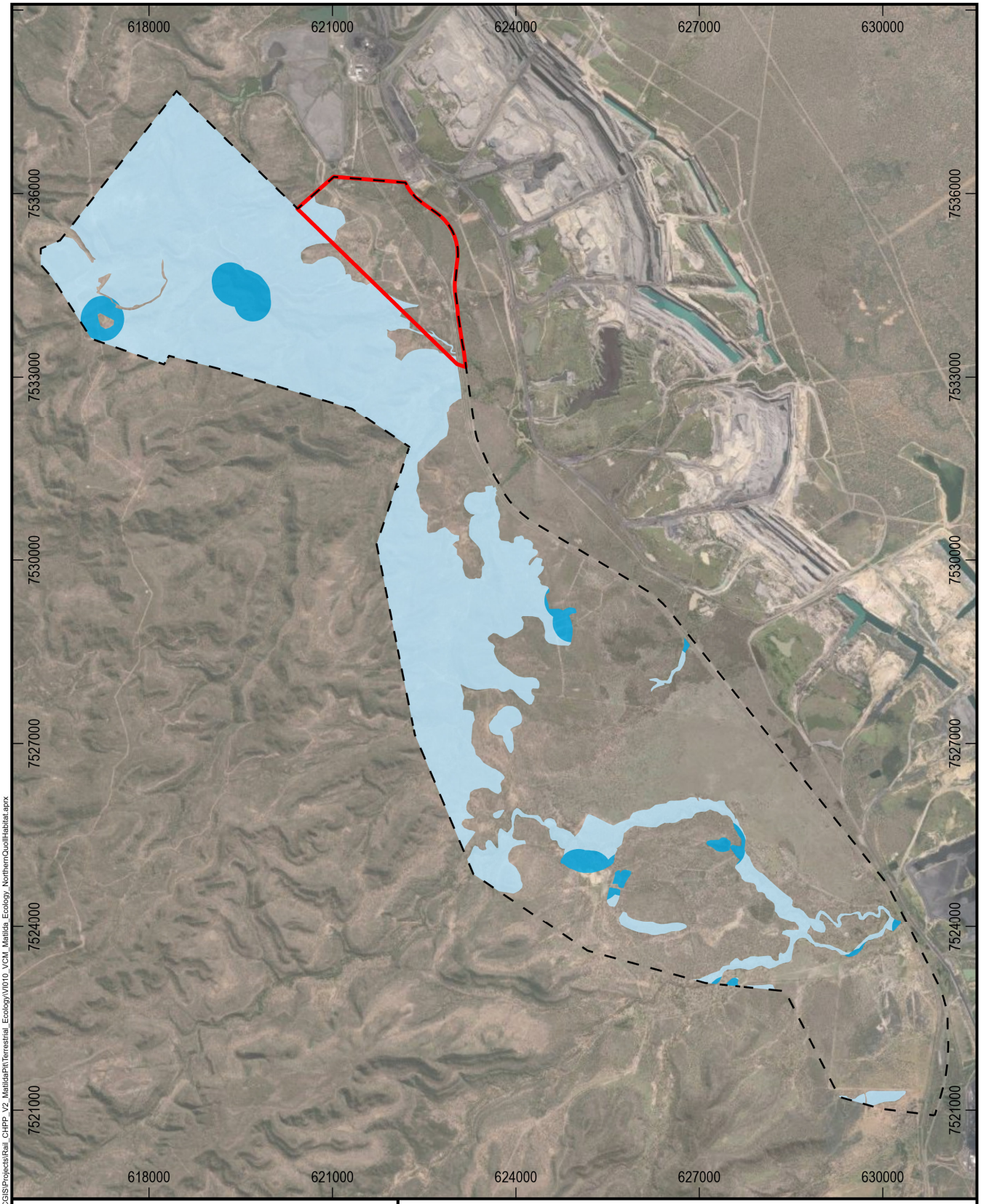
2010). Den sites close to (within 300 m of) permanent fresh water are preferred by the species (Pollock 1999); such sites were very scarce within the survey area (**Figure 4-14**).

The two major threats to Northern Quolls (Feral Cats and Cane Toads: Hill and Ward 2010) were common and widespread across the survey area.

The *EPBC Act Referral Guideline for the Endangered Northern Quoll* (Department of the Environment 2016) recommends a minimum of ten baited remote-sensory cameras to be deployed for four nights each (total of 40 camera-nights). The current survey included 122 camera-nights of sampling, in addition to 31 trap-nights of cage trapping. These surveys failed to detect any Northern Quolls.

In recent decades, the Queensland distribution of the Northern Quoll has contracted towards the most rugged habitats close to the coast (Braithwaite and Griffiths 1994; Woinarski *et al.* 2008). The nearest recent (post-2000) records of the Northern Quoll are from the Clarke Range, 100 km northeast of the survey area. No Northern Quolls have been detected at neighbouring mines within the Bowen Basin.

The lack of nearby records despite extensive ecological surveys undertaken in the Moranbah region in recent decades may suggest that the Northern Quoll is extinct in the region. Nevertheless, as the habitat present on site meets the criteria specified in the *EPBC Act Referral Guideline for the Endangered Northern Quoll*, the presence of the species within the survey area remains a possibility. If present, the local population is expected to be of very low density, given the lack of detection, abundance of toads and cats, and the relative paucity of surface water in rocky areas.



Legend

- Survey Area
- ML 700060

Potential Northern Quoll Habitat

- Habitat Within 300m of Water
- Landzone 3 and 10

Source: Vitrinite 2022, METServe 2020-2022, Earthstar Geographics.

Vulcan Coal Mine Amendment

Potential Northern Quoll Habitat

0 1.5 3

Kilometers

Scale: 1:90,000 (A4)

14/06/2022

Datum: GDA2020
Projection: MGA55

FIGURE 4-14

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\Terrestrial_Ecology\VI010_VCM_Matilda_Ecology_NorthernQuollHabitat.aprx

4.3.2.8 Australian Painted-snipe

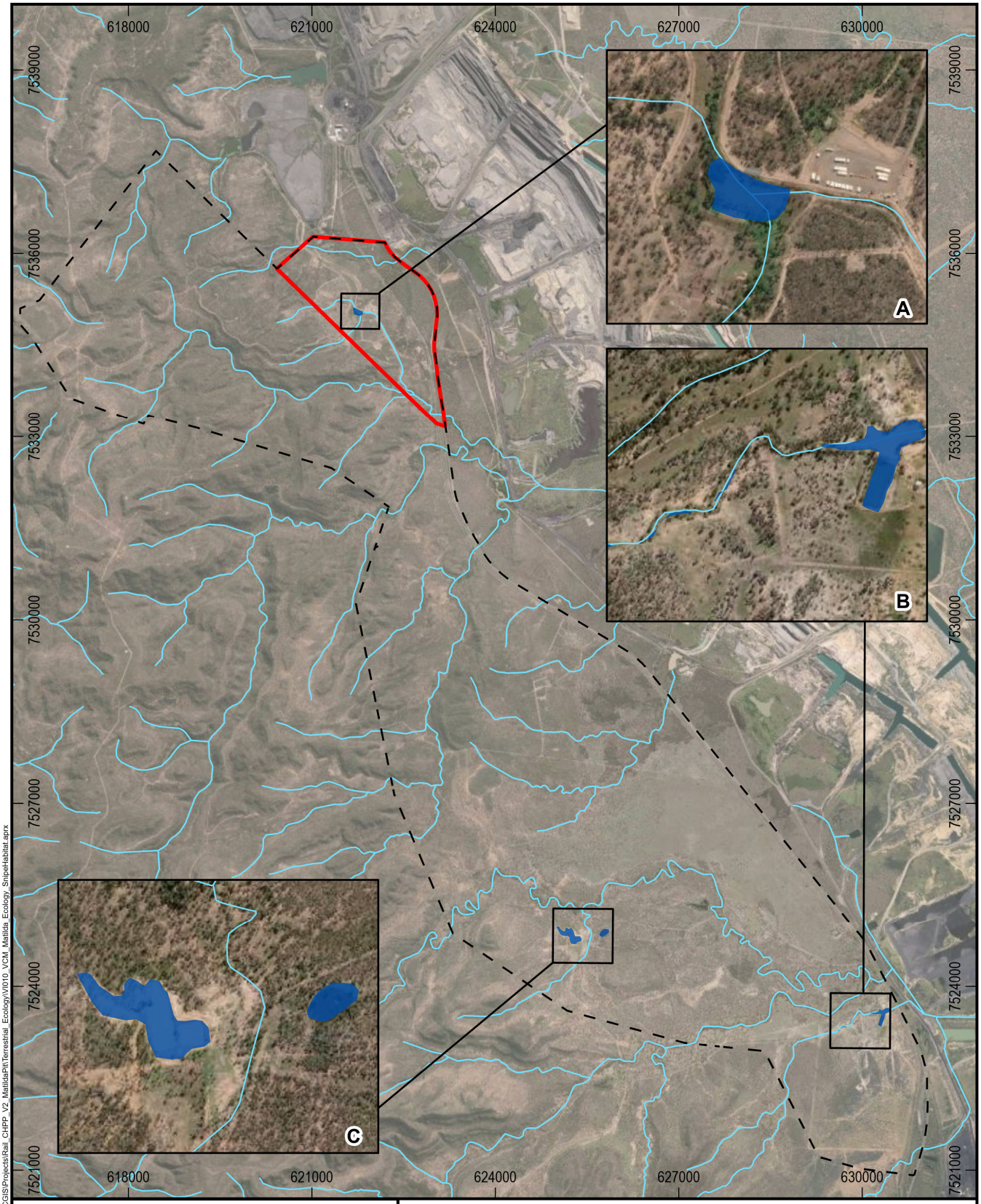
The Australian Painted-snipe is a nomadic shorebird that is an endangered species under the EPBC Act. This species was not recorded within the survey area. There are also very few records of the species from the region, and none of these are recent; it was recorded from near Moranbah on a couple of occasions prior to 1976 (per BirdLife Australia's historical bird atlas). Nevertheless, as this is a secretive, highly mobile species and potential habitat occurs in the vicinity of the project, it is considered a possible visitor to the survey area.

There is no recovery plan in place for the species. However, the Commonwealth Government has provided advice about the species' ecology and priority actions to mitigate key threats within the conservation advice (Threatened Species Scientific Committee 2013) and the SPRAT profile for the species (Department of Climate Change, Energy, the Environment and Water 2022f).

The Australian Painted Snipe generally inhabits shallow terrestrial freshwater (occasionally brackish) wetlands, including temporary and permanent lakes, swamps and claypans (Department of Climate Change, Energy, the Environment and Water 2022f). Favoured wetlands have muddy shorelines and margins of rank grass, sedges, rushes, reeds, samphire, lignum (*Muehlenbeckia*), canegrass or sometimes tea-tree (*Melaleuca*) (Department of Climate Change, Energy, the Environment and Water 2022f). The Australian Painted Snipe can use modified habitats, including farm dams; however, they do not necessarily breed in such habitats (Department of Climate Change, Energy, the Environment and Water 2022f). Nest records are all, or nearly all, from or near small islands in freshwater wetlands, provided that these islands are a combination of very shallow water, exposed mud, dense low cover and sometimes some tall dense cover (Department of Climate Change, Energy, the Environment and Water 2022f).

Potential habitat for the Australian Painted Snipe was recorded at natural and artificial (dams) wetlands in the southern third of the survey area (**Figure 4-15**). In addition, a small dam in the project area also possessed margins vegetated with suitable sedges and rushes, but the steep banks lacking areas of shallow mud limit the suitability of this habitat for Australian Painted-snipe.

One of the habitats within the survey area contains a small island, which has potential as a nest site for Australian Painted-snipe (inset 3 in **Figure 4-15**). This wetland lies outside the project area. The Australian Painted Snipe is highly mobile and is considered to occur in a single, contiguous breeding population (Department of Climate Change, Energy, the Environment and Water 2022f). Small numbers (singles or small groups) possibly utilise habitat within the project area for short periods during transit through the region.



Legend

- Drainage Lines
- Survey Area
- ML 700060
- Potential Australian Painted-snipe Habitat

Source: Vitrinite 2022, METServe 2020-2022, Maxar, Earthstar Geographics.

Vulcan Coal Mine Amendment

Potential Habitat for Australian Painted-snipe

0 1.5 3

Kilometers

Scale: 1:90,000 (A4)

14/06/2022

Datum: GDA2020
Projection: MGA55

FIGURE 4-15

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\Terrestrial_Ecology\VI010_VCM_Matilda_Ecology_SnipeHabitat.aprx

4.3.2.9 Red Goshawk

The Red Goshawk is a bird-eating hawk listed as vulnerable under the EPBC Act. There is a recovery plan in place for the species (Department of Environment and Resource Management 2012).

The Red Goshawk formerly had a wide distribution across northern and eastern Australia, occupying a variety of forested environments, but favouring the ecotone between dense forest and open woodland, especially near rivers and wetlands. In partly cleared parts of eastern Queensland it is associated with gorge and escarpment country (Threatened Species Scientific Committee 2015b). Within the last two decades, it has largely disappeared from the southern half of its former distribution. Since 2000, there have been very few (possibly no) confirmed records within New South Wales, where it is listed as critically endangered (NSW Scientific Committee 2008). Likewise, over the past 20 years in Queensland there are very few records of the species south of Townsville. The Birdata database lists a single record (from Main Range, southeast Queensland, in 2000), while the eBird database contains a single record (from Maryborough, in 2005). Neither record is supported by photographic evidence. A total of 10 Queensland records south of Townsville since 2000 are listed within the Wildnet database, without details to assess their validity. Given the propensity for misidentification of the species (Department of Environment and Resource Management 2012), it is likely that many of these records are erroneous. Some of the records (especially those older than ten years) are undoubtedly authentic, given that at least three nests were known in southeast Queensland between 2001 and 2003 (Czechura *et al.* 2010). However, extensive targeted surveys at the same locations between 2013 and 2014 failed to find any Red Goshawks (Seaton 2014).

The survey area occurs within the historical distribution of the Red Goshawk. Potential habitat for the species occurs on site, although it is not of high quality; escarpments and nearby waterways mostly lack surface water, dense forest is lacking, and the surrounding landscape is highly modified through mining and clearing for grazing. The Red Goshawk rarely breeds in areas with fragmented native vegetation (Threatened Species Scientific Committee 2015b), and never more than 1 km from water.

While it is considered possible that dispersing Red Goshawks may occasionally use the survey area, the importance of the site to the species is considered to be low.

4.3.2.10 Annual Wiregrass

The Annual Wiregrass (*Aristida annua*) is thought to be restricted to the black clay soils of central Queensland (Simon 1984), where almost all herbarium specimens have been collected. These soils are mostly derived from basalt and support native grasslands or open woodlands dominated by *Eucalyptus orgadophila, Eucalyptus crebra* or *Eucalyptus melanophloia*. One specimen (held at the Queensland Herbarium) was anomalously collected by D. Osten "on a ridge...[with] sandy red loam". However, according to regional ecosystem mapping, the collection location falls within land zone 8 (clay soil derived from basalt), and the habitat reported is probably erroneous.

No basalt-derived soil exists within the survey area, but black clay soils derived from fine-grained sedimentary rock occur on site and support similar vegetation communities (regional ecosystem 11.9.2). However, these areas were heavily degraded by grazing, with the exotic pasture grass *Bothriochloa pertusa* comprising more than 90% of the vegetation cover. No areas dominated by native grasses were observed on clay soil.

No Annual Wiregrass was recorded during flora surveys. Elsewhere in central Queensland, the species has been collected in flower (when easiest to detect and identify) between February and June. The survey period coincided with the start of this period. Given the early start to the 2018-2019 growing season (e.g., heavy rain commenced in October 2018), and the abundance of flowering annual grasses of other species recorded in February 2019 and March 2020, it is expected that, if present, Annual Wiregrass would have been flowering and readily detectable at the time of survey.

The survey area lies outside the known distribution of Annual Wiregrass, and outside the modelled map of where the "species or species habitat may occur" (Department of Climate Change, Energy, the Environment and Water 2022g). However, the nearest record is only 35 km southwest of the survey

area. Given that potential habitat for this threatened grass exists within the survey area, its occurrence on site is considered possible. However, based on the highly degraded nature of the habitat present, the survey area is likely to be of negligible importance to the species. Furthermore, the species is highly unlikely to be present on the sandy soils of the project area.

4.3.2.11 Ghost Bat

Ghost Bats are large, carnivorous bats whose distribution is primarily limited by suitable roost sites. Ghost bats roost and breed in caves that comprise a small entrance hole and a large chamber, where conditions remain warm and humid year-round (Toop 1985; Armstrong and Anstee 2000). Roost sites are often 30-50 m deep within the cave, where conditions are most stable (Armstrong and Anstee 2000). However, smaller caves may be used transiently (Armstrong and Anstee 2000). Ghost Bats move between a number of caves seasonally or as dictated by weather conditions, and require a range of cave sites. Ghost Bats also colonise disused mines, especially those that are deep and complex, with an isothermal zone (Armstrong and Anstee 2000).

Ghost Bats forage in a wide range of native vegetation types. Foraging areas average 61 ha in size, and are generally within 1-10 km of roost sites (Tideman *et al.* 1985; Diete *et al.* 2016).

Suitable roost sites are scarce across eastern Queensland. There are only two known breeding colonies of Ghost Bats in central eastern Queensland: at Rockhampton and Cape Hillsborough. Genetic studies indicate that these populations are isolated from other populations and each other (Worthington Wilmer *et al*. 1999). This suggests a general lack of suitable breeding habitat elsewhere in central eastern Queensland (Worthington Wilmer *et al*. 1999). Ghost Bats may disperse in winter 20-50 km from the maternity roosts (Toop 1985), and the closest record of a dispersing individual (presumably from Cape Hillsborough) is at the Clarke Range (80 km northeast of the survey area).

The survey area is well outside the known winter dispersal and foraging zones of the two central Queensland populations of Ghost Bats. However, given that the existence of unknown breeding sites is possible, and the proliferation of mining across the Bowen Basin may have inadvertently created new roosting habitats (in disused mines), it is considered possible that the survey area may be used intermittently by Ghost Bats. This use would solely be in a foraging capacity, as none of the sandstone ridges on site supported caves of a size and structure suitable as a roost site. No Ghost Bats were recorded during surveys.

4.3.2.12 Dunmall's Snake

The Dunmall's Snake is poorly known and rarely recorded. The species inhabits a variety of wooded habitats, ranging from *Acacia harpophylla* on cracking clay soil to *Corymbia citriodora, Eucalyptus crebra* and *Eucalyptus melanophloia* open forest on sandstone-derived soil (Department of Climate Change, Energy, the Environment and Water 2022h). In the *Draft Referral Guidelines for the Nationally Listed Brigalow Belt Reptiles*, important habitat for the species is defined as any forest or woodland "within the 'Known/Likely to occur' modelled distribution of the species…and any habitat corridors in between" Department of Sustainability, Environment, Water, Population and Communities 2011). Despite containing potential habitat for the species, the survey area lies outside the known/likely distribution of the Dunmall's Snake, as modelled in the *Draft Referral Guidelines for the Nationally Listed Brigalow Belt Reptiles*. It is, therefore, not considered "important habitat" for the species. Nevertheless, the survey area lies within the modelled "may occur" zone, and given the difficulty associated with detecting this highly cryptic species, its presence on site is considered possible. No Dunmall's Snakes were detected during surveys. The nearest record is from Clermont, 80 km southwest of the survey area. The species has never been recorded in the Dysart-Moranbah region, despite extensive ecological survey effort at other mine sites. Given the absence of local records despite targeted searches undertaken for the VCM and numerous neighbouring mining operations, it is considered unlikely that the species occurs locally.

4.3.2.13 Allan's Lerista

Allan's Lerista is a skink that is confined to black soil downs (undulating plains formed primarily on basalt) in the vicinity of Clermont. It burrows within the upper profile of heavy clay soil under tussocks

of grass (Department of Climate Change, Energy, the Environment and Water 2022i). It is typically recorded from *Eucalyptus orgadophila* and *Corymbia erythrophloia* open woodlands (Department of Climate Change, Energy, the Environment and Water 2022i).

No Allan's Leristas were found during surveys. The nearest known population to the survey area is 30 km west. However, it is separated from the survey area by a 130-km long sandstone range, which likely constitutes an important barrier to dispersal. The species has never been recorded east of this range.

The *Draft Referral Guidelines for the Nationally Listed Brigalow Belt Reptiles* (Department of Sustainability, Environment, Water, Population and Communities 2011) defines suitable habitat for the species as being regional ecosystems 11.8.5 and 11.8.11, both of which are lacking from the survey area. Nevertheless, regional ecosystem 11.9.2 (*E. orgadophila* open woodland on soil derived from fine-grained sedimentary rock) occurs on site, and closely resembles 11.8.5 in its floristics and soil attributes. Furthermore, models within the *Draft Referral Guidelines for the Nationally Listed Brigalow Belt Reptiles* indicate that the species may occur within the survey area, despite the site being outside the modelled "known/likely to occur" zone. No 11.9.2 or clay soil occurs within the project area, and it is highly unlikely that Allan's Leristas occur there.

A total of four trap sites were installed in the only patch of potential habitat located within the survey area (three in remnant 11.9.2 and one in cleared 11.9.2), which is twice the sample effort recommended by the *Draft Referral Guidelines for the Nationally Listed Brigalow Belt Reptiles*.

Taking into account the known distribution of the species and the search effort conducted to date, it is unlikely that Allan's Lerista occurs within the survey area.

4.3.2.14 King Blue-grass

King Blue-grass (*Dicanthium queenslandicum*) inhabits native grasslands and open woodlands on black cracking clay soil derived from basalt. The species also colonises pastures established following the clearance of *Acacia harpophylla* and other dense vegetation communities growing on heavy clay soil. King Blue-grass cannot tolerate continual heavy stocking regimes, and is outcompeted by exotic grass species and weeds, which tend to dominate heavily grazed pastures (Fensham 1999). For this reason, most extant populations are confined to road reserves and other sites semi-protected from grazing livestock.

Heavy clay soils supporting grasses are represented within the survey area by remnant regional ecosystem 11.9.2 and cleared pastures that formerly supported regional ecosystem 11.4.9. Neither habitat is present within the project area. Both habitats have been subjected to long periods of heavy grazing. This has led to the almost complete replacement of native perennial grasses with the exotic *Bothriochloa pertusa.* Road verges protected from grazing livestock were dominated by other weed grasses, such as *Cenchrus ciliaris, Megathyrsus maximus, Chloris* spp. and *Hyparrhenia rufa*. Nowhere within the survey area were clay soils observed to support a native grassland community.

The nearest recorded King Blue-grass is in the vicinity of Moranbah Airport, 30 km north of the survey area. While the species possibly once inhabited the survey area, its continued existence is unlikely considering current grazing regimes. The survey area lies just outside the Department of Climate Change, Energy, the Environment and Water's (2022j) modelled "may occur" range of the species.

4.3.2.15 Hairy Bluegrass

Hairy Bluegrass (*Dicanthium setosum*) is associated with heavy basaltic black soils and red-brown loams with clay subsoil (Department of Climate Change, Energy, the Environment and Water 2022k). It is tolerant of a moderate amount of disturbance, but excessive grazing and invasion by exotic grasses threatens the species (Department of Climate Change, Energy, the Environment and Water 2022k). All clay soils within the survey area were dominated by the exotic pasture grass *Bothriochloa pertusa*. No native grass communities were observed on clay within the survey area.

Hairy Bluegrass has a patchy distribution across subcoastal eastern Australia. Based on herbarium records, there appears to be a 280 km gap between known populations at Springsure and Glenden. The survey area occurs within this gap; the nearest known record is 95 km to the north.

The survey area lies just outside the Department of Climate Change, Energy, the Environment and Water's (2022k) modelled "may occur" range of the species. Despite potential habitat occurring on site, the lack of local records and the heavily degraded nature of the available habitat suggest that the survey area is not important for the Hairy Bluegrass. No potential habitat (i.e, clay soil) exists within the project area.

4.3.3 Migratory Species

Migratory species listed in the following international agreements are protected under the EPBC Act as matters of national environmental significance:

- Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention);
- China-Australia Migratory Bird Agreement;
- Japan-Australia Migratory Bird Agreement; and
- Republic of Korea-Australia Migratory Bird Agreement.

Two listed migratory species, the Rufous Fantail and White-throated Needletail, were detected within the survey area. Two additional species (Fork-tailed Swift and Latham's Snipe) are likely visitors, and an additional six species (Sharp-tailed Sandpiper, Oriental Cuckoo, Gull-billed Tern, Black-faced Monarch, Satin Flycatcher, Glossy Ibis) are possible visitors (**Table 4-6**).

The survey area (and the project area within it) contains important habitat for the Rufous Fantail, Oriental Cuckoo and Satin Flycatcher, according to definitions of the Department of the Environment (2015a). However, for no migratory species does the survey area contain "important habitat" that supports an "ecologically significant proportion of the population", as defined by the *Matters of National Environmental Significance: Significant Impact Guidelines 1.1* (Department of the Environment 2013), *Referral Guidelines for 14 Birds Listed as Migratory Species under the EPBC Act* (Department of the Environment 2015a) and *Industry Guidelines for Avoiding, Assessing and Mitigating Impacts on EPBC Act Listed Migratory Shorebird Species* (Department of Environment and Energy 2017). Each species is discussed further in the following sub-sections.

Table 4-6 Migratory species flagged by database searches as potentially occurring in or near the survey area

Taxon	Species	Common Name	EPBC status*	NC status†	Habitat requirements	Presence in survey area‡	Presence in project area‡
Bird	*Hirundapus caudacutus*	White-throated Needletail	V/M	V	Airspace containing flying insects, above a diversity of landscapes.	C	C
Bird	*Rhipidura rufifrons*	Rufous Fantail	M	SL	Dense woody vegetation, including vine thickets, paperbark forests and rainforest.	C	L
Bird	*Apus pacificus*	Fork-tailed Swift	M	SL	Almost exclusively aerial, foraging on flying insects above all habitat types.	L	L
Bird	*Gallinago hardwickii*	Latham's Snipe	M	SL	Freshwater wetlands with well-vegetated muddy edges.	L	L
Bird	*Cuculus optatus*	Oriental Cuckoo	M	SL	Primarily coastal forest and woodland. Rarely moves inland west of the coastal ranges.	P	P
Bird	*Monarcha melanopsis*	Black-faced Monarch	M	SL	Typically associated with rainforest. Migrating individuals may utilise dense riparian vegetation.	P	P
Bird	*Myiagra cyanoleuca*	Satin Flycatcher	M	SL	Tall wet forests of the coast and nearby ranges. Vagrant individuals may occasionally occur inland, where they are most likely in denser forests (e.g., along waterways).	P	P
Bird	*Plegadis falcinellus*	Glossy Ibis	M	SL	Shallow, marshy edges of large freshwater wetlands.	P	U
Bird	*Calidris acuminata*	Sharp-tailed Sandpiper	M	SL	Estuarine and freshwater wetlands with extensive shallow, muddy margins.	P	U
Bird	*Gelochelidon nilotica*	Gull-billed Tern	M	SL	Primarily a coastal species. Can occur at inland lakes.	P	U
Bird	*Actitis hypoleucos*	Common Sandpiper	M	SL	Inhabits primarily tidal rivers and rocky foreshores. Occasionally uses the edges of inland wetlands.	U	U
Bird	*Calidris ferruginea*	Curlew Sandpiper	CE/M	E	Primarily coastal mudflats, but occasionally also uses the muddy margins of large freshwater wetlands.	U	U
Bird	*Calidris melanotos*	Pectoral Sandpiper	M	SL	Estuarine and freshwater wetlands with extensive shallow, muddy margins.	U	U
Bird	*Motacilla flava*	Yellow Wagtail	M	SL	The shallow, muddy edges of wetlands. Primarily a coastal species.	U	U
Bird	*Pandion haliaetus*	Osprey	M	SL	Restricted to coastlines, estuaries and large inland rivers/lakes.	U	U
Bird	*Phaethon rubricauda*	Red-tailed Tropicbird	M	SL	A marine species that has only been recorded near the survey area following a cyclone.	U	U
Bird	*Tringa nebularia*	Common Greenshank	M	SL	Primarily coastal, but occasionally also uses the muddy margins of large freshwater wetlands.	U	U

Taxon	Species	Common Name	EPBC status*	NC status†	Habitat requirements	Presence in survey area‡	Presence in project area‡
Bird	*Tringa stagnatilis*	Marsh Sandpiper	M	SL	Muddy margins of shallow fresh or brackish water.	U	U

*Status under the *Environment Protection and Biodiversity Conservation Act 1999*: CE = critically endangered, V = vulnerable, M = migratory.

†Status under the *Nature Conservation Act 1992*: E = endangered, V = vulnerable, SL = special least concern.

‡Presence within survey area in which the project is contained: C = presence confirmed, L = likely to be present, P = possibly present, U = unlikely to be present.

4.3.3.1 Rufous Fantail

Rufous Fantails are migratory birds protected under the Bonn Convention and the EPBC Act. In Queensland, they are also listed as Special Least Concern under the *Nature Conservation (Wildlife) Regulation 2006*.

Rufous Fantails pass through the project area during transit in spring and autumn. The species lives primarily along the east coast and nearby ranges, in rainforest and wet eucalypt forests with a dense, shrubby midstorey. During migration, they can inhabit drier woodlands further west. Two individuals were recorded within the survey area in September-October 2019: one within vine-thicket and the other within dense *Acacia* regrowth (**Figure 4-16**). The subspecies of these individuals is not known, but given the suboptimal habitat usage, these were likely to be migrants. Therefore, they belonged either to *Rhipidura rufifrons rufifrons* (south-eastern Australian subspecies) or migratory sub-populations of *Rhipidura rufifrons intermedia* (Queensland subspecies).

It is likely that small numbers (5 to 10) pass through the survey area during each northward or southward migration. According to population estimates provided by the *Referral guideline for 14 birds listed as migratory species under the EPBC Act* (Department of the Environment 2015a), this constitutes a tiny fraction (0.001% to 0.002%) of the total population size of the subspecies involved.

Within the survey area, habitats possessing a dense midstorey of *Acacia, Melaleuca* or vine-thicket species are most likely to be used (**Figure 4-16**). In total, 2,453.3 ha of such habitat exist within the survey area. A total of 57.1 ha of potential habitat occur within the project area.

The survey area is of marginal significance for the Rufous Fantail, given that most of the population migrates through more coastal habitats further east (based on eBird and Atlas of Living Australia records). Breeding has never been recorded in dry habitats west of the coastal ranges in central Queensland (Barrett *et al.* 2003), and is not likely within the survey area.

4.3.3.2 White-throated Needletail

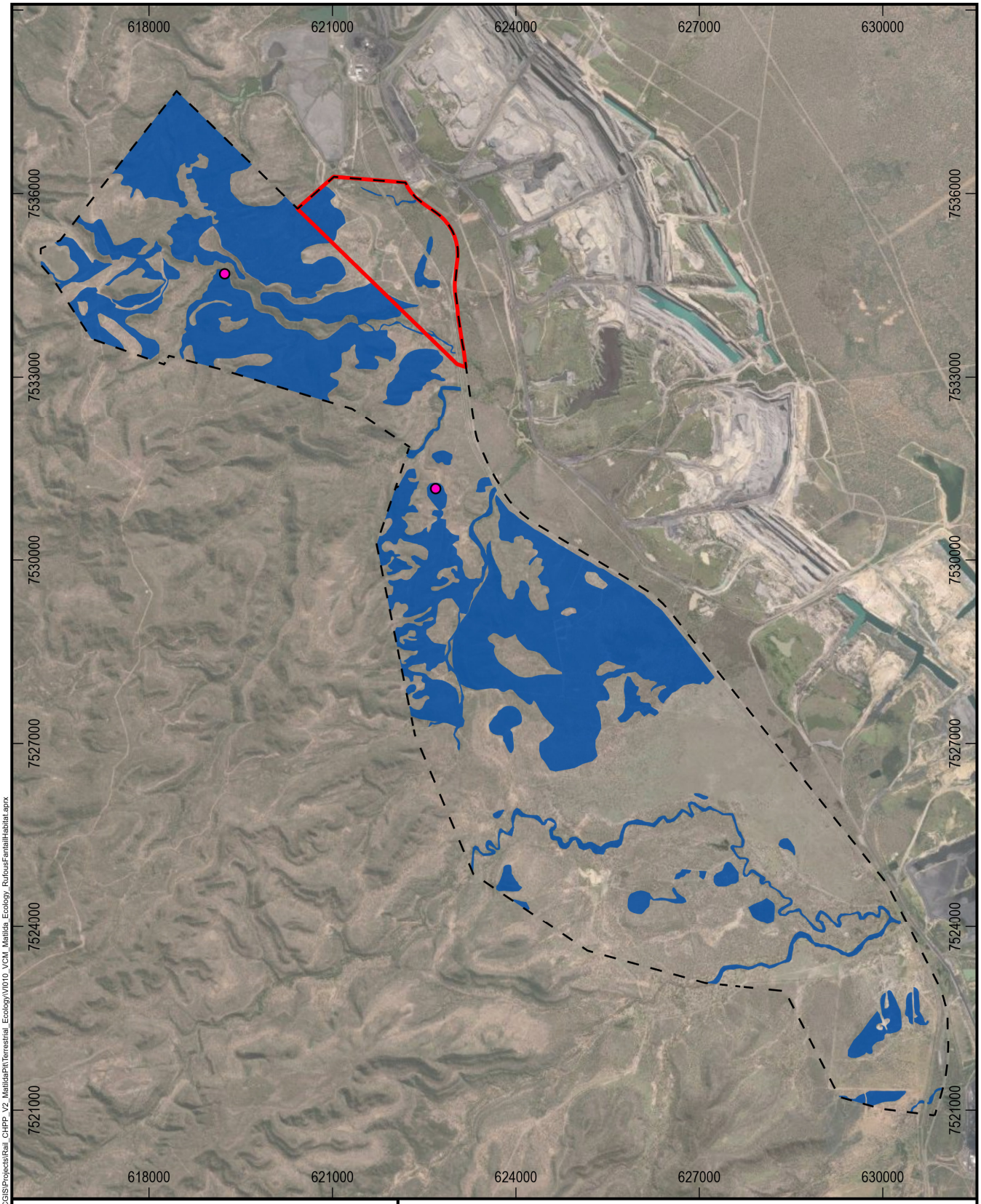
White-throated Needletails are migratory birds protected under the China-Australia Migratory Bird Agreement, Japan-Australia Migratory Bird Agreement, Republic of Korea-Australia Migratory Bird Agreement and EPBC Act. The species is also protected as a threatened species under the EPBC Act, and is discussed in detail within **Section 4.3.2.4**.

White-throated Needletails were recorded on site on a single occasion. The survey area is likely to be west of their primary migration route, but flocks occasionally feed in the area when drawn west by low pressure systems. The survey area is of no particular importance to the White-throated Needletail on a local or regional scale, and the project will not include any wind turbines, tall buildings, airports or other structures that threaten airspace used by the species for foraging and dispersal.

4.3.3.3 Fork-tailed Swift

Fork-tailed Swifts are migratory birds protected under the China-Australia Migratory Bird Agreement, Japan-Australia Migratory Bird Agreement, Republic of Korea-Australia Migratory Bird Agreement and EPBC Act. In Queensland, they are also listed as Special Least Concern under the *Nature Conservation (Wildlife) Regulation 2006.*

Fork-tailed Swifts visit Australia during their non-breeding season (the Austral summer). They are exclusively aerial, foraging for flying insects in airspace above most habitats, including cleared farmland. The species is ecologically similar to the White-throated Needletail, and the two species often flock together. The Fork-tailed Swift is the more likely of the two species to forage over inland plains. Flocks of Fork-tailed Swifts are highly mobile and don't remain long in any one location. While no Fork-tailed Swifts were recorded during ecological surveys, it is likely that passing flocks utilise the survey area briefly and intermittently during summer, but possibly not every year. The nearest record is from 45 km north of the survey area.



Legend

- Survey Area
- ML 700060
- Rufous Fantail Sighting
- Rufous Fantail Habitat

Source: Vitrinite 2022, METServe 2020-2022, Earthstar Geographics.

Vulcan Coal Mine Amendment

Rufous Fantail Habitat

0 1.5 3

Kilometers

Scale: 1:90,000 (A4)

14/06/2022

Datum: GDA2020
Projection: MGA55

FIGURE 4-16

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\Terrestrial_Ecology\VI010_VCM_Matilda_Ecology_RufousFantailHabitat.aprx

The survey area is of no particular importance to the Fork-tailed Swift on a local or regional scale, and the project will not include any wind turbines, tall buildings, airports or other structures that threaten airspace used by the species for foraging and dispersal.

4.3.3.4 Latham's Snipe

The Latham's Snipe is a shorebird with similar ecological requirements to the Australian Painted-snipe (see **Section 4.3.2.8**). Latham's Snipe are migratory birds protected under the Bonn Convention, Japan-Australia Migratory Bird Agreement, Republic of Korea-Australia Migratory Bird Agreement and EPBC Act. In Queensland, they are also listed as Special Least Concern under the *Nature Conservation (Wildlife) Regulation 2006.*

Latham's Snipe inhabit the muddy edges of freshwater and brackish wetlands where there exists abundant low, dense vegetation for shelter. Important habitat for Latham's Snipe is defined in the *Wildlife Conservation Plan for Migratory Shorebirds* (Department of the Environment 2015b) as "areas that have previously been identified as internationally important for the species, or areas that support at least 18 individuals of the species".

The Latham's Snipe was not recorded within the survey area, despite surveys coinciding with seasons when presence is most likely (August-April). Nevertheless, this is a cryptic species and small numbers may have gone undetected. Latham's Snipe commonly utilises relatively small farm dams, provided that its needs for a muddy substrate and vegetated margins are met. There are numerous records of the species within a 100 km radius of the survey area, in many cardinal directions.

Locations of potential habitat are as for the Australian Painted-Snipe (see **Figure 4-15**). None of these habitats are likely to support 18 individuals, and therefore do not qualify as important habitat.

4.3.3.5 Oriental Cuckoo

Oriental Cuckoos are migratory birds protected under the China-Australia Migratory Bird Agreement, Japan-Australia Migratory Bird Agreement, Republic of Korea-Australia Migratory Bird Agreement and EPBC Act. In Queensland, they are also listed as Special Least Concern under the *Nature Conservation (Wildlife) Regulation 2006.* No Oriental Cuckoos were recorded within the survey area. The nearest published record is 78 km northeast of the survey area.

Oriental Cuckoos visit Australia when not breeding in the Austral summer (November-April). When in Australia, Oriental Cuckoos typically inhabit monsoonal rainforest, vine thickets, wet sclerophyll forest and open woodlands. They typically favour riparian areas and other ecotones between dense forest and more open habitat.

Most eastern Australian records are along the coast or sub-coastal ranges, with very few sightings further than 100 km from the coast. All inland records listed in eBird are in the vicinity of watercourses, corresponding with the species' preference for denser forests. The survey area lies 135 km from the coast. Occasional individuals may stray to the survey area, where they are most likely to occur along forested watercourses.

A nationally important, ecologically significant proportion of the species' population is described by the former Department of the Environment (2015a) as 1,000 individuals. No more than one or two Oriental Cuckoos are expected to utilise the survey area in any one 12-month period.

4.3.3.6 Black-faced Monarch

Black-faced Monarchs are migratory birds protected under the Bonn Convention and EPBC Act. In Queensland, they are also listed as Special Least Concern under the *Nature Conservation (Wildlife) Regulation 2006.*

Black-faced Monarchs breed in rainforest and wet sclerophyll forest, especially in mountainous areas, sheltered gullies and slopes with a dense understorey of ferns and/or shrubs. In central Queensland, migrating individuals are rarely observed in drier woodlands further than 100 km from the coast. No Black-faced Monarchs were recorded within the survey area, although there is a published record (from

1999) at the adjacent Peak Downs Mine. As the survey area is west of their primary migration route, it does not contain important habitat for the Black-faced Monarch.

4.3.3.7 Satin Flycatcher

Satin Flycatchers are migratory birds protected under the Bonn Convention and EPBC Act. In Queensland, they are also listed as Special Least Concern under the *Nature Conservation (Wildlife) Regulation 2006.*

Satin Flycatchers breed in tall, wet sclerophyll forest at high altitudes in southeastern Australia and winter at rainforest edges in north Queensland and New Guinea. The survey area lies outside the known breeding and wintering range of the species. Most records of migrating individuals are along the coast and sub-coastal ranges, but occasional records occur in drier woodlands further west. No Satin Flycatchers were recorded within the survey area. The nearest published record is from 63 km southeast of the survey area.

Most inland records listed in eBird occur in September-October or February-March, coinciding with southward and northward migration. While the survey area is west of their primary migration route, small numbers (fewer than five) may pass through annually in a transient capacity. The survey area does not support a nationally important, ecologically significant proportion (defined by the former Department of the Environment (2015a) as 1,700 individuals) of the population at any time.

4.3.3.8 Glossy Ibis

The Glossy Ibis is a migratory bird protected under the Bonn Convention and EPBC Act. In Queensland, it is also listed as Special Least Concern under the *Nature Conservation (Wildlife) Regulation 2006.*

Glossy Ibis inhabit the shallow, muddy edges of lakes, wet, marshy areas, and flooded pastures with short vegetation. The natural wetlands present on site are too small and/or are too heavily treed to provide favourable habitat for the Glossy Ibis. However, two dams constitute marginal habitat that may be used briefly under optimal weather conditions (i.e., when water levels are optimal). Both of these dams are located in the southern half of the survey area (refer to inset 2 and 3 on **Figure 4-2**). The small dam within the project area is unlikely to be suitable for this species, as it lacks favourable, marshy margins. None of the habitat present within the survey area is considered important for the Glossy Ibis. No Glossy Ibis were recorded within the survey area, but the species has been recorded at the adjacent Peak Downs Mine.

4.3.3.9 Sharp-tailed Sandpiper

The Sharp-tailed Sandpiper is a migratory bird protected under the Bonn Convention, China-Australia Migratory Bird Agreement, Japan-Australia Migratory Bird Agreement, Republic of Korea-Australia Migratory Bird Agreement and EPBC Act. In Queensland, it is also listed as Special Least Concern under the *Nature Conservation (Wildlife) Regulation 2006.*

No Sharp-tailed Sandpipers were recorded within the survey area, but there is a nearby record from Peak Downs Mine in 2001. They are likely to be occasional summer visitors to suitable habitat within the survey area.

Sharp-tailed Sandpipers depend on open wetlands with shallow, muddy margins and often short, damp vegetation. The natural wetlands present on site are too small and/or are too heavily treed to provide favourable habitat for this species. However, two dams constitute marginal habitat that may be used briefly under optimal weather conditions (i.e., when retreating water levels expose muddy banks). Both of these dams are located in the southern half of the survey area (see inset 2 and 3 in **Figure 4-2**). No suitable habitat is found within the project area. None of the habitat present within the survey area is considered important for the Sharp-tailed Sandpiper.

4.3.3.10 Gull-billed Tern

The Gull-billed Tern is a migratory bird protected under the China-Australia Migratory Bird Agreement and EPBC Act. In Queensland, it is also listed as Special Least Concern under the *Nature Conservation (Wildlife) Regulation 2006.*

Gull-billed Terns forage over coastal estuaries and large inland lakes and wetlands for fish. All water bodies within the survey area are too small to be favourable for the species, although the two largest dams in the southern part of the survey area (see inset 2 and 3 on **Figure 4-2**) may be used for brief periods by transient individuals. The dam within the project area is too small to be utilised by Gull-billed Terns. The species has been recorded (in 1999) at the adjacent Peak Downs Mine, which contains larger dams than are present within the survey area. None of the habitat present within the survey area is considered important for the Gull-billed Tern.

4.4 STATE ENVIRONMENTAL SIGNIFICANCE

Matters of state environmental significance are defined in the *State Planning Policy 2017.* Each of these are summarised below, with respect to the project.

4.4.1 Protected Areas

No national parks, conservation parks, resource reserves, special wildlife reserves, nature refuges or coordinated conservation areas are located in or near the survey area.

4.4.2 Marine Matters

No marine parks, marine plants or fish habitat protected under the *Fisheries Act 1994*, *Fisheries Regulation 2008* or the *Marine Parks Act 2004* is contained in the survey area.

4.4.3 Designated Precinct in Strategic Environmental Areas

No strategic environmental areas are listed for the Isaac Regional Council area.

4.4.4 Wetlands and Watercourses

No wetlands or watercourses of high ecological significance are located within the survey area.

4.4.5 Secured Offset Areas

No legally secured offset areas from other projects are located in or near the survey area.

4.4.6 Regulated Vegetation

The following regulated vegetation under the *Vegetation Management Act 1999* (VM Act) is classed as a matter of state environmental significance in the *State Planning Policy 2017*:

(i) category B areas (regional ecosystems) on the regulated vegetation management map that are 'endangered' and 'of concern' regional ecosystems;

(ii) category C areas (regrowth) on the regulated vegetation management map that are 'endangered' and 'of concern' regional ecosystems;

(iii) category R areas (non-remnant vegetation within 50 m of watercourses) on the regulated vegetation management map;

(iv) areas of essential habitat on the essential habitat map for wildlife prescribed as 'endangered wildlife' or 'vulnerable wildlife' under the *Nature Conservation Act 1992*;

(v) category A, B, C or R areas on the regulated vegetation management map that are located within a defined distance from the defining banks of a relevant watercourse identified on the vegetation management watercourse and drainage feature map; and

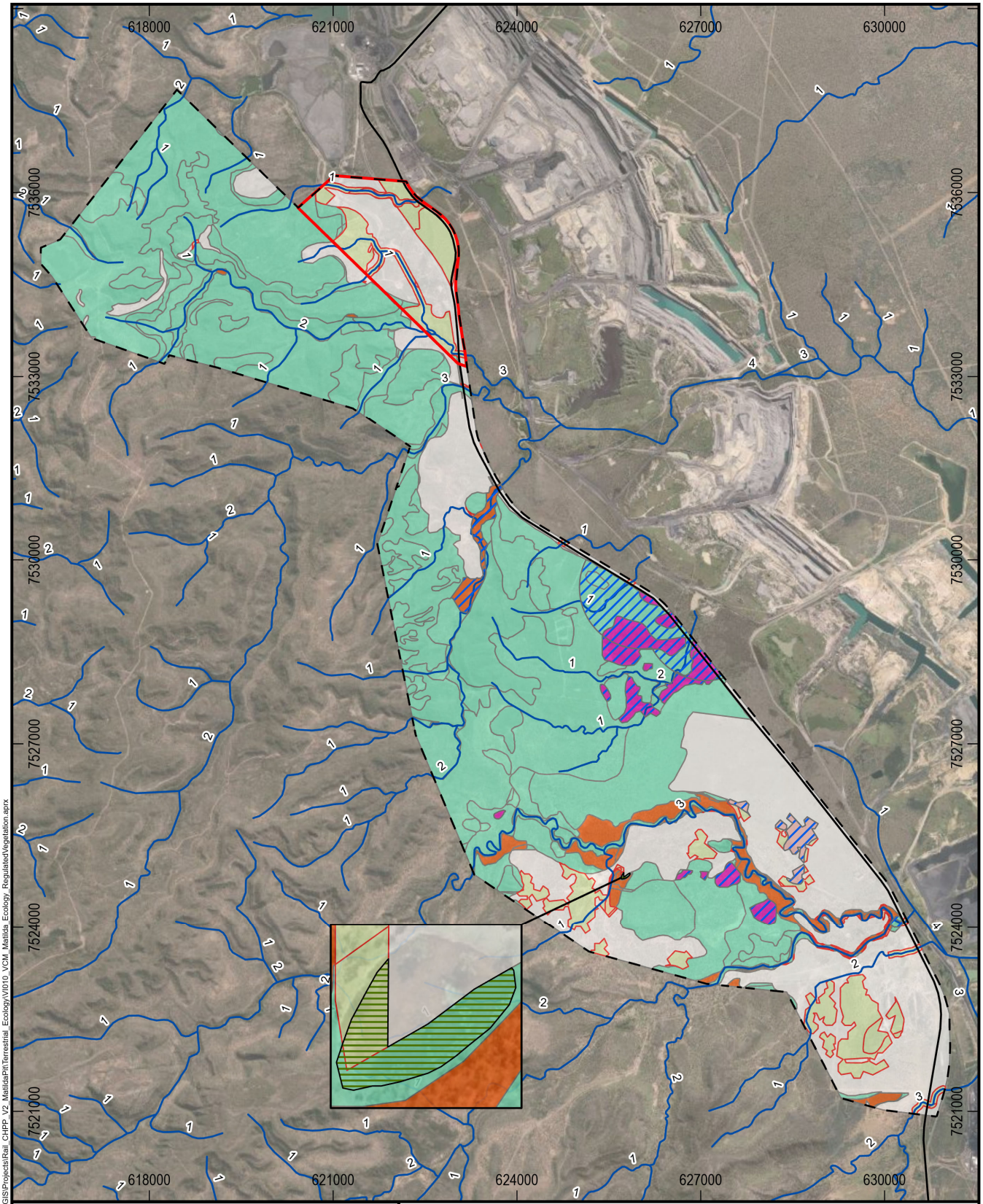
(vi) category A, B, C or R areas on the regulated vegetation management map that are located within a wetland or within 100 metres from the defining bank of a wetland identified on the vegetation management wetlands map.

The regulated vegetation management map, on which the above definitions of regulated vegetation are based (**Figure 4-17**), differs slightly from the field-verified regional ecosystem map. The main differences reflect the extent of regrowth (categories C and R) versus cleared areas (category X). On the regulated vegetation management map, these boundaries are primarily a legacy of a historical property map of assessable vegetation (PMAV). Despite the field-verified regional ecosystem map being a better reflection of what is present on site (hence why it is used for all habitat assessments and calculations for threatened species), the units on the regulated vegetation management map are what is protected under the VM Act. The regulated vegetation contained in the survey area is presented in **Table 4-7**.

Table 4-7 Regulated vegetation constituting MSES

Vegetation Type	Constituent REs	Total Area within the Survey Area	Total Area within the Project Area
Endangered and of concern regional ecosystems (category B)	11.3.2 (of concern) 11.4.8 (endangered) 11.4.9 (endangered) 11.10.8 (of concern) **Total**	177.7 ha 135.8 ha 17.2 ha 2.4 ha **333.0 ha**	0 ha 0 ha 0 ha 0 ha **0 ha**
Endangered and of concern regrowth (category C)	11.3.2 (of concern) 11.4.9 (endangered) **Total**	9.3 ha 32.3 ha **41.6 ha**	4.9 ha 0 ha **3.1 ha**
Non-remnant vegetation along watercourses (Category R)	n/a	54.7 ha	31.8 ha
Essential habitat for threatened wildlife	11.3.2, 11.3.25, 11.4.8, 11.4.9, HVR 11.4.9, 11.5.9	350.3 ha	0 ha
Category A, B, C or R areas that occur within 100 m of any wetland	11.3.2 (category B) 11.3.27b (category B) 11.5.3 (category B) HVR 11.3.2 (category C) HVR 11.3.27b (category C) HVR 11.5.3 (category C) Non-remnant (category R) **Total**	3.1 ha 0.9 ha 1.3 ha 0.1 ha 0.4 ha 0.3 ha 0 ha **6.2 ha**	0 ha 0 ha 0 ha 0 ha 0 ha 0 ha 0 ha **0 ha**
Category A, B, C or R areas that are located within a defined distance from the defining banks of a relevant watercourse*	11.3.2 (category B) 11.3.7 (category B) 11.3.25 (category B) 11.3.27b (category B) 11.4.8 (category B) 11.5.3 (category B) 11.5.9b (category B) 11.9.2 (category B) 11.10.1 (category B) 11.10.3 (category B) 11.10.8 (category B) HVR 11.3.2 (category C) HVR 11.3.25 (category C) HVR 11.5.3 (category C) HVR 11.5.9b (category C) HVR11.10.1 (category C) Non-remnant (category R) **Total**	69.1 ha 8.1 ha 88.7 ha 0.2 ha 1.9 ha 23.1 ha 108.6 ha 1.5 ha 55.5 ha 87.5 ha 0.7 ha 1.8 ha 2.4 ha 2.0 ha 15.9 ha 3.1 ha 38.3 ha **508.4 ha**	0 ha 0 ha 0 ha 0 ha 0 ha 0 ha 0.3 ha 0 ha 0 ha 0 ha 0 ha 1.0 ha 2.4 ha 0 ha 10.0 ha 3.1 ha 19.0 ha **35.8 ha**

*The defined distance was listed by Department of Environment and Heritage Protection (2017b) as 25 m for a first- or second-order stream and 50 m for a third- or fourth-order stream. The certified vegetation management watercourse map shows the centreline of relevant watercourses, but not the exact locations of their banks. Bank location was estimated based on the average width of watercourses in the survey area. Watercourse widths (distance between banks) were estimated to be 5 m for first-order streams, 10 m for second-order streams, 15 m for third-order streams and 20 m for fourth-order streams. Buffers around the watercourse centreline were enlarged beyond the "defined distance" to account for these stream widths.



Legend

- Road
- Vegetation Management Watercourse/Drainage Feature Map (Stream Order Labelled)
- Survey Area
- ML 700060
- Essential Habitat
- Vegetation management wetlands map

Regulated Vegetation Management Map

- Category A or B area containing endangered regional ecosystems
- Category A or B area containing of concern regional ecosystems
- Category A or B area that is a least concern regional ecosystems
- Category C or R area containing endangered regional ecosystems
- Category C or R area containing of concern regional ecosystems
- Category C or R area that is a least concern regional ecosystems
- Category X area

Source: State of Queensland (Department of Resources) 2022, Vitrinite 2022, METServe 2020-2022, Maxar.

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\Terrestrial_Ecology\VI010_VCM_Matilda_Ecology_RegulatedVegetation.aprx

Vulcan Coal Mine Amendment

Regulated Vegetation Management Map

0 1.5 3

Kilometers

Scale: 1:90,000 (A4)

14/06/2022

Datum: GDA2020
Projection: MGA55

FIGURE 4-17

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

4.4.7 Threatened and Special Least Concern Wildlife

Forty-two species of plants and animals listed as matters of state significance were flagged by database searches as being potentially present in the region. Field surveys confirmed that six of these (Koala, Greater Glider, Squatter Pigeon, Short-beaked Echidna, White-throated Needletail and Rufous Fantail) were present within the survey area. Furthermore, a seventh species (Glossy Black-cockatoo) was recorded within the survey area despite not being flagged as present in the region. No threatened or near threatened species of plants were detected within the survey area.

Most of the species that constitute matters of state significance are also matters of national significance, and were therefore discussed in **Section 4.3.2** and **Section 4.3.3** (see **Table 4-3** and **Table 4-6** for a list of their conservation status under the NC Act).

Only three species that are matters of state environmental significance are not also matters of national significance protected under the EPBC Act. These are the Glossy Black-cockatoo (*Calyptorhynchus lathami*), Short-beaked Echidna (*Tachyglossus aculeatus*) and Common Death Adder (*Acanthophis antarcticus*). The first two species were detected within the survey area and the third is a possible inhabitant. Each is discussed in the following subsections.

4.4.7.1 Glossy Black-cockatoo

The Glossy Black-cockatoo is listed as vulnerable under the NC Act. The Glossy Black-cockatoo was not recorded on site during ecology surveys and there were no recent records (from last 50 years) within 100 km of the survey area. Desktop reviews therefore did not flag it as a species that potentially occurred in the vicinity of the VCM. Nevertheless, one pair was observed during weed monitoring undertaken within the survey area in March 2022 (**Figure 4-18**).

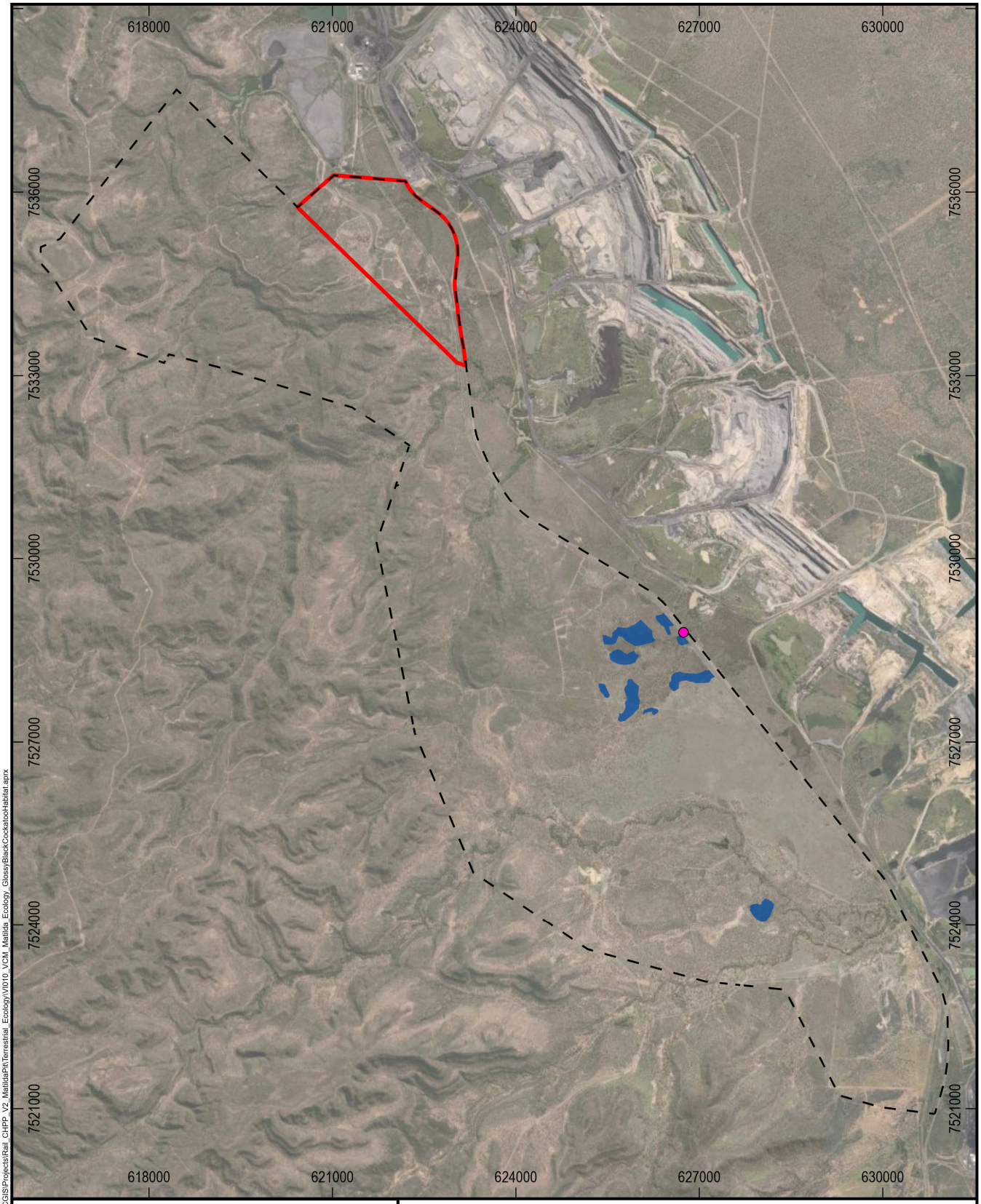
Glossy Black-cockatoos are dietary specialists, feeding on the seeds of only nine species of *Casuarina* and *Allocasuarina* (Chapman 2007). The cockatoo subspecies found in central Queensland (*C. L. erebus*) is known to feed primarily on *Casuarina cristata, Allocasuarina torulosa* and *Allocasuarina littoralis.* Of these food trees, only *C. cristata* (Belah) occurs within the survey area, where it grows within small patches of Brigalow. The pair of Glossy Black-cockatoos was observed feeding in one of these small groves of Belah. The other food trees are restricted to higher rainfall areas near the coast and nearby ranges.

The occurrence of Glossy Black-cockatoos within the survey area was unusual for several reasons:

- The survey area is far from the closest known permanent populations to the south and east, at Blackdown Tableland, the Clarke Range and the Rockhampton-Shoalwater Bay region.
- The survey area contains multiple small patches of feeding habitat (total of 74.5 ha) isolated from other feeding habitat by extensive tracts of cleared farmland, mines and forest lacking food trees. The small areas of habitat present are almost certainly insufficient to provide a year-round supply of seed. Glossy Black-cockatoos on Kangaroo Island generally require at least 400 ha of feeding habitat within 12 km of nests for successful breeding (Mooney and Pedler 2005).
- The species was not recorded during the extensive fauna surveys undertaken on site, despite particular focus on habitats likely to support the species (i.e., Brigalow areas), due to the potential of this habitat to also harbour Ornamental Snakes and other threatened species.

Taken together, the above evidence suggests that the site provides foraging habitat used occasionally by transient individuals, rather than a locally resident breeding population. The Capricornia region is currently experiencing a severe rainfall deficit. Furthermore, large areas of Glossy Black-cockatoo habitat at Shoalwater Bay experienced bushfires in 2021 (NAFI 2022). These environmental factors may be causing a food shortage within their more usual home ranges, encouraging dispersal to new, suboptimal locations. A similar pattern was observed in southeastern Queensland following the drought and fires of 2019 (Cornell Lab of Ornithology 2022).

No food trees are located within the project area.



Legend

- Survey Area
- ML 700060
- Glossy Black-Cockatoo Sighting
- Glossy Black-Cockatoo Habitat

Source: Vitrinite 2022, METServe 2020-2022, Earthstar Geographics.

Vulcan Coal Mine Amendment

Habitat for the Glossy Black-Cockatoo

0 0.75 1.5 3

Kilometers

Scale: 1:90,000 (A4)

14/06/2022

Datum: GDA2020
Projection: MGA55

FIGURE 4-18

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\Terrestrial_Ecology\VI010_VCM_Matilda_Ecology_GlossyBlackCockatooHabitat.aprx

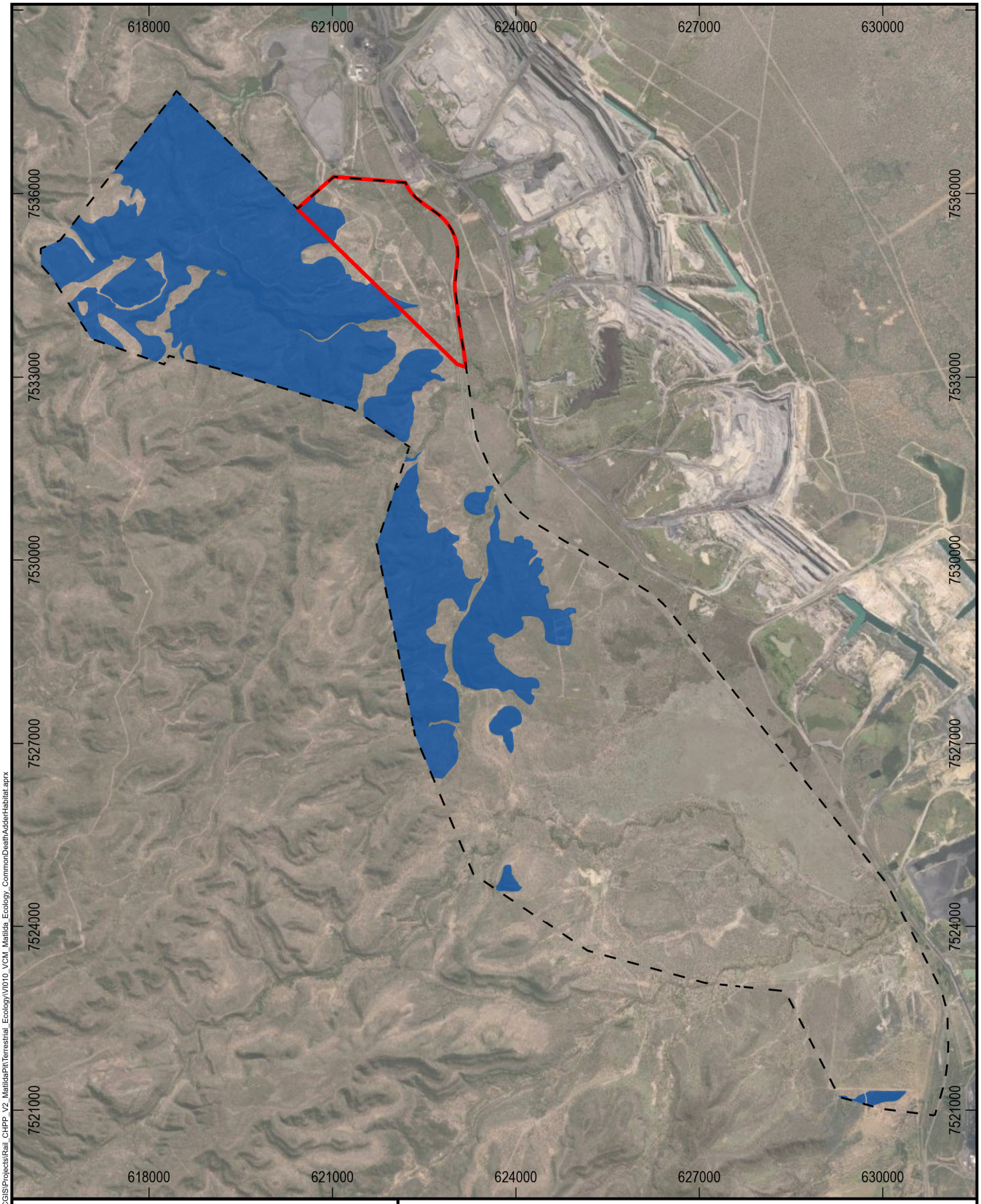
4.4.7.2 Short-beaked Echidna

The Short-beaked Echidna is the most widespread native mammal in Australia. It is listed as "special least concern" under the *Nature Conservation (Wildlife) Regulation 2006*. It has no particular habitat requirements other than potential den sites (beneath rocks or fallen timber) and a supply of ants and termites, on which it feeds (Augee 2008). Short-beaked Echidnas, or their scats or excavations, were recorded on seven occasions during ecological surveys. These included within remnant and non-remnant vegetation. As echidnas utilise a broad diversity of natural and modified habitats, and have very large home ranges spanning up to 100 ha (Nichol *et al.* 2011), the entire survey area (6,982.4 ha) comprises potential habitat for the Short-beaked Echidna.

4.4.7.3 Common Death Adder

The Common Death Adder is a snake that inhabits a broad range of habitats across eastern Australia. Its chief habitat requirement is abundant shelter in the form of leaf litter, woody debris and/or rocks. A low density of Cane Toads (*Rhinella marina*) is important, as ingested toads cause lethal poisoning (Phillips *et al.* 2009). Habitats well away from permanent water (where toads congregate and breed) are therefore likely to be most important for the species.

No Common Death Adders were recorded during ecological surveys. However, the species was recently recorded (in 2012) 25 km northeast of the project, and it is possible that populations persist on site despite high densities of Cane Toads. Within the survey area, the sandstone ridges in the western half probably contain the most valuable habitat for the species (**Figure 4-19**). Such habitats have the highest density of shelter sites and lowest densities of toads. There are 2,829.6 ha of remnant and regrowth vegetation on Land zone 10 (sandstone) within the the survey area.



Legend

- Survey Area
- ML 700060
- Potential Common Death Adder Habitat

Source: Vitrinite 2022, METServe 2020-2022, Earthstar Geographics.

Vulcan Coal Mine Amendment

Potential Habitat for the Common Death Adder

0 1.5 3

Kilometers

Scale: 1:90,000 (A4)

14/06/2022

Datum: GDA2020
Projection: MGA55

FIGURE 4-19

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\Terrestrial_Ecology\VI010_VCM_Matilda_Ecology_CommonDeathAdderHabitat.aprx

4.5 WEEDS AND PEST ANIMALS

A total of 56 species of non-native plants were recorded within the survey area. Of these, 30 species were recorded within the project area during a lease-wide weed survey undertaken in April 2022 (**Table 4-8**). Exotic pasture grasses (Red Natal Grass, Indian Couch, Sabi Grass, Buffel Grass and Green Panic) comprise the five most abundant non-native plants within the project area. Most other species occur in low densities and primarily inhabit creek banks and the verge of Saraji Road, where additional water runoff favours growth and establishment.

Table 4-8 Weeds recorded within ML 700060

Weed	Common Name	Mean cover (%) within ML
Harrisia martinii	Harrisia Cactus	0.001
Jatropha gossypiifolia	Bellyache Bush	0.003
Parthenium hysterophorus	Parthenium	0.010
Acanthospermum hispidulum	Goat's Head Burr	0.016
Ageratum conyzoides	Billy Goat Weed	0.003
Bidens sp.	Cobbler's Pegs	0.004
Bothriochloa pertusa	Indian Couch	2.737
Cenchrus ciliaris	Buffel Grass	2.333
Chamaecrista rotundifolia	Wynn Cassia	0.021
Chloris gayana	Rhodes Grass	0.010
Chloris virgata	Feathery Rhodes Grass	0.003
Cynodon dactylon	Green Couch	0.001
Digitaria eriantha	Pangola Grass	0.002
Emilia sonchifolia	Emilia	0.001
Erigeron bonariensis	Fleabane	<0.001
Euphorbia hirta	Asthma Weed	0.002
Hyparrhenia rufa	Thatch Grass	0.317
Macroptilium atropurpureum	Siratro	0.038
Macroptilium lathryoides	Phasey Bean	0.007
Megathyrsus maximus	Green Panic	0.726
Melinis repens	Red Natal Grass	7.133
Passiflora foetida	Stinking Passionfruit	0.004
Richardia brasiliensis	White-eye	0.004
Senna occidentalis	Coffee Senna	<0.001
Sida cordifolia	Flannel Weed	0.126
Sida rhombifolia	Arrow-leaf Sida	0.004
Sida spinosa	Spiny Sida	0.008
Stylosanthes sp.	Stylo	0.678
Urochloa mosambicensis	Sabi Grass	1.357
Verbesina encelioides	Crownbeard	0.003

Highlighted weeds are listed as category 3 restricted matters under the *Biosecurity Act 2014*

In addition to the three listed weeds recorded within the project area, four species of weeds present elsewhere within the survey area are category 3 restricted matters under the *Biosecurity Act 2014*, which prohibits their sale, trade or spread. These restricted weeds are:

- *Cryptostegia grandiflora* (Rubber Vine);
- *Hymenachne amplexicaulis* (Olive Hymenachne);
- *Opuntia stricta* (Prickly Pear); and
- *Opuntia tomentosa* (Velvet Pear).

All of the above, except Harrisia Cactus (*H. martini*), are also classed as Weeds of National Significance. While this classification does not introduce additional restrictions, it acts to coordinate management across states.

The following eight species of non-native animals were recorded within the survey area:

- Feral Cat (*Felis catus*)*;
- Red Fox (*Vulpes vulpes*)*;
- Dingo (*Canis lupus dingo*)*;
- European Rabbit (*Oryctolagus cuniculus*)*;
- House Mouse (*Mus musculus*);
- Feral Pig (*Sus scrofa*)*;
- Cane Toad (*Rhinella marina*); and
- Common Myna (*Acridotheres tristis*).

Species marked with an asterisk are category 3, 4 and 6 restricted matters under the *Biosecurity Act 2014*. The Red Fox, Dingo and European Rabbit are also category 5 restricted matters under the *Biosecurity Act 2014.* Category 3 restricted matters must not be distributed or released, category 4 restricted matters must not be moved, category 5 restricted matters must not be kept, and category 6 restricted matters must not be fed.

5 ECOLOGICAL IMPACTS OF PROPOSED ACTIVITIES

5.1 GENERAL IMPACTS

5.1.1 Clearing

The clearing of vegetation to accommodate the Matilda Pit, rail loop and CHPP is the principal ecological impact of the project. The extent of this impact has been minimised to the greatest extent practicable by utilising in-pit dumping of overburden, to reduce the overall size of the project footprint.

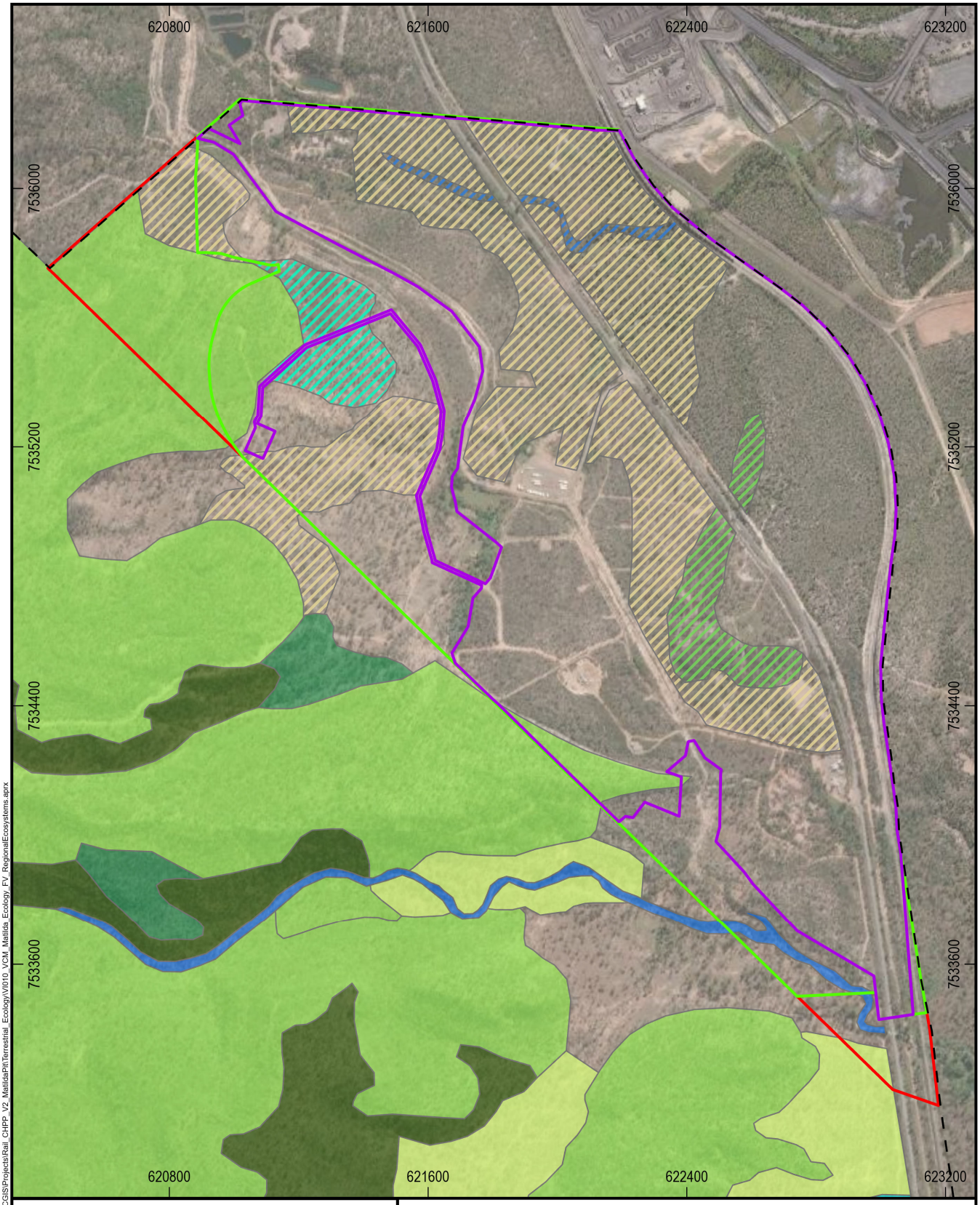
A total of 10.6 ha of remnant vegetation (category B regulated vegetation), 59.2 ha of high-value regrowth (category C regulated vegetation) and 23.6 ha of cleared pasture is contained within the footprint of the additional disturbance proposed by the VCM amendment. The composition of this vegetation is listed in **Table 5-1** and shown in **Figure 5-1**.

Clearing this vegetation constitutes the main potential loss of habitat that could result from the project. How this potential habitat loss affects matters of state and national environmental significance is assessed in **Section 5.3**.

Table 5-1 Maximum amount of vegetation to be disturbed for the VCM amendment

Regional Ecosystem	Description	Maximum amount to be cleared for original VCM (ha)		Additional amount to be cleared for VCM amendment (ha)	
		Field-verified	Regulated Vegetation Map	Field-verified	Regulated Vegetation Map
11.3.25	*Eucalyptus camaldulensis* forest fringing drainage lines.	0	0	1.7	0
11.5.9	*Eucalyptus crebra* and other *Eucalyptus* spp. and *Corymbia* spp. woodland on Cainozoic sand plains and/or remnant surfaces.	0	2.2	0	0.07
11.10.1	*Corymbia citriodora* woodland on coarse-grained sedimentary rocks.	0	0.1	0	3.1
11.10.3	*Acacia shirleyi* open forest on coarse-grained sedimentary rocks. Crests and scarps.	4.1	2.1	9.1	7.4
11.10.7	*Eucalyptus crebra* woodland on coarse-grained sedimentary rocks.	0	0	0	0
Regrowth 11.3.2	Regrowth *Eucalyptus populnea* woodland on alluvial soil.	0	2.8	0	0
Regrowth 11.3.25	Regrowth *Eucalyptus camaldulensis* forest fringing drainage lines.	2.6	6.6	0	0
Regrowth 11.4.9	Regrowth *Acacia harpophylla* shrubby woodland with *Terminalia oblongata* on clay plains	0	0.3	0	0
Regrowth 11.5.9	Regrowth *Eucalyptus crebra* and other *Eucalyptus* spp. and *Corymbia* spp. woodland on Cainozoic sand plains and/or remnant surfaces.	83.2	0	16.1	16.8
Regrowth 11.10.1	Regrowth *Corymbia citriodora* woodland on coarse-grained sedimentary rocks.	0	31.8	0	42.4
Regrowth 11.10.3	Regrowth *Acacia shirleyi* open forest on coarse-grained sedimentary rocks. Crests and scarps.	12	0	2.2	0
Regrowth 11.10.7	Regrowth *Eucalyptus crebra* woodland on coarse-grained sedimentary rocks.	0.3	0	8.8	0

Regional Ecosystem	Description	Maximum amount to be cleared for original VCM (ha)		Additional amount to be cleared for VCM amendment (ha)	
		Field-verified	Regulated Vegetation Map	Field-verified	Regulated Vegetation Map
Non-remnant (moderately disturbed)	Young regrowth dominated by *Acacia burdekensis, Alphitonia* and young *E. crebra, E. melanophloia* and/or *C. clarksoniana* on sand plains.	152.9	165.2	55.2	23.6
Non-remnant (highly disturbed)	Former railway line, sealed road, parking areas and existing buildings	26.4		0.3	
Total project footprint		281.5	281.5	93.4	93.4



Legend

- Survey Area
- Approved Maximum Disturbance Footprint
- Proposed Additional Disturbance Footprint
- ML 700060

Field-verified RE mapping

- 11.10.1
- 11.10.1x1
- 11.10.3
- 11.10.7
- 11.3.25
- 11.3.7
- HVR 11.10.3
- HVR 11.10.7/11.10.3
- HVR 11.3.25
- HVR 11.5.9

Source: State of Queensland (Department of Resources)2022, Vitrinite 2022, METServe 2022, Maxar.

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\Terrestrial_Ecology\VI010_VCM_Matilda_Ecology_FV_RegionalEcosystems.aprx

Vulcan Coal Mine Amendment

Project Footprint Relative to Field-verified Regional Ecosystems

0 125 250 500

Meters

Scale: 1:17,000 (A4)

2/06/2022

Datum: GDA2020
Projection: MGA55

FIGURE 5-1

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

The habitats present within the project's footprint are not unique in a local context. All vegetation to be disturbed is represented by extensive areas of remnant vegetation within the broader survey area (see **Table 4-1** and **Figure 4-3**). Furthermore, all flora and fauna recorded within or near the disturbance footprint were widespread within similar habitats across the survey area, with the following exceptions:

- Two reptiles (the Common Dwarf Skink *Menetia greyii*, and Coral Snake *Brachyurophis australis*) were recorded at a trap site within heavily grazed regrowth (site S30: see **Appendix A**), which was within the proposed disturbance footprint. Despite not being recorded elsewhere within the survey area, these species are geographically widespread and common (both are listed as least concern under the NC Act). They are likely to occur widely within the survey area, but the highly degraded habitats they were recorded within were not a focus of survey effort.
- Several species not recorded elsewhere within the survey area were recorded in riparian vegetation around the small dam within the project area (Water Rat *Hydromys chrysogaster*, Green Tree Snake *Dendrelaphis punctulatus*, and Chestnut-breasted Mannikin *Lonchura castaneothorax*). This dam will be retained during the project. These three species are geographically widespread and common (all are listed as least concern under the NC Act), and are highly mobile. They almost certainly utilise riparian habitats around dams, natural wetlands and creeks across the survey area and broader region.

5.1.2 Habitat Fragmentation

The VCM amendment will disturb habitat immediately adjacent to the approved disturbance footprint. Furthermore, the VCM is located immediately south and west of the existing Peak Downs Mine, which already interrupts west-east movement of wildlife.

The rail loop and Matilda Pit will effectively surround the pre-existing small farm dam with highly altered landscapes that will deter movement by some fauna. This may render the dam temporarily inaccessible as a water source for macropods and other terrestrial fauna. Most birds are expected to continue using this dam as a water source. The isolation of the dam is only short-term, with the VCM operating for four years. During operation, the mine water dams and sediment ponds installed as part of water management infrastructure for the project will provide alternate water sources for fauna. No long-lasting impacts of this habitat fragmentation are anticipated.

The VCM amendment will result in the removal of 400 m of riparian vegetation along a tributary of Boomerang Creek (in the far south of the project area). This may impact the movement of Koalas and Central Greater Gliders along this creek. There are two reasons why this habitat fragmentation is expected to have a minor impact. First, only 1 km of riparian vegetation occurs along this creek downstream of the proposed disturbance, before the creek becomes interrupted by Peak Downs Mine. This small, to-be-isolated habitat patch is unlikely to represent an important source or sink of dispersing individuals. Furthermore, both Koalas and Central Greater Gliders are expected to disperse through other vegetation types immediately south of the ML, allowing them to circumvent the proposed gap in riparian vegetation.

Overall, there will be negligible effects of habitat fragmentation as a result of the proposed VCM amendment.

5.1.3 Edge Effects

Forest edges are associated with altered microclimate, invasion of weeds and disturbance to wildlife. The proposed amendment to the VCM will not substantially increase the total length of edges in the project, but rather simply shift these westwards.

5.1.4 Direct Mortality

Nocturnal fauna that shelter during the day (when clearing is undertaken) in hollow trees and under rocks and fallen timber are susceptible to injury or death during the clearing process. Risk of direct mortality is highest for remnant vegetation to be cleared, due to the presence of hollow trees. The VCM amendment will remove very little remnant vegetation, and this mostly comprises *Acacia shirleyi* open forest, which lacks hollows. Removal of hollow trees may occur during the construction of the explosive

magazine access road, in the far south of the ML. This access road passes through a narrow riparian corridor of *Eucalyptus camaldulensis* open forest, which typically contains a high hollow density.

Direct mortality of amphibians, reptiles, small mammals and nesting birds is possible when clearing younger vegetation lacking hollow trees.

5.1.5 Vehicle Collisions

The VCM amendment will not introduce any new major roads to the region. It will also not substantially increase the workforce (the number of commuters to/from the site each day). On the contrary, the shift from road to rail transport of coal will result in reduced heavy traffic on the existing road network. The current VCM involves 80 heavy vehicle movements to the off-site processing facility per day. Cessation of road transportation of coal will reduce the daily traffic along Saraji Road by up to 3.5% (Stantec 2020).

Rail transport results in fewer collisions with fauna than road transport simply because this allows fewer, larger shipments.

5.1.6 Dust

Dust can impact nearby vegetation by blocking photosynthesis and increasing leaf temperature; both impacts can reduce drought tolerance (Farmer 1993). Dust that is severe enough to inhibit plant growth is only likely where vegetation is close to (within 100 m of) the source (roads, operational areas).

Greater Gliders and Koalas both feed on new plant growth. It's possible dust could reduce food availability for these species. However, such effects would only occur close to highly disturbed areas, which these species will most likely avoid for other reasons (noise, light). Therefore, minimal effects from dust on these species are anticipated.

Any potential effects of dust are expected to be short-term (maximum of four years), as any effects will cease immediately upon cessation of the adjacent operations.

No threatened plant species are located within the vicinity of the VCM. No threatened ecological communities or regional ecosystems occur within 500 m of operational areas that could act as a source of dust.

5.1.7 Groundwater Drawdown

Open-cut mining can lead to the drawdown of groundwater, potentially harming groundwater-dependent ecosystems. Groundwater modelling of the survey area suggests that any drawdown is highly localised and only likely to affect 1.8 ha of potentially groundwater-dependent ecosystems. For further details, refer to **Section 5.3.2.**

5.1.8 Noise and Vibration

Noise from traffic and industrial sources can have significant detrimental impacts on fauna (Shannon *et al.* 2016; Cunnington and Fahrig 2010; Barber *et al*. 2010). The VCM is located on a busy highway (Saraji Road), immediately west of a large mining operation. Furthermore, the proposed VCM amendment is located immediately adjacent to the existing VCM operational areas. The increase in noise resulting from the amendment is expected to be negligible relative to existing background noise. Nevertheless, there may be localised disturbance from noise where operational areas are close to (e.g., within 200 m of) habitats for threatened fauna (e.g., Greater Gliders, Koalas). Any effects of noise will be of short duration, given the four-year life of the VCM.

5.1.9 Artificial Lighting

The VCM operates 24 hours per day, which requires flood-lighting around operational areas. Artificial lighting can impact fauna through interfering with the navigation of nocturnal species (Howell *et al.* 1954; Salmon *et al.* 1995; Poot *et al.* 2008; Longcore *et al.* 2012), interrupting natural patterns of sleep and cell repair (Ben-Shlomo and Kyriacou 2010), exposing nocturnal prey to elevated predation risks (Baker and Richardson 2006; Rotics *et al*. 2011; Davies *et al*. 2012), disturbing the timing of daily

activities (Miller 2006; Kempenaers *et al*. 2010), and leading to long-term declines in insect populations (Conrad *et al*. 2006). Artificial lighting may also interfere with photosynthesis (Roman *et al*. 2000) and flower development in plants (Wang *et al*. 2003). The footprint of the VCM amendment lies adjacent to existing operations, and close to the large and strongly lit Peak Downs Mine. Considering these background light levels, it is expected that any impacts of the amendment due to lighting will be small and highly localised (to within 500 m of operational areas). Impacts of lighting will be short-term, as the VCM has a limited age of four years.

5.1.10 Waste

Waste produced by mining operations (e.g., runoff from stockpiles) can have long-term detrimental effects on the surrounding ecology if allowed to enter waterways. All waste rock on site is chemically benign, and not expected to cause acid or metalliferous drainage. Sediment-collecting infrastructure has been incorporated into the project's design, and no downstream impacts are anticipated. The VCM amendment will not result in an increase in food waste generated by mine workers, which potentially attracts feral animals (Black Rats, Feral Cats, Red Foxes).

5.1.11 Weeds and Pest Animals

Land disturbance and the movement of soils, vehicles and people between areas can promote weed invasion. The risk that the VCM amendment could encourage invasion by the seven restricted weeds recorded within the survey area (see **Section 4.5**) is assessed in **Table 5-2**. Controls must be in place to manage the risks posed by Rubber Vine, Harrisia Cactus, Prickly Pear, Velvet Pear and Parthenium in order for the VCM amendment to avoid being in violation of the *Biosecurity Act 2014.* While there are no legal obligations to manage non-declared weeds on site, the potential for these to spread and reduce habitat quality for threatened fauna must be considered when assessing the significance of impacts to individual matters. Non-native plants such as Buffel Grass, Indian Couch, Sabi Grass and Natal Grass are already abundant and widespread on site, and have likely already reached the limits of their potential local distribution (limited by soil type and moisture availability).

The VCM amendment will have a negligible effect on pest animal populations.

Table 5-2 Inherent Risk (without controls) that the VCM amendment could spread restricted weeds

Species	Inherent Risk	Justification
Cryptostegia grandiflora (Rubber Vine)	Low	Rubber Vine was confined to creek banks well away from the VCM (i.e., Middle and Boomerang Creeks).
Harrisia martinii (Harrisia Cactus)	High	While not in high density, this cactus was recorded in several locations within the proposed disturbance footprint. As it can spread via stem fragments, new infestations could establish in soil stockpiles.
Hymenachne amplexicaulis (Olive Hymenachne)	Nil	Olive Hymenachne is an aquatic weed recorded 9 km south of the project footprint. Potential habitat for the species is present within the project area, but is not to be disturbed by the VCM amendment.
Jatropha gossypiifolia (Bellyache Bush)	Moderate	A small infestation (<10 plants) of this weed within topsoil stockpiles within the existing VCM was the only record of the species across the survey area. If not controlled prior to use of this topsoil for rehabilitation purposes, seeds may be spread to new areas.
Opuntia stricta (Prickly Pear)	Low	This cactus was only recorded once within the entire survey area, 1.8 km south of the proposed footprint. As the VCM amendment will not result in any soil movement between the infestation and uninfested areas, there is a low risk of impact.
Opuntia tomentosa (Velvet Pear)	Moderate	This cactus occurred widely, in low densities, across most of the survey area, but was absent from the project area (probably due to the sandy, infertile soil present). As it can spread via stem fragments, there is a risk that new infestations could establish from contaminated material.
Parthenium hysterophorus (Parthenium)	Moderate	Parthenium was abundant on clay soils and alluvial areas (sites with moisture-retentive soil). While disturbance to clay soil is avoided, there will be minor disturbance to riparian areas.

5.1.12 Cumulative Impacts

The VCM adjoins other existing coal mining operations (Peak Downs Mine and Saraji Mine). Environmental impacts of these operations are expected to be additive rather than cumulative or synergistic. The VCM amendment will not cause the extent of habitat for any species or ecological community to fall below a threshold at which local populations are likely to become inviable. As the impacts of existing projects have been assessed previously, only the impacts of the VCM amendment are assessed.

5.1.13 Summary

The clearance of 10.6 ha of remnant vegetation, 59.2 ha of regrowth vegetation and 23.6 ha of lightly treed pasture will be the principal impact of the VCM amendment on ecological matters. Direct mortality, artificial lighting and weeds are additional risks that require management.

5.2 Recommended Mitigation Measures

As part of a site-specific application for a new environmental authority for a resource activity, supporting information must include "strategies for avoiding, mitigating or managing the predicted impacts on the environmental values". A list of recommended measures for reducing each of the impacts listed in **Section 5.1** is shown in **Table 5-3**.

Table 5-3 Recommended impact mitigation measures

Potential Impact	Recommended mitigation measures
Clearing	1) Vitrinite employees and contractors are to be made aware of environmental obligations and compliance requirements through a site induction program. 2) The edges of the VCM amendment footprint are to be marked out to prevent unnecessary accidental clearing of neighbouring habitats. 3) Overburden is to be mostly to be returned to the mined pits, to limit the total project footprint of the project. 4) Topsoil removed from each site in preparation for mining is to be stored and managed in accordance with a Progressive Rehabilitation and Closure Plan, to protect a favourable growing medium for vegetation post-mining. 5) Post-mine rehabilitation should aim for a post-mine land use with similar environmental values to those being lost (see the Progressive Rehabilitation and Closure Plan).
Habitat fragmentation	Not applicable
Edge effects (invasion of weeds)	1) The VCM is to operate in accordance with a Weed Management Plan. 2) All vehicles that will enter undisturbed parts of the site are to be washed and certified prior to arrival at the project site, to restrict the introduction of new weeds. Weed management activities are to control weeds in high traffic areas. 3) Light vehicles used for commuting between the project area and nearby towns (where they may be exposed to weeds) are to be parked in the visitor carpark. 4) Operational areas and the visitor carpark are to be inspected regularly (at least biannually) to identify new infestations of restricted weeds. These should be treated soon after detection, with follow-up treatment required until populations are eradicated.
Direct mortality	1) Clearing should occur in stages, and progress outwards from the edge of existing disturbance, to allow fauna the opportunity to exit the area. 2) Injured fauna is to be taken to the nearest wildlife carer or veterinarian. 3) Any injury and/or mortality is to be communicated to the Department of Environment and Science within 24 hours. 4) Vitrinite employees and contractors will be made aware of environmental obligations and compliance requirements through the site induction program.
Vehicle collisions	1) Buses are to transport ~80% of workers daily from accommodation to site, to reduce the total number of vehicles using the roads. 2) Trains used to transport coal are to be of the largest size safely driven on the relevant tracks, to reduce the total number of trips required. 3) On-site speed limits are to be restricted to 60 km/h on all roads through or adjacent to habitat critical to the survival of the koala during dawn and dusk and at night (Department of the Environment 2014).
Dust	1) Mitigation measures for managing dust are described elsewhere in the Air Quality Assessment Report. No threatened plant species are located within close proximity to dust-generating operations, and any dust management measures in place for human health will be sufficient for managing risks of dust to environmental values.
Groundwater drawdown	Not applicable.
Noise and vibration	1) Mitigation measures for managing noise and vibration are described elsewhere in the Noise Assessment Report.
Artificial lighting	1) The following lighting designs should be used, where appropriate, in operational areas within 500 m of remnant vegetation: i. Artificial lighting used in operational areas is to be angled away from habitats supporting sensitive species (e.g., riparian areas supporting Koalas and Greater Gliders). ii. Floodlights with "low glare" louvres/attachments are recommended to limit lateral transmission of light. Note that newer LED-type flood lights may have glare-reduction technology built-in. iii. Any street lights used are recommended to be of the "aeroscreen" type (flat glass lenses), to reduce sideways glare. iv. Light fittings should be positioned as close to horizontally as possible.

Potential Impact	Recommended mitigation measures
Waste	1) Food wastes are to be stored in sealed containers and disposed off-site. 2) Mitigation measures for managing mine-affected water are described elsewhere in the Surface Water Assessment Report.
Weeds and pest animals	5) Putrescible waste is to be stored in animal-proof containers and removed from site. 6) All vehicles that will enter undisturbed parts of the site are to be washed and certified prior to arrival at the project site, to restrict the introduction of new weeds. Weed management activities will control weeds in high traffic areas. 7) Light vehicles used for commuting between the project area and nearby towns (where they may be exposed to weeds) are to be parked in the visitor carpark. 8) Operational areas and the visitor carpark are to be inspected regularly (at least biannually) to identify new infestations of restricted weeds. These should be treated soon after detection, with follow-up treatment required until populations are eradicated. 9) Any weeds germinating on topsoil stockpiles should be treated and eradicated to maintain a source of weed-free growing medium for use post-mining. 10) Only native species, or species with low weed risk, are to be included within seed mixes applied to rehabilitated sites.
Cumulative impacts	Not applicable.

5.3 RESIDUAL IMPACTS ON PROTECTED MATTERS

5.3.1 Regulated Vegetation

As it is a resource activity under the *Environmental Protection Act 1994,* section 107, the VCM represents exempt clearing work under the *Vegetation Management Act 1999*. Nevertheless, disturbance to some vegetation classed as a matter of state environmental significance may be subject to offsets. The vegetation to be disturbed for the VCM amendment is listed in **Table 5-4**.

Table 5-4 Regulated vegetation to be disturbed by the VCM amendment

Regulated Vegetation Category	Description	Area to be disturbed by original VCM & bulk sample (ha)	Additional area to be disturbed by the amendment (ha)
A	**Declared area, offset area or other protected vegetation*†**	0	0
B	**Remnant vegetation: Endangered*†**	0	0
	Remnant vegetation: Of Concern*†	0	0
	Remnant vegetation: Least Concern	4.4	10.5
C	**High-value regrowth: Endangered***	0.3	0
	High-value regrowth: Of Concern*	4.9	0
	High-value regrowth: Least Concern	83.1	53.1
R	**Non-remnant vegetation within 50 m of a watercourse***	23.9	6.1
X	Already-cleared areas or other exempt areas not regulated by vegetation management laws	165.2	23.6
Total		281.8	93.3

*Vegetation categories in bold are classed as matters of state environmental significance.
†Subset of matters of state environmental significance that are "prescribed matters" requiring offsets (Department of Enrivonment and Science 2020).

While the above vegetation categories not shown in bold do not individually constitute matters of state environmental significance, most are classed as significant if they occur "within a defined distance from the defining banks of a relevant watercourse" or "within 100 metres of the defining bank of a wetland identified on the vegetation management wetlands map". Vegetation categories occurring within a defined distance from the defining banks of a relevant watercourse that will be disturbed for the VCM amendment are listed in **Table 5-5**. No vegetation within 100 metres of the defining bank of a wetland identified on the vegetation management wetlands map will be disturbed.

Table 5-5 Area of each vegetation category contained within a defined distance of the defining banks of relevant watercourses

Regulated Vegetation Category	Description	Area to be disturbed by original VCM (ha)	Additional area to be disturbed by the amendment (ha)
A*	Declared area, offset area or other protected vegetation	0	0
B*	Remnant vegetation: Endangered	0	0
	Remnant vegetation: Of Concern	0	0
	Remnant vegetation: Least Concern	0	0
C	High-value regrowth: Endangered	0	0
	High-value regrowth: Of Concern	3.4	0
	High-value regrowth: Least Concern	0.2	10.9
R	Non-remnant vegetation within 50 m of a watercourse	13.7	3.6
Total		**17.3**	**14.5**

*The subset of watercourse vegetation that is subject to offsets

Overall, the regulated vegetation that is a matter of state environmental significance to be disturbed by the VCM amendment is 6.1 ha of category R vegetation and 14.5 ha of category C or R areas on the regulated vegetation management map that are located within a defined distance from the defining banks of a relevant watercourse.

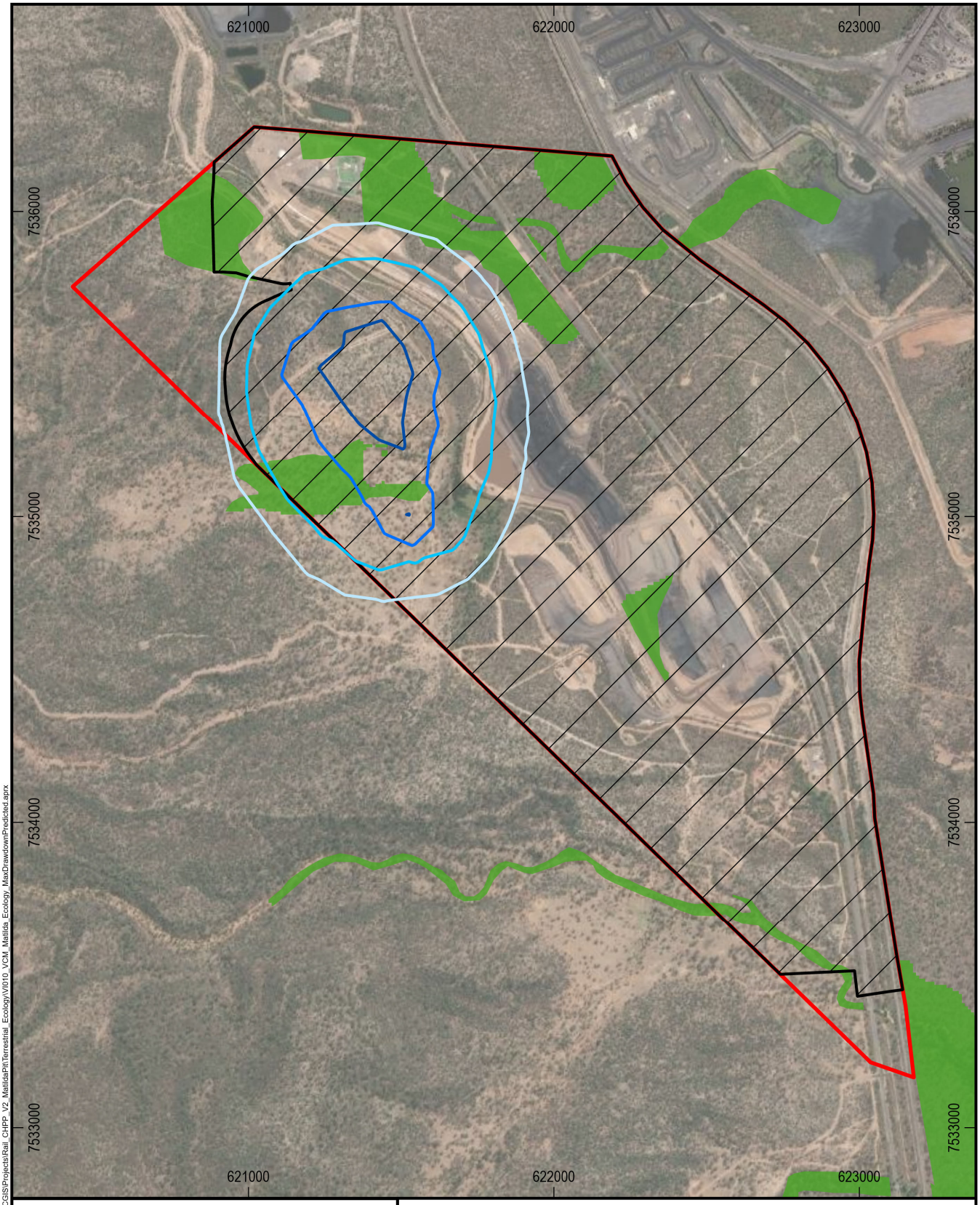
5.3.2 Groundwater-dependent Ecosystems

Hydrogeologist.com.au (2022) has developed a numerical groundwater flow model of the project area and broader region to predict the effects of the VCM amendment on local groundwater levels. Groundwater flow into the main and Matilda Pits will be negligible, and these pits will be essentially dry. Groundwater flow into the Matilda Pit will be up to 2.7 m^3/day, which will cause localised drawdown in surrounding aquifers. The drawdown predicted from the groundwater flowing into the pits at the VCM is limited in geographic extent (up to 300 m from the pit crest), and most of the vegetation within this zone of drawndown will be removed to accommodate the rail loop and other infrastructure. As the pits will be back-filled, no residual drawdown is expected following the cessation of the project. Nevertheless, 1.8 ha of potentially groundwater-dependent vegetation outside the project's clearing footprint is found within the zone of drawdown (**Figure 5-2**). All of this comprises regrowth 11.5.9.

The effect of drawdown on vegetation within this 1.8 ha is expected to be minimal. The dominant species present (*Eucalyptus crebra* and *Eucalyptus melanophloia*) are unlikely to utilise groundwater and will not be affected by drawdown. The principal impact could be on the sub-dominant tree, *Corymbia clarksoniana*, which frequently utilises shallow groundwater. It is unclear whether a drawdown of 1–2 m (as forecast by modelling) will have any effect on tree health. However, even if all *C. clarksoniana* within this small patch of 11.5.9 were to die, this would have relatively little effect on local wildlife. This species is not usually a Koala food tree, rarely develops hollow limbs, and does not provide key habitat resources for other threatened fauna.

The groundwater quality is unlikely to be significantly altered by the VCM and, in any case, all local potentially groundwater-dependent ecosystems occur upgradient (in terms of the groundwater flow, which mimics the surface water drainage pattern from west to east) of potential effects.

In summary, negligible impacts to GDEs are predicted to result from the VCM amendment, beyond that which will occur due to vegetation clearing.



Legend

- ML 700060
- Clearing Footprint for VCM, Including Proposed Amendment
- Potential Terrestrial GDEs

Predicted Drawdown (m)

- 1m
- 2m
- 5m
- 10m

Source: Bureau of Meteorology 2012, Hydrogeologist.com.au 2020-2022, Vitrinite 2022, METServe 2022, Maxar.

Vulcan Coal Mine Amendment

Maximum Drawdown of Groundwater Predicted

0 300 600

Meters

Scale: 1:18,000 (A4)

9/08/2022

Datum: GDA2020
Projection: MGA55

FIGURE 5-2

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\Terrestrial_Ecology\VI010_VCM_Matilda_Ecology_MaxDrawdownPredicted.aprx

5.3.3 Matters of National Environmental Significance

An action that has, will have or is likely to have a significant impact on one or more matters of national environmental significance must be referred and assessed under the EPBC Act. As discussed in detail below, significant residual impacts of the VCM amendment are anticipated for three threatened species (Squatter Pigeon, Koala and Central Greater Glider). A referral is therefore recommended.

5.3.3.1 Brigalow Threatened Ecological Community

While the threatened ecological community listed as "Brigalow (*Acacia harpophylla* dominant and co-dominant)" occurs within the survey area, none is found within the project area. No Brigalow occurs within 500 m of the disturbance proposed for the VCM amendment, and there will therefore be negligible impacts from dust, lighting or weeds.

According to the *Matters of National Environmental Significance Significant Impact Guidelines 1.1* (Department of the Environment 2013), an action is likely to have a significant impact on a critically endangered or endangered ecological community if there is a real chance or possibility that it will:

- reduce the extent of an ecological community
- fragment or increase fragmentation of an ecological community, for example by clearing vegetation for roads or transmission lines
- adversely affect habitat critical to the survival of an ecological community
- modify or destroy abiotic (non-living) factors (such as water, nutrients, or soil) necessary for an ecological community's survival, including reduction of groundwater levels, or substantial alteration of surface water drainage patterns
- cause a substantial change in the species composition of an occurrence of an ecological community, including causing a decline or loss of functionally important species, for example through regular burning or flora or fauna harvesting
- cause a substantial reduction in the quality or integrity of an occurrence of an ecological community, including, but not limited to:
  - assisting invasive species, that are harmful to the listed ecological community, to become established, or
  - causing regular mobilisation of fertilisers, herbicides or other chemicals or pollutants into the ecological community that kill or inhibit the growth of species in the ecological community, or
- interfere with the recovery of an ecological community.

The VCM amendment will not cause any of the above impacts on the Brigalow threatened ecological community.

5.3.3.2 Squatter Pigeon

A total of 92.4 ha of foraging habitat (of which 76.4 ha is also breeding habitat) are contained within the proposed disturbance footprint of the VCM amendment (**Figure 5-3**).

No sources of water (dams) used by Squatter Pigeons will be removed for the VCM amendment. On the contrary, mine management dams and sediment dams installed as part of surface water management may provide additional water sources.

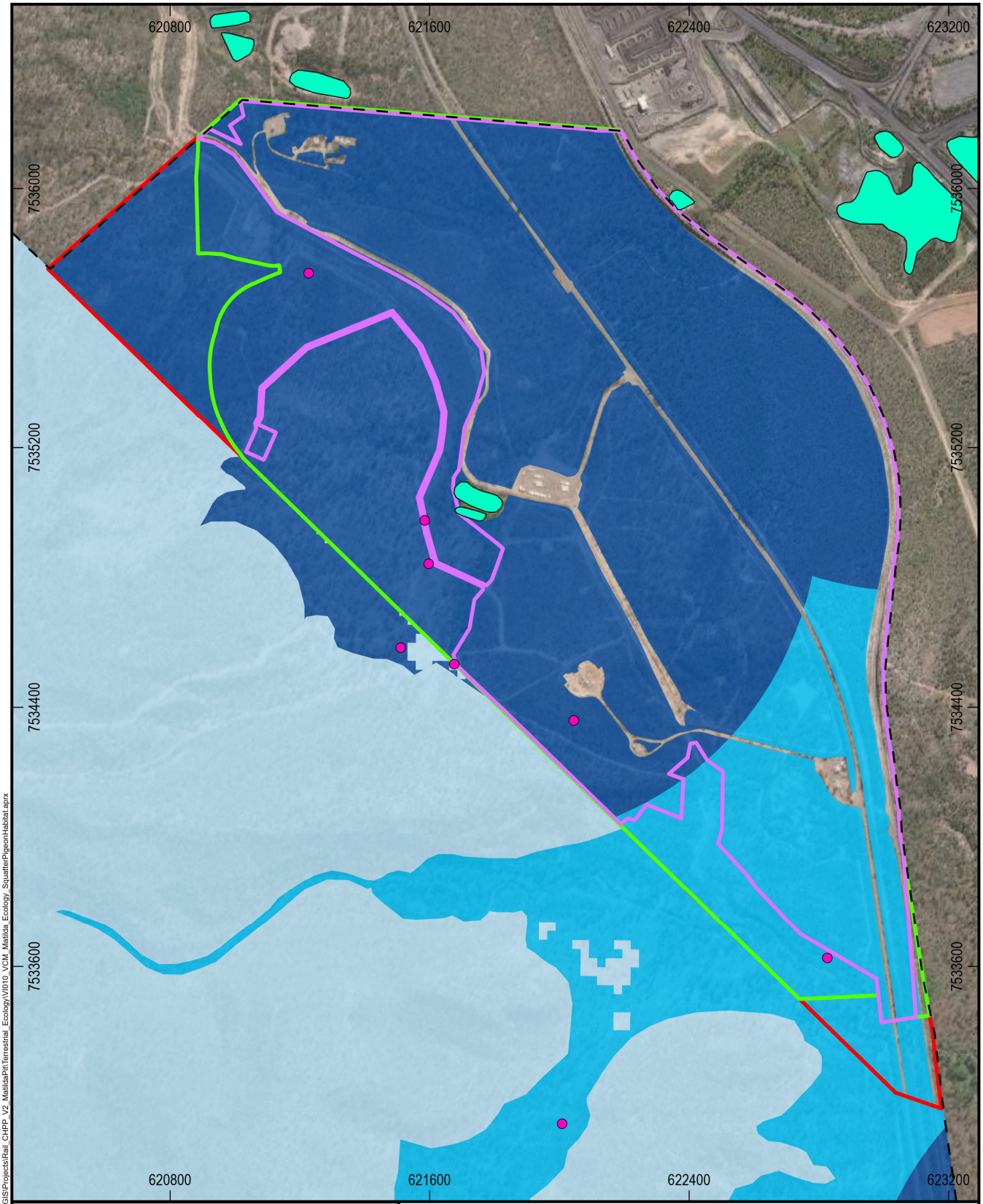
The size of the average home range of a pair of Squatter Pigeons is not known, but the related Partridge Pigeon (*Geophaps smithii*) is thought to occupy a home range of approximately 8 ha (Fraser *et al.* 2003). Assuming Squatter Pigeons are similar—a likely scenario, given their similar biology—the amendment could impact up to 18 breeding pairs of Squatter Pigeons. This is very likely to be an over-estimate, and occupancy rates of 50% within potential habitat are more consistent with rates of detection in the field. This implies an expected loss of habitat for up to nine pairs of Squatter Pigeons as a result of the VCM amendment.

The net loss of habitat constitutes 3.5% of the total breeding habitat and 2.6% of the total foraging habitat contained within the survey area. An additional 209.8 ha of breeding habitat are approved to be removed for the original VCM and bulk sample. This means that breeding habitat for 116 pairs will be retained in the local landscape throughout the project (assuming each pair occupies 8 ha and 50% of available territories are occupied). The estimated size of this retained local population is highly conservative, as it does not include contiguous habitat west and south of the survey area. It is more likely that habitat for several hundred pairs will be retained in the local region, supporting a viable population that will serve as a source of recruitment for rehabilitated land post-mining.

The impacts of habitat clearance will persist at least for the short- to medium-term, until vegetation is re-established on mined land. Being a ground-dwelling bird, they are not dependent on old trees, and rehabilitated sites are expected to meet their requirements for a low, protective tree cover within 15 years post-rehabilitation (Ngugi and Neldner 2015). It is unknown whether the relatively simple understorey vegetation communities that typically establish on rehabilitated sites (Grigg *et al.* 2000; Ngugi and Neldner 2015) will meet the ecological needs of Squatter Pigeons. Their readiness to feed on introduced pasture species such as *Urochloa mosambicensis* and *Stylosanthes* spp. (Crome 1976; C. Wiley pers. obs. 2019) suggests that re-establishing appropriate food plants is likely to be achievable. Consequently, it is estimated that the duration of impacts will be approximately 19 years, although this estimate has low confidence, given the lack of data on the dietary requirements of the species.

The significance of impacts to MNES is defined by the *Matters of National Environmental Significance Significant Impact Guidelines 1.1*. An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:

1) lead to a long-term decrease in the size of an important population of a species;
2) reduce the area of occupancy of an important population;
3) fragment an existing important population into two or more populations;
4) adversely affect habitat critical to the survival of a species;
5) disrupt the breeding cycle of an important population;
6) modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline;
7) result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat;
8) introduce disease that may cause the species to decline; or
9) interfere substantially with the recovery of the species.



Legend

- Survey Area
- ML 700060
- Approved Maximum Disturbance Footprint
- Proposed Additional Disturbance Footprint
- Waterbodies
- Squatter Pigeon Sighting

Squatter Pigeon Habitat

- Breeding and foraging habitat
- Foraging habitat
- Dispersal habitat

Source: Geoscience Australia 2015, Australian Government (Department of Industry, Science, Energy and Resources) 2021, METServe 2019-2022, Maxar. Squatter Pigeon habitat derived from the National Forest and Sparse Woody Vegetation dataset (Version 5.0) and field-verified regional ecosystem data.

Vulcan Coal Mine Amendment

Project Footprint Relative to Existing Squatter Pigeon Habitat

0 150 300 600

Meters

Scale: 1:17,000 (A4)

14/06/2022

Datum: GDA2020
Projection: MGA55

FIGURE 5-3

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\Terrestrial_Ecology\VI010_VCM_Matilda_Ecology_SquatterPigeonHabitat.aprx

As the VCM lies north of the Carnarvon Ranges, the local population of Squatter Pigeons does not qualify as an "important population" according to the Department of Climate Change, Energy, the Environment and Water (2022b), and hence criteria 1, 2, 3 and 5 are not relevant. The scale of habitat loss, relative to the large extent of habitat remaining in the local landscape, means that the project is not likely to jeopardise the viability of local populations (criterion 9 is not triggered).

Nevertheless, this local population is expected to temporarily decline by approximately 18 individuals, which may trigger a significant impact under the sixth criterion listed above. Also, because habitat used for foraging, breeding, roosting and dispersal (qualifies as "habitat critical to the survival of a species" under the *Matters of National Environmental Significance Significant Impact Guidelines 1.1*) is proposed to be removed, criterion 4 is also triggered by the project.

The VCM amendment may also lead to localised increases in some weeds, which qualify as invasive species potentially threatening ground-feeding Squatter Pigeons. Weed introduction could potentially occur during the construction, operation and rehabilitation phases of the project. However, these impacts are not likely to extend far beyond the VCM amendment's disturbance footprint. Furthermore, the infertile, sandy soils present on site are relatively unfavourable for weed establishment. As this impact assessment assumes all habitat within the disturbance footprint is to be removed, no additional impacts of weeds are anticipated.

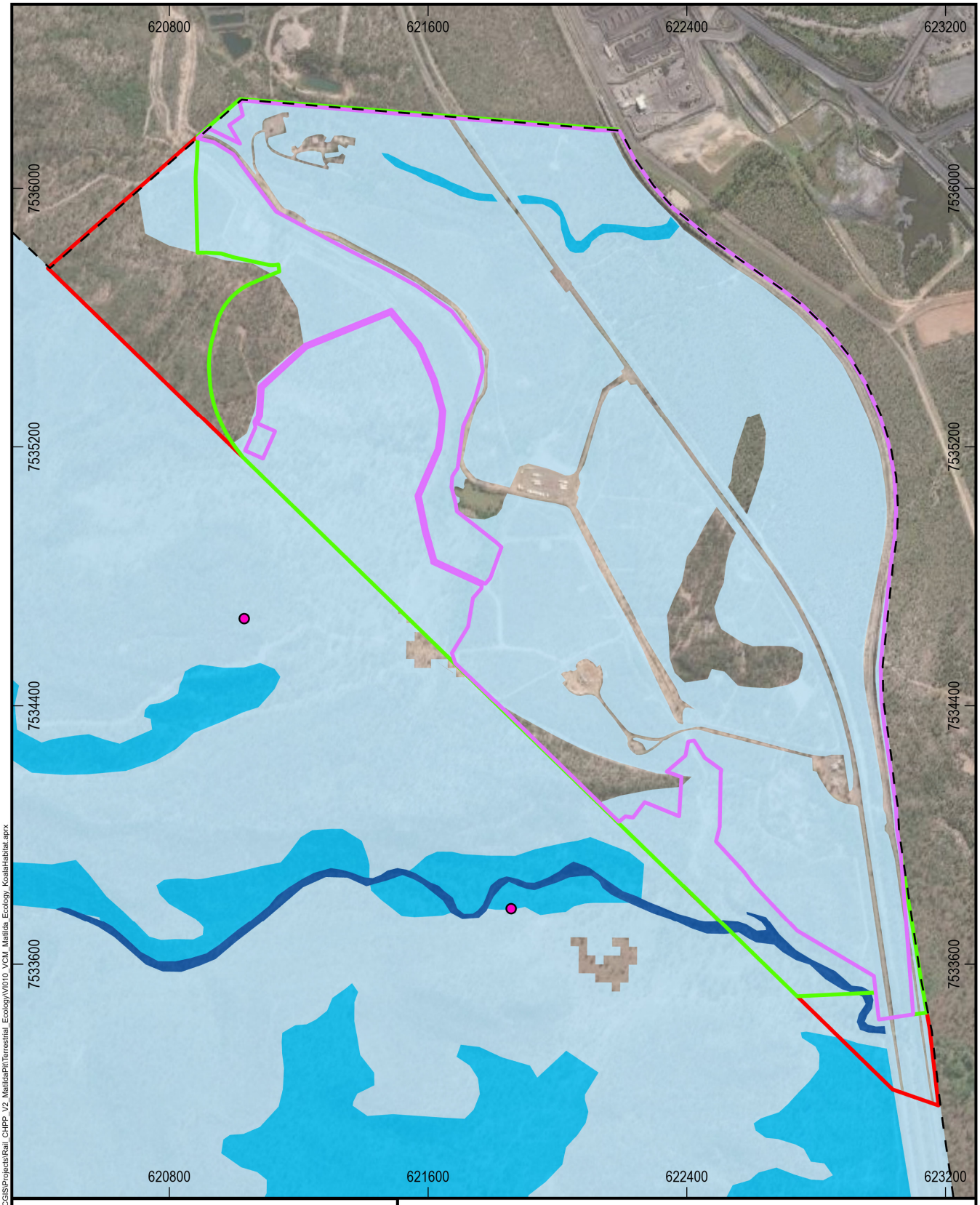
Overall, the VCM amendment is likely to have a significant residual impact on the Squatter Pigeon under the EPBC Act due to the expectation that it causes the loss of 76.4 ha of breeding and foraging habitat and 16.0 ha of foraging (but not breeding) habitat to the extent that the population is likely to decline, albeit to a limited extent and only temporarily.

5.3.3.3 Koala

A total of 83.9 ha of Koala habitat are contained within disturbance footprint of the VCM amendment. Little of this (1.7 ha in the clearing footprint) is high-quality habitat (the habitat type in which most records occurred). The remaining 82.2 ha of the disturbance footprint are low-quality habitats (**Figure 5-4**).

Table 5-6 Koala habitat to be cleared

Habitat Class	Vegetation Unit	Food Trees	Area to be removed (ha)
High quality	11.3.25	**Primary:** *Eucalyptus camaldulensis* dominant **Secondary:** *Eucalyptus populnea* and/or *Eucalyptus crebra* sometimes subdominant	1.7
Moderate quality	Regrowth 11.3.25	**Primary:** *Eucalyptus camaldulensis* dominant **Secondary:** *Eucalyptus populnea* and/or *Eucalyptus crebra* sometimes subdominant	0
	11.10.7	**Primary:** absent **Secondary:** *E. crebra* dominant	0
Low quality	Regrowth 11.5.9 and 11.10.7	**Primary:** absent **Secondary:** *E. crebra* sometimes dominant, but some variants of this RE lack food trees	27
	Cleared 11.5.9	**Primary:** absent **Secondary:** *E. crebra* sometimes dominant, but some variants of this RE lack food trees	55.2



Legend

- Survey Area
- ML 700060
- Approved Maximum Disturbance Footprint
- Proposed Additional Disturbance Footprint
- Koala Sighting

Koala Habitat

- High Quality
- Moderate Quality
- Low Quality

Source: Australian Government (Department of Industry, Science, Energy and Resources) 2021, METServe 2020-2022, Vitrinite 2022, Maxar. Koala habitat derived from the National Forest and Sparse Woody Vegetation dataset (Version 5.0) and field-verified regional ecosystem data.

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\Terrestrial_Ecology\VI010_VCM_Matilda_Ecology_KoalaHabitat.aprx

Vulcan Coal Mine Amendment

Project Footprint Relative to Koala Habitat

0 150 300 600

Meters

Scale: 1:17,000 (A4)

14/06/2022

Datum: GDA2020
Projection: MGA55

FIGURE 5-4

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

The impact of clearing will last until mature food trees have re-established in rehabilitated areas post-mining. Re-colonisation of rehabilitated sites after six years has been observed in wetter climates in south-east Queensland (Cristescu *et al.* 2013), but a more conservative estimate of 15 years is adopted here due to the drier climate and slower growth rates expected. As the final blocks of disturbed land can only commence rehabilitation at the cessation of mining activities (approximately four years after the commencement of the VCM amendment), the duration of disturbance is estimated to be 19 years. Viable populations of Koalas are expected to be maintained in extensive neighbouring habitats (98.9% of the high-quality habitat within the survey area is being retained, and extensive tracts of moderate-quality habitat occur throughout the adjacent Harrow Range) throughout this disturbance period, providing a source of recruitment to rehabilitated areas in the future. Average koala densities in the Brigalow Belt are thought to be 0.005 Koalas/ha (Threatened Species Conservation Committee 2012). Given that the Cherwell-Harrow Range spans over 170,000 ha, the remaining koala population is expected to exceed 850 individuals.

The location of the proposed disturbance adjacent to existent mining operations means that no new barriers to dispersal are anticipated to arise as a result of the VCM amendment. The VCM amendment will result in a slight decrease in road traffic along existing roads. This will reduce the risk of vehicular collisions with Koalas, albeit to a negligible extent.

An additional 2.8 ha of high-quality habitat, 22.5 ha of moderate-quality habitat and 156.5 ha of low-quality habitat are located within 500 m of the disturbance footprint and therefore may experience some disturbance from lighting, noise and dust. This disturbance is short-term, lasting only for the duration of the adjacent operations (four years).

In their conservation advice, the Department of Agriculture, Water and the Environment (2022b) defines habitat critical to the survival of the Koala as "areas that the species relies on to avoid or halt decline and promote the recovery of the species". The following are defined as important populations:

- Populations that have the potential to act as source populaitons to adjacent areas of suitable, or potentially suitable, habitat;
- Populations that exist in areas of climatically suitable refugia during periods of environmental stress including droughts, heatwaves, and long-term climate change;
- Genetically diverse populations;
- Populations that are disease-free and/or that exhibit low rates of infection with important pathogens;
- Populations that contain genes that may confer adaptation to current and future environmental stressors;
- Populations that are geographical or environmental outliers within the species' range;
- Populations with particular cultural and spiritual importance to indigenous people;
- Populations close to residential areas, which add social value; and
- Populations used by local business and tourism.

Based on the criteria that local populations have the potential to act as source populations, inhabit drought refugia along creeks, and are probably genetically diverse (owing to their large size), the local Koala population is considered important.

The VCM amendment will not reduce the area of occupancy of the Koala, as defined by the Department of Agriculture, Water and the Environment (2022a) as the area within the extent of occurrence that is occupied by the species using 2 km × 2 km grid cells. The disturbance associated with the VCM amendment (in isolation or in cumulation with the original VCM) does not fill a 2 km × 2 km cell, and the local area will thus remain "occupied".

However, the VCM amendment will adversely affect habitat critical to the survival of the species (habitat used for feeding and resting: Department of Agriculture, Water and the Environment (2022a), and the action thereby qualifies as a significant residual impact under the EPBC Act.

5.3.3.4 Central Greater Glider

The VCM amendment will remove 1.7 ha of Central Greater Glider habitat (**Figure 5-5**). This represents a loss of 0.3 % of Central Greater Glider habitat located within the survey area.

This impact will last until tree hollows have been replaced in rehabilitated areas post-mining. It is expected to take 120 years post-planting for trees to be large enough to form natural hollows (Gibbons and Lindenmayer 2002; Smith & Agnew 2002). Re-colonisation of rehabilitated sites after 13 years has been recorded in central Queensland where nest boxes support glider populations in mining rehabilitation sites devoid of natural hollows (Cristescu 2011). However, nest boxes require regular maintenance and replacement (Beyer & Goldingay 2006), and it is doubtful whether such a commitment can be fulfilled over a 120-period, until natural hollows form. For this reason, it is conservatively predicted that the loss of hollow trees within Central Greater Glider habitat constitutes a near-permanent loss. However, where hollows are available nearby, Central Greater Gliders are expected to commence foraging within rehabilitated areas within 15 years. As the disturbance is for roads (see **Figure 2-2**), it is expected that most of this will be usable by Central Greater Gliders within 15 years after rehabilitation, as hollow trees wil be retained nearby.

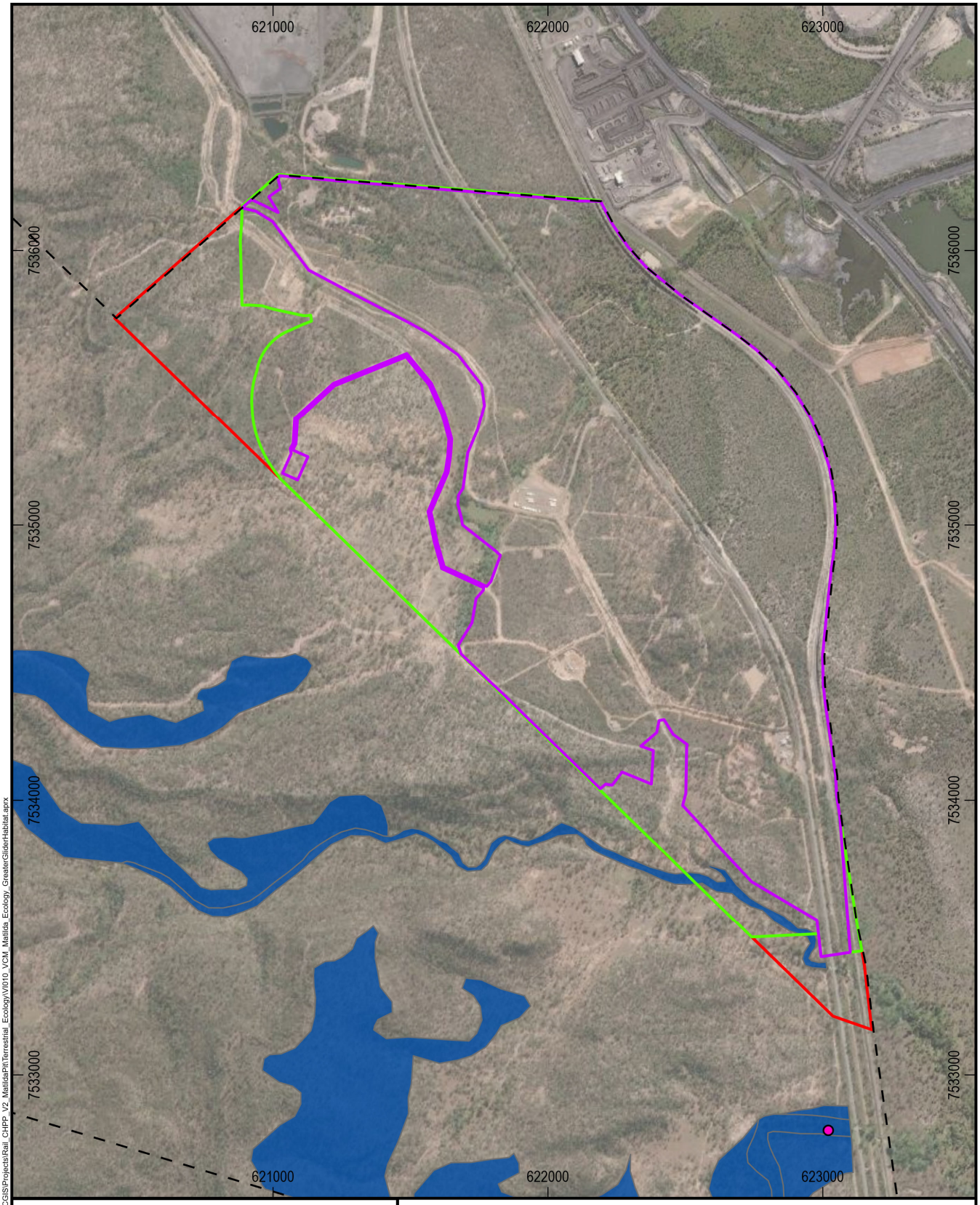
Viable populations of Greater Gliders are expected to be maintained in extensive neighbouring habitats (99.7 % of Greater Glider habitat is retained in the broader landscape) throughout the disturbance period, providing a source of recruitment to rehabilitated areas in the future. No data on population density is available for Central Greater Gliders within the Brigalow Belt, but the related Southern Greater Glider occurs at average densities of 0.6 to 4 individuals per hectare (Henry 1984; Kehl and Borsboom 1984; van der Ree *et al.* 2004; Nelson *et al.* 2018), while the Northern Greater Glider occurs at a density of 3.3 to 3.8 individuals per hectare at the single site (Taravale) in which they have been studied (Comport *et al.* 1996). With a conservative assumption that densities within the survey area are on the lower end of published data (i.e., 0.6 per hectare), the 615.5 ha of habitat that will remain uncleared within the survey area supports at least 369 individuals. Furthermore, this population is likely to be connected to others throughout the Harrow Range to the west.

The location of this disturbance immediately west of existing mining operations means that no new barriers to dispersal are anticipated to arise as a result of the project. West of the project footprint, continuous tracts of riparian habitat remain connected to forests in sheltered gorges of the Harrow Range.

An additional 3.8 ha of habitat for Greater Gliders is located within 500 m of the main operational areas (Matilda pit, CHPP, loading area) and therefore may experience some disturbance from lighting, noise and dust. This disturbance is short-term, lasting only for the duration of the VCM (four years).

The significance of impacts to MNES is defined by the *Matters of National Environmental Significance Significant Impact Guidelines 1.1*. An action is likely to have a significant impact on an endangered species if there is a real chance or possibility that it will:

1. lead to a long-term decrease in the size of a population;
2. reduce the area of occupancy of the species;
3. fragment an existing population into two or more populations;
4. adversely affect habitat critical to the survival of a species;
5. disrupt the breeding cycle of a population;
6. modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline;
7. result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat;
8. introduce disease that may cause the species to decline; or
9. interfere with the recovery of the species.



Legend

- Survey Area
- ML 700060
- Approved Maximum Disturbance Footprint
- Proposed Additional Disturbance Footprint
- Central Greater Glider Sighting
- Central Greater Glider Habitat

Source: Vitrinite 2022, METServe 2020-2022, Maxar.

Vulcan Coal Mine Amendment

Project Footprint Relative to Central Greater Glider Habitat

0 300 600

Meters

Scale: 1:20,000 (A4)

14/06/2022

Datum: GDA2020
Projection: MGA55

FIGURE 5-5

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\Terrestrial_Ecology\VI010_VCM_Matilda_Ecology_GreaterGliderHabitat.aprx

On the grounds that the project will reduce the area of occupancy by 1.7 ha and adversely affect habitat critical to the survival of a species (i.e., by removing hollow trees), the VCM amendment is likely to significantly impact the Central Greater Glider.

The VCM amendment may also lead to localised increases in some weeds, although no local weeds pose a threat to the health and long-term viability of large eucalypts used by Central Greater Gliders.

5.3.3.5 White-throated Needletail

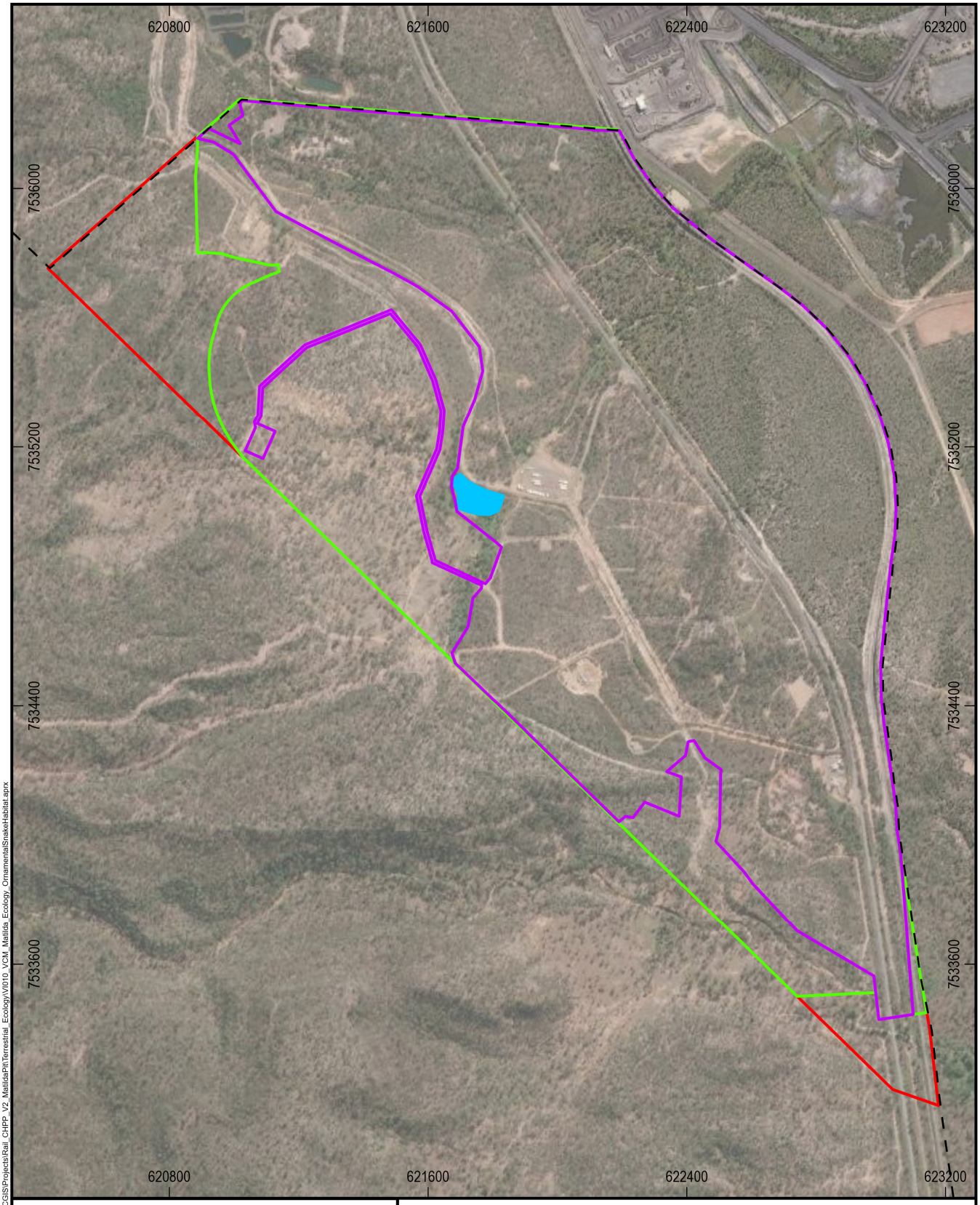
The VCM amendment will not introduce any aerial obstacles or hazards to the White-throated Needletail. The clearance of vegetation may result in the temporary reduction of flying insect prey, although this effect will be highly localised and have negligible impact on this fast-moving and wide-ranging bird.

According to the SPRAT profile (Department of Climate Change, Energy, the Environment and Water 2022l), there are few threats to the species in Australia, apart from collisions with overhead wires, lighthouses and windows on tall buildings. These threats will not be elevated by the VCM amendment. The VCM amendment is not expected to significantly impact the White-throated Needtletail.

5.3.3.6 Ornamental Snake

No habitat for the Ornamental Snake is present within the disturbance footprint of the VCM amendment (**Figure 5-6**). The farm dam located within the project area provides potential breeding habitat for frogs, and could support dispersing Ornamental Snakes. Spotlighting at this dam failed to detect the species, so the dam is unlikely to provide high-quality habitat. The closest records of Ornamental Snakes are on the eastern side of the Peak Downs Mine and Saraji Mine, and those mines already act as a barrier to westwards dispersal towards the VCM.

The VCM amendment will result in the temporary (four years) isolation of the dam. No other barriers to dispersal are anticipated to be introduced by the VCM amendment and, given the marginal quality of the affected dam, negligible impacts to the Ornamental Snake are antipated to result from the VCM amendment.



Legend

- Survey Area
- ML 700060
- Approved Maximum Disturbance Footprint
- Proposed Additional Disturbance Footprint

Potential Ornamental Snake Habitat

- Primary
- Secondary

Source: Vitrinite 2022, METServe 2020-2022, Maxar.

Vulcan Coal Mine Amendment

Project Footprint Relative to Potential Ornamental Snake Habitat

0 250 500

Meters

Scale: 1:17,000 (A4)

14/06/2022

Datum: GDA2020
Projection: MGA55

FIGURE 5-6

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\Terrestrial_Ecology\VI010_VCM_Matilda_Ecology_OrnamentalSnakeHabitat.aprx

In accordance with the *Draft Referral Guidelines for the Nationally Listed Brigalow Belt Reptiles*, "important habitat" for the Ornamental Snake is to be used as a surrogate for an "important population" when assessing the significance of potential impacts. Important habitat for Brigalow Belt reptiles is defined as:

- habitat where the species has been identified during a survey
- near the limit of the species' known range;
- large patches of contiguous, suitable habitat and viable landscape corridors (necessary for the purposes of breeding, dispersal or maintaining the genetic diversity of the species over successive generations); or
- a habitat type where the species is identified during a survey, but which was previously thought not to support the species.

No Ornamental Snakes were recorded on site during surveys, despite appropriate search effort during optimal seasonal conditions. The survey area is also not located near the limit of the known range of the Ornamental Snake. Suitable habitat for the species (i.e., gilgais) were absent from the project area. The *Draft Referral Guidelines for the Nationally Listed Brigalow Belt Reptiles* offer the following comment in specific reference to defining important habitat for the Ornamental Snake: "habitat connectivity between gilgais and other suitable habitats is important". In light of the poor connectivity and low quality of local habitats on site, in addition to the failure to detect the species on site, impacts to the Ornamental Snake are unlikely to qualify as significant under the EPBC Act.

5.3.3.7 Yakka Skink

Up to 10.8 ha of remnant habitat for the Yakka Skink is contained within the disturbance footprint of the VCM amendment. The *Draft Referral Guidelines for the Nationally Listed Brigalow Belt Reptiles* defines important habitat for the Yakka Skink as "any contiguous patch of suitable habitat, particularly remnant vegetation, where a colony is known or identified…[or] any microhabitat where colonies are likely to be found". The disturbance area does not contain habitat connected to known populations of the Yakka Skink. Furthermore, as no colonies have ever been recorded in the northern Bowen Basin, despite extensive ecological surveys undertaken across Dysart-Moranbah-Collinsville as part of various mining projects, colonies are not "likely to be found" in the vicinity of the VCM. Consequently, no "important habitat" is located within the disturbance area, and no significant residual impacts to the Yakka Skink are anticipated.

5.3.3.8 Northern Quoll

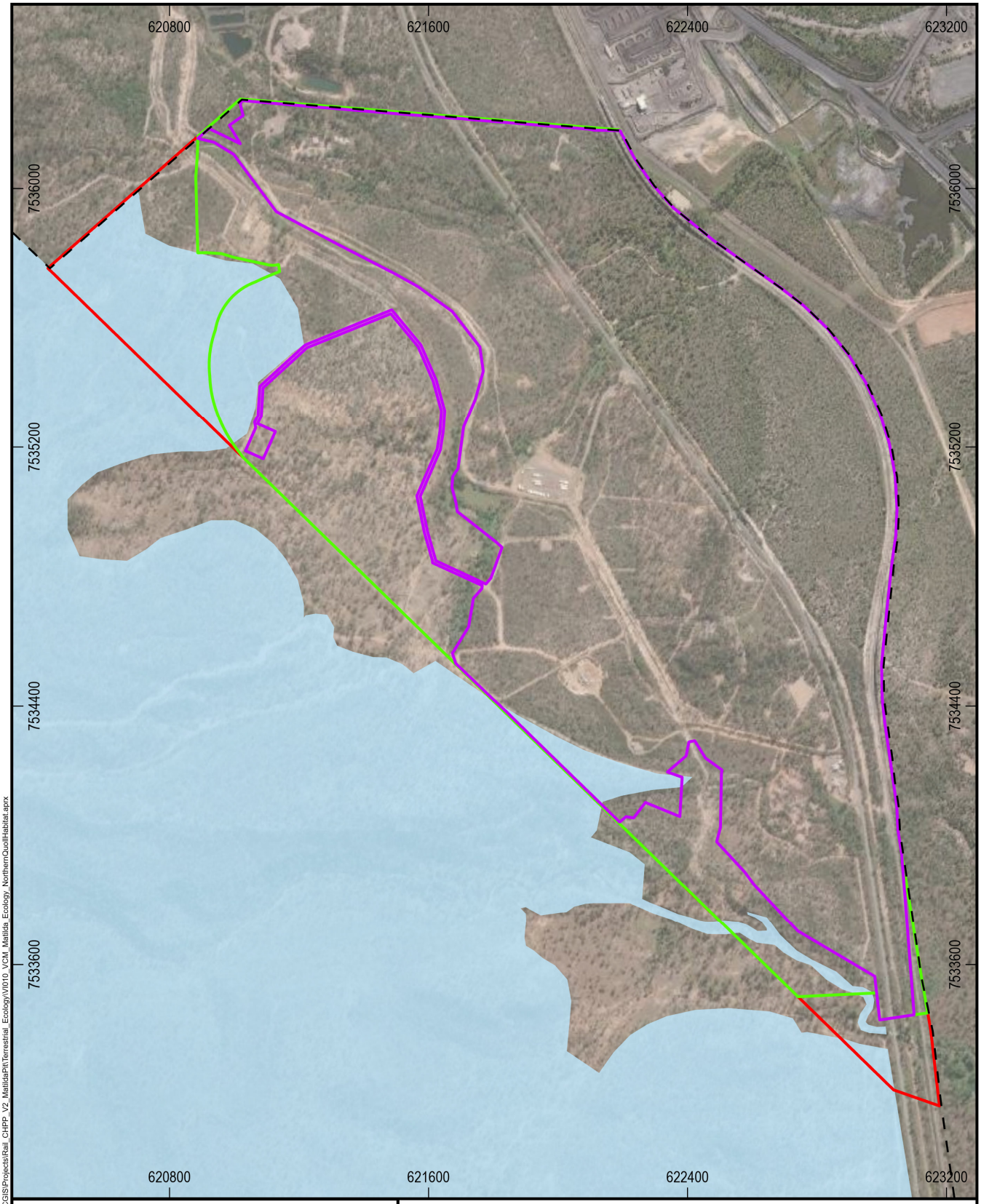
An action is likely to have a significant impact on an endangered species if there is a real chance or possibility that it will:

- lead to a long-term decrease in the size of a population;
- reduce the area of occupancy of the species;
- fragment an existing population into two or more populations;
- adversely affect habitat critical to the survival of a species;
- disrupt the breeding cycle of a population;
- modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline;
- result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat;
- introduce disease that may cause the species to decline; or
- interfere with the recovery of the species.

Important habitat for the Northern Quoll is located in "rocky habitats, treed creek lines and structurally diverse forest with large trees, termite mounds and hollow logs" (Department of the Environment 2016), which is locally restricted to the Harrow Range and major watercourses (see **Section 4.3.2.7**). Some of this habitat (up to 10.8 ha; 0.4 % of the total potential Northern Quoll habitat within the survey area) will be removed for the VCM amendment (**Figure 5-7**). No Northern Quolls were recorded there.

Overall, the impacts of the VCM amendment on the Northern Quoll are difficult to predict as a result of uncertainty as to whether any of the potential habitat for Northern Quolls is occupied by the species. Extensive survey efforts, in optimal conditions, failed to detect one within the survey area. There are also no records of the species west of the Clarke Range or Redcliffe Plateau in the past 40 years. It is therefore most likely that the Northern Quoll is absent from the vicinity of the VCM, and the amendment will not affect the species.

In the unlikely event that the species does occur on site, the VCM amendment may have a residual impact on the Northern Quoll under the EPBC Act. However, key habitats in rocky gorges west of the project area will remain undisturbed, and the VCM is not expected to affect local population size, connectedness or viability. Overall, it is considered unlikely that the VCM amendment will affect the Northern Quoll, but the action should be referred to the Department of Climate Change, Energy, the Environment and Water for a formal assessment in order to decide on whether the anticipated impacts to the Northern Quoll qualify as significant.



Legend

- Survey Area
- ML 700060
- Approved Maximum Disturbance Footprint
- Proposed Additional Disturbance Footprint

Potential Northern Quoll Habitat

- Habitat Within 300m of Water
- Landzone 3 and 10

Source: Vitrinite 2022, METServe 2020-2022, Maxar.

Vulcan Coal Mine Amendment

Project Footprint Relative to Potential Northern Quoll Habitat

0 300 600

Meters

Scale: 1:17,000 (A4)

14/06/2022

Datum: GDA2020
Projection: MGA55

FIGURE 5-7

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\Terrestrial_Ecology\VI010_VCM_Matilda_Ecology_NorthernQuollHabitat.aprx

5.3.3.9 Australian Painted-snipe

The VCM amendment will not remove any dams or wetlands that could provide habitat for the Australian Painted-snipe. A small farm dam that will be surrounded by mine infrastructure will be exposed to elevated noise and light, which may discourage utilisation of the site by the Australia Painted-snipe. These effects will be of short duration (up to four years), given the short life of the VCM. Furthermore, the habitat provided by this dam is of marginal quality to begin with.

Given the low-quality of the habitat present, and the short duration of disturbance, the VCM amendment is expected to have a negligible impact on the Australian Painted-snipe. The action is unlikely to trigger any of the significant impacts on an endangered species defined by the *Matters of National Environmental Significance Significant Impact Guidelines 1.1*.

5.3.3.10 Red Goshawk

Red Goshawks are probably extinct in the local region. Potential habitat for the species that occurs on site is of poor quality; escarpments and nearby waterways mostly lack surface water, and the surrounding landscape is already highly modified through mining and clearing for grazing. The Red Goshawk rarely breeds in areas with fragmented native vegetation (Threatened Species Scientific Committee 2015b), and never more than 1 km from water. Consequently, the importance of the region to the species is considered to be low. The loss of 37.8 ha of possible local habitat for the species (all remnant and regrowth, as defined on the field-verified vegetation map) is, therefore, considered inconsequential for its long-term conservation. The VCM amendment does not trigger any of the significant impacts on vulnerable species defined by the *Matters of National Environmental Significance Significant Impact Guidelines 1.1*.

5.3.3.11 Annual Wiregrass

No habitat for Annual Wiregrass (i.e., basalt-derived, clay soil) is present within the project area. The VCM amendment does not trigger any of the significant impacts on vulnerable species defined by the *Matters of National Environmental Significance Significant Impact Guidelines 1.1*.

5.3.3.12 Ghost Bat

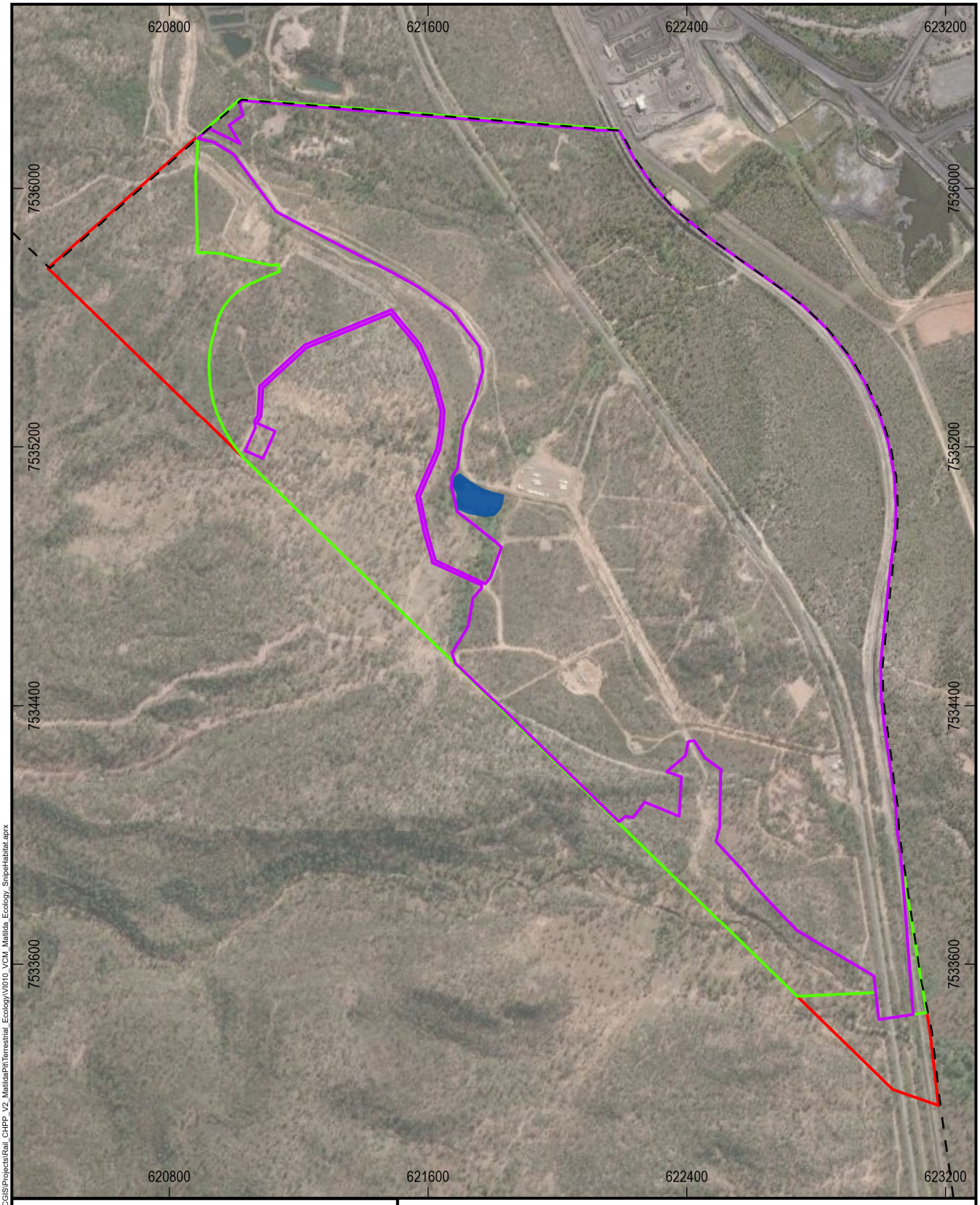
The VCM amendment will not disturb any roosts for Ghost Bats or remove foraging habitat within 1-10 km of known roost sites. It is unlikely that the project footprint contains important habitat for the species, and no residual impacts on Ghost Bats are anticipated.

5.3.3.13 Dunmall's Snake

The *Draft Referral Guidelines for the Nationally Listed Brigalow Belt Reptiles* defines important habitat for the Dunmall's Snake as any forest or woodland "within the 'Known/Likely to occur' modelled distribution of the species…and any habitat corridors in between" (Department of Sustainability, Environment, Water, Population and Communities 2011). As the disturbance area lies outside the known/likely distribution of the Dunmall's Snake, as modelled in the *Draft Referral Guidelines for the Nationally Listed Brigalow Belt Reptiles*, no significant impacts to the species are anticipated.

5.3.3.14 Allan's Lerista

The *Draft Referral Guidelines for the Nationally Listed Brigalow Belt Reptiles* (Department of Sustainability, Environment, Water, Population and Communities 2011) defines important habitat for the species as being "vegetation occurring on mid to dark-brown-coloured, non-cracking clay soils in Queensland regional ecosystems 11.8.5 and 11.8.11/11.8.5 and grassy open-woodland mapped as cleared but where the above regional ecosystems formerly occurred". The project area does not contain important habitat for the species, and no significant residual impacts of the VCM amendment are anticipated.



Legend

- Survey Area
- ML 700060
- Approved Maximum Disturbance Footprint
- Proposed Additional Disturbance Footprint
- Potential Australian Painted-snipe Habitat

Source: Vitrinite 2022, METServe 2020-2022, Maxar.

Vulcan Coal Mine Amendment

Project Footprint Relative to Potential Habitat for Australian Painted-snipe

0 150 300 600

Meters

Scale: 1:17,000 (A4)

14/06/2022

Datum: GDA2020
Projection: MGA55

FIGURE 5-8

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\Terrestrial_Ecology\VI010_VCM_Matilda_Ecology_SnipeHabitat.aprx

5.3.3.15 King Bluegrass

No habitat for King Bluegrass (i.e., basalt-derived, clay soil) is present within the project area. The VCM amendment does not trigger any of the significant impacts on endangered species defined by the *Matters of National Environmental Significance Significant Impact Guidelines 1.1*.

5.3.3.16 Hairy Bluegrass

No habitat for Hairy Bluegrass (i.e., clay soil) is present within the project area. The VCM amendment does not trigger any of the significant impacts on vulnerable species defined by the *Matters of National Environmental Significance Significant Impact Guidelines 1.1*.

5.3.3.17 Migratory Species

The Rufous Fantail and White-throated Needletail are migratory species that utilise habitats in the vicinity of the VCM. The latter is also a vulnerable species (see **Section 5.3.3.5**). The Fork-tailed Swift, Latham's Snipe, Oriental Cuckoo, Black-faced Monarch and Satin Flycatcher are additional migratory species that possibly utilise habitats in the vicinity of the VCM. An action is likely to have a significant impact on a migratory species if there is a real chance or possibility that it will:

- Substantially modify (including by fragmenting, altering fire regimes, altering nutrient cycles or altering hydrological cycles), destroy or isolate an area of important habitat for a migratory species;
- result in an invasive species that is harmful to the migratory species becoming established in an area of important habitat for the migratory species; or
- seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.

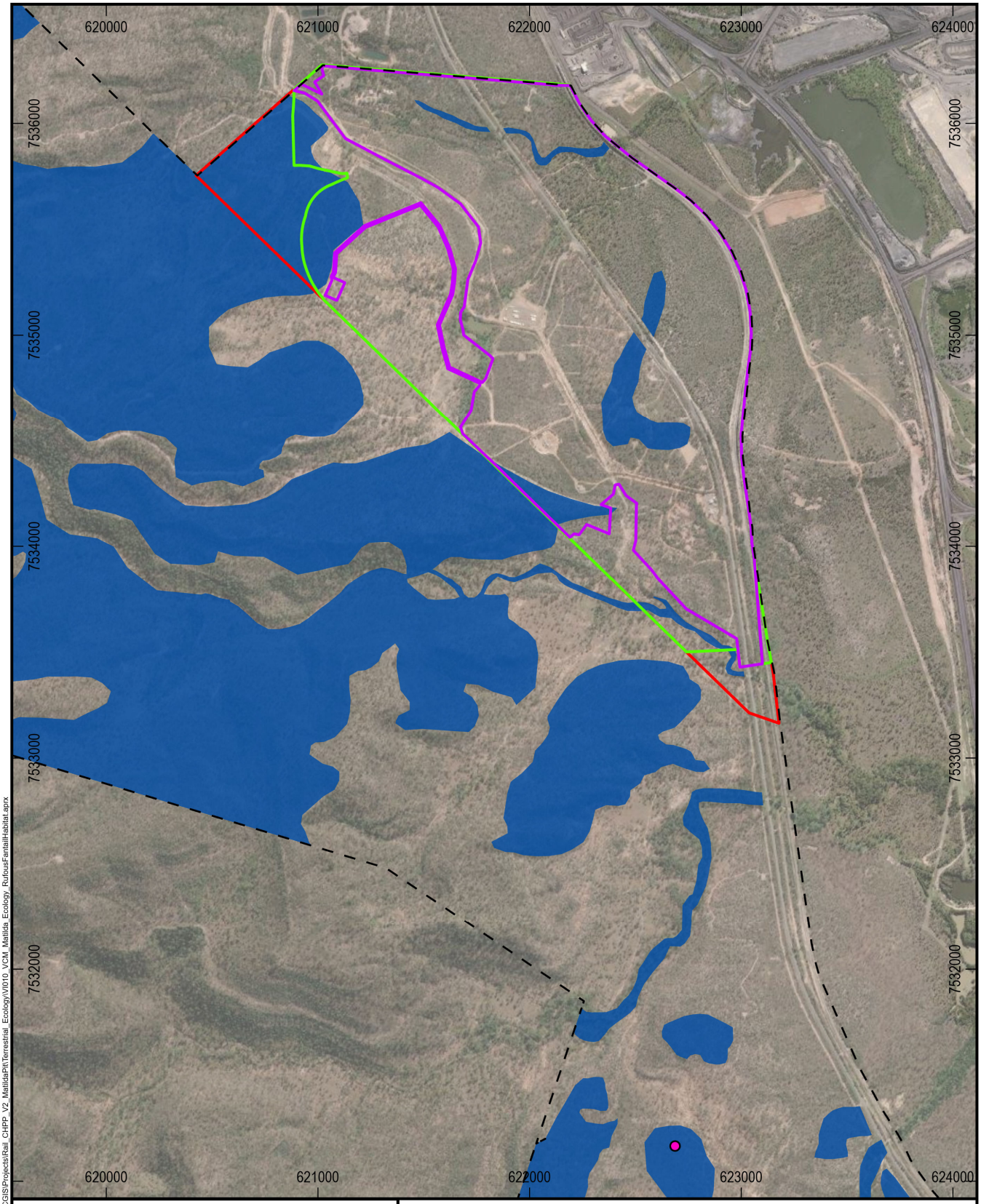
The definitions of "important habitat" for each of these species are defined by the *Referral Guideline for 14 birds Listed as Migratory* (Department of the Environment 2015a), the *Industry Guidelines for Avoiding, Assessing and Mitigating Impacts on EPBC Act listed Migratory Shorebird Species* (Department of Agriculture, Water and the Environment 2017) and the *Revision of the East Asian-Australasian Flyway Population Estimates for 37 Listed Migratory Shorebird Species* (Hansen *et al.* 2017). These are summarised in **Table 5-7**.

Table 5-7 Definitions of "important habitat" and "ecologically significant proportion of the population" for migratory species potentially utilising the project area

Species	Important habitat	Invasive species that could be harmful	Ecologically significant proportion of the population	Area of important habitat likely to result in a significant impact if affected
Rufous Fantail	Moist, dense habitats, including mangroves, rainforest, riparian forests and thickets, and wet eucalypt forests with a dense understorey. When on passage a wider range of habitats are used including dry eucalypt forests and woodlands and Brigalow shrublands.	Black Rat *Rattus rattus*, invasive vines of riparian habitat (e.g. rubber vine *Cryptostegia grandiflora*).	1,100 individuals	260 ha
Fork-tailed Swift	Found across a range of habitats, from inland open plains to wooded areas, where it is exclusively aerial.	Unknown	100 individuals	Impacts only considered possible when wind turbines, tall buildings, airports, or other developments interrupt airspace.

Species	Important habitat	Invasive species that could be harmful	Ecologically significant proportion of the population	Area of important habitat likely to result in a significant impact if affected
Latham's Snipe	Areas that have previously been identified as internationally important for the species, or areas that support at least 18 individuals of the species.	Feral Cat, Red Fox	18 individuals	Not prescribed
Oriental Cuckoo	Monsoonal rainforest, vine thickets, wet sclerophyll forest or open *Casuarina*, *Acacia* or *Eucalyptus* woodlands. Frequently at edges or ecotones between habitat types. Riparian forest is favoured habitat in the Kimberley region.	Unknown	1,000 individuals	25,000 ha
Black-faced Monarch	Wet forest specialist, found mainly in rainforest and wet sclerophyll forest, especially in sheltered gullies and slopes with a dense understorey of ferns and/or shrubs.	Black Rat *Rattus rattus*, invasive vines of riparian habitat (e.g. rubber vine *Cryptostegia grandiflora*).	460 individuals	260 ha
Satin Flycatcher	Eucalypt forest and woodlands, at high elevations when breeding. They are particularly common in tall wet sclerophyll forest, often in gullies or along water courses. In woodlands they prefer open, grassy woodland types. During migration, habitat preferences expand, with the species recorded in most wooded habitats except rainforests. Wintering birds in northern Queensland will use rainforest/gallery forests interfaces, and birds have been recorded wintering in mangroves and paperbark swamps.	Black Rat *Rattus rattus*, invasive vines of riparian habitat (e.g. rubber vine *Cryptostegia grandiflora*).	1,700 individuals	440 ha

The VCM amendment will not disrupt an ecologically significant proportion of any migratory species. The amendment is also not anticipated to cause the establishment of harmful invasive species. Within the project's footprint, important habitat (as defined by Department of the Environment 2015a) exists for the Rufous Fantail, Oriental Cuckoo and Satin Flycatcher. However, the habitats present on site are marginal (more inland, drier and open than is generally preferred) for all three species. It is expected that only one or two Oriental Cuckoos and Satin Flycatchers, and up to 10 Rufous Fantails, pass through the survey area each year. A total of 14.3 ha of potential habitat for transient Rufous Fantails is contained within the disturbance footprint of the VCM amendment (**Figure 5-9**), along with 1.7 ha of potential habitat for transient Satin Flycatchers and Oriental Cuckoos. It is highly unlikely that the marginal habitats to be disturbed are a limiting factor constraining the migration of any of the migratory bird species listed in **Table 5-7**. For this reason, it is considered unlikely that VCM amendment will result in a significant impact on any migratory species protected under the EPBC Act.



Legend

- Survey Area
- ML 700060
- Approved Maximum Disturbance Footprint
- Proposed Additional Disturbance Footprint
- Rufous Fantail Sighting
- Rufous Fantail Habitat

Source: Vitrinite 2022, METServe 2020-2022, Maxar.

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\Terrestrial_Ecology\VI010_VCM_Matilda_Ecology_RufousFantailHabitat.aprx

Vulcan Coal Mine Amendment

Project Footprint Relative to Rufous Fantail Habitat

0 0.25 0.5 1

Kilometers

Scale: 1:26,000 (A4)

14/06/2022

Datum: GDA2020
Projection: MGA55

FIGURE 5-9

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

5.3.4 Species of State Environmental Significance

Most species of State environmental significance are also matters of national significance, and potential impacts to these matters were assessed in **Section 5.3.3**. Nevertheless, the Queensland Government applies different definitions of "significant impacts" under the NC Act to the definitions under the EPBC Act. As the criteria differ for threatened wildlife and special least concern wildlife, these are assessed separately in **Table 5-8** and **Table 5-9**, respectively.

Table 5-8 Assessment of significance of impacts to threatened species of state significance

Threatened Species	Will there be a long-term decrease in the size of a local population?	Will the extent of occurrence of the species be reduced?	Will an existing population be fragmented?	Will it cause genetically distinct populations to form through isolation?	Will it result in harmful invasive species?	Will it introduce disease?	Will it interfere with the recovery of the species?	Will it cause disruption to ecologically significant locations?*
Koala	No	Minor	No	No	No	No	No	Yes
Greater Glider	No	Minor	No	No	No	No	No	Yes
Squatter Pigeon	No	Minor	No	No	No	No	No	Yes
Glossy Black-cockatoo	No	No	No	No	No	No	No	No
White-throated Needletail	No	No	No	No	No	No	No	No
Ornamental Snake	No	No	No	No	No	No	No	No
Australian Painted-snipe	No	No	No	No	No	No	No	No
Common Death Adder	No	Possibly Minor	No	No	No	No	No	Possibly Minor
Red Goshawk	No	No	No	No	No	No	No	No
Yakka Skink	No	No	No	No	No	No	No	No
Annual Wiregrass	No	No	No	No	No	No	No	No
Ghost Bat	No	No	No	No	No	No	No	No
Dunmall's Snake	No	No	No	No	No	No	No	No
Allan's Lerista	No	No	No	No	No	No	No	No
King Blue-grass	No	No	No	No	No	No	No	No

*Ecologically significant locations are defined as breeding, feeding, nesting, migration or resting sites.

Table 5-9 Assessment of significance of impacts to Special Least Concern species of state significance

Special Least Concern Species	Will there be a long-term decrease in the size of a local population?	Will the extent of occurrence of the species be reduced?	Will an existing population be fragmented?	Will gene flow among populations be reduced?	Will ecologically significant locations be disrupted?* (net disruption)
Short-beaked Echidna	No	No	No	No	Minor
Fork-tailed Swift	No	No	No	No	No
Latham's Snipe	No	No	No	No	No
Rufous Fantail	No	No	No	No	No
Sharp-tailed Sandpiper	No	No	No	No	No
Oriental Cuckoo	No	No	No	No	No
Gull-billed Tern	No	No	No	No	No
Black-faced Monarch	No	No	No	No	No
Satin Flycatcher	No	No	No	No	No
Glossy Ibis	No	No	No	No	No

*Ecologically significant locations are defined as breeding, feeding or nesting sites.

The State government can only impose an offset condition in relation to a prescribed activity, if the same, or substantially the same impact and the same or substantially the same matter has not been subject to assessment under the EPBC Act. As the VCM amendment is likely to impact several matters of national environmental significance, it will be referred and assessed under the EPBC Act. Consequently, only three matters of state significance (Common Death Adder, Glossy Black-cockatoo and Short-beaked Echidna) will not be assessed under the EPBC Act, and these are therefore discussed in further detail below.

5.3.4.1 Short-beaked Echidna

Short-beaked Echidnas occupy home ranges of 50-100 ha (Nichol *et al*. 2011), and the removal of 93.0 ha of potential habitat (all vegetation within the disturbance footprint) therefore amounts to a loss of one or two territories. Given the extensive and continuous matrix of potential habitat to the west and south of the VCM, these prescribed actions will have a negligible effect on local populations. As the habitat being removed could be used for feeding and breeding, it qualifies as an ecologically significant location according to the *Queensland Environmental Offsets Policy Significant Residual Impact Guideline* (Department of Environment and Heritage Protection 2014). Nevertheless, there are no habitat features of the proposed footprint that make it locally significant, and extensive tracts of similar habitat will be retained to the west. This retained habitat is of a higher quality than most of the habitat being removed, because much of it is remnant vegetation and thus contains an abundance of fallen timber, important for denning and providing termites. Sandstone areas to the west also contain an abundance of boulders, which provide den sites.

The main prey of Short-beaked Echidnas (ants and termites) recolonise rehabilitated mine sites almost immediately (i.e., at the time of soil profile reconstruction: Andersen *et al.* 2003; Spain *et al.* 2010). Likewise, Short-beaked Echidnas recolonise rehabilitated mine sites relatively quickly (8 years: Nichols and Grant 2007; 6-10 years: unpublished data from Gove, Northern Teritory). Consequently, any impacts of the VCM amendment on the Short-beaked Echidna will be short-term only.

5.3.4.2 Glossy Black-cockatoo

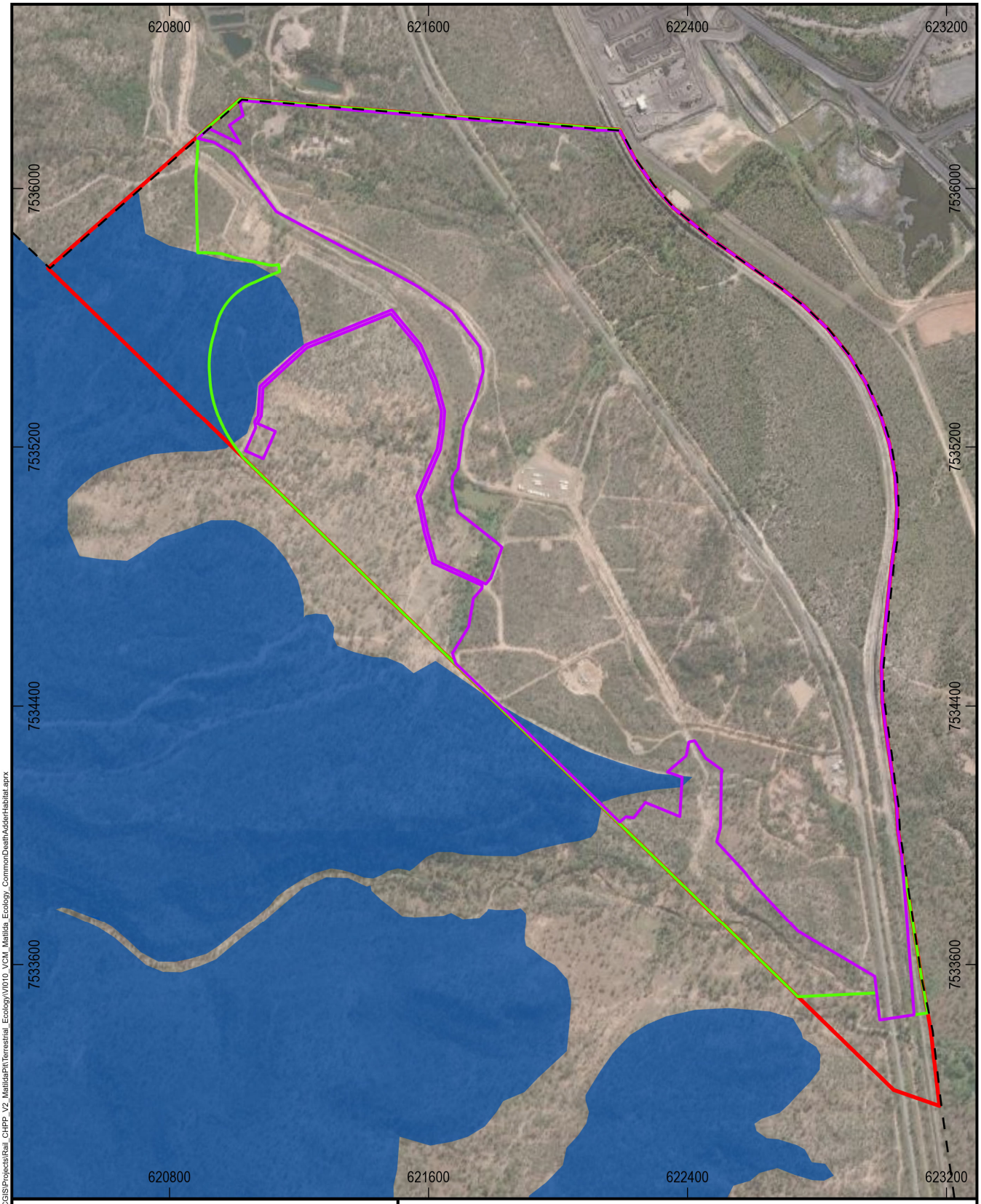
No food trees for the Glossy Black-cockatoo will be removed for the VCM amendment. *Casuarina cristata* (the local food tree) is a sub-dominant component of regional ecosystems 11.4.9 and 11.4.8, neither of which occurs in the vicinity of the project area.

5.3.4.3 Common Death Adder

While no Common Death Adders were detected in the survey area, possible habitat for the species occurs on site. The VCM amendment largely avoids habitat of the highest quality (remnant vegetation with sandstone boulders in elevated areas where Cane Toads are least abundant), which occurs throughout the Harrow Range to the west of the project area (**Figure 5-10**). Nevertheless, Common Death Adders are not confined to sandstone ranges, and could potentially utilise any vegetated habitats (remnant and regrowth) on site. 37.8 ha of these more marginal habitats (lowland areas with an abundance of Cane Toads and few rocks) will be removed for the VCM amendment.

The project area already supports high densities of Cane Toads, a major threat to Common Death Adders. The construction of new potential toad-breeding locations in the form of sediment dams and water supply dams is unlikely to significantly elevate existing toad densities.

Overall, the low quality of most habitat, the small scale of disturbance to potentially important habitat corridors (along the Harrow Range), and the fact that no Common Death Adders were detected despite extensive survey effort in optimal conditions, means that the VCM amendment will likely have a minor effect on local populations.



Legend

- Survey Area
- ML 700060
- Approved Maximum Disturbance Footprint
- Proposed Additional Disturbance Footprint
- Potential Common Death Adder Habitat

Source: Vitrinite 2022, METServe 2020-2022, Maxar.

Vulcan Coal Mine Amendment

Project Footprint Relative to Potential Habitat for the Common Death Adder

0 150 300 600

Meters

Scale: 1:17,000 (A4)

14/06/2022

Datum: GDA2020
Projection: MGA55

FIGURE 5-10

VITRINITE BRIGHTER COAL

METSERVE Mining & Energy Technical Services Pty Ltd

Path: S:\Projects\VI010_Vulcan_Complex_Project_Jupiter_section\ARCGIS\Projects\Rail_CHPP_V2_MatildaPit\Terrestrial_Ecology\VI010_VCM_Matilda_Ecology_CommonDeathAdderHabitat.aprx

5.4 OFFSET REQUIREMENTS

Offsets are required if the residual impacts to prescribed matters, after avoidance and mitigation measures have been implemented, are considered significant in accordance with the relevant guidelines.

5.4.1 National

Based on the assessment contained in **Section 5.3.3**, the following impacts of the VCM amendment on matters of national environmental significance are likely to qualify as significant impacts:

- Removal of 1.7 ha of high-quality habitat and 82.2 ha of low-quality habitat for the Koala;
- Removal of 1.7 ha of habitat for the Central Greater Glider; and
- Removal of 92.4 ha of foraging habitat (76.4 ha of which is also breeding habitat) for the Squatter Pigeon.

The VCM amendment may possibly also affect the Northern Quoll, although this species was not recorded on site, and the habitat present is suboptimal. Due to the likelihood of the above impacts, the project should be referred to the Department of Climate Change, Energy the Environment and Water for approval under the EPBC Act. It is likely that approval for the project will be conditional on the provision of offsets in accordance with *EPBC Act Environmental Offsets Policy 2012.* An offset proposal should be developed for all matters likely to experience a significant residual impact.

5.4.2 State

Significant residual impacts to matters of state significance may require offsetting under the *Environmental Offsets Act 2014.* In Queensland, the significance of residual impacts to prescribed matters is defined by the *Queensland Environmental Offsets Policy Significant Residual Impact Guideline* (Department of Environment and Heritage Protection 2014), which is administered under the *Environmental Offsets Act 2014*.

As the matters of state environmental significance that are most likely to experience significant impacts are also matters of national environmental significance (to be assessed under the EPBC Act), duplicate offsets are not required. In accordance with the *Queensland Environmental Offsets Policy 2017*, the Queensland Government can only impose an offset condition in relation to a prescribed activity, if the same, or substantially the same, impact and the same, or substantially the same, matter has not been subject to assessment as a controlled action under the EPBC Act. However, an activity referred to the Commonwealth Government that receives a 'not a controlled action' or a 'not controlled action - particular manner' notice, could still be subject to an offset condition imposed by the Queensland Government. Given that it is likely that the VCM amendment will be considered a controlled action, only state matters that are not protected under the EPBC Act may require offsetting under the *Environmental Offsets Act 2014.*

Despite being matters of state environmental significance, Category R vegetation and Category C vegetation are not prescribed matters (defined in Schedule 2 of the *Environmental Offsets Regulation 2014*) and do not require offsetting.

In addition to the above vegetation, impacts to low-quality habitat for the Short-beaked Echidna (special least concern) and Common Death Adder (vulnerable) possibly qualify as significant, due to the disturbance of potential feeding and/or breeding sites, which qualify as "ecologically significant locations". Nevertheless, not all significant impacts require offsets under the Queensland Environmental Offset Framework; according to the *Queensland Environmental Offsets Policy Significant Residual Impact Guideline* (Department of Environment and Heritage Protection 2014), if residual impacts are significant an offset *may* be required. In light of the small scale of the proposed impacts, the possible absence of Common Death Adders from the site, and the negligible effects the VCM amendment is likely to have on local populations of these two species, offsets may not be deemed necessary. This decision ultimately lies with the Department of Environment and Science, who will assess this via the Environmental Authority application process.

6 REFERENCES CITED

Andersen, A.N., B.D. Hoffmann and J. Somes (2003). Ants as indicators of minesite restoration: community recovery at one of eight rehabilitation sites in central Queensland. *Ecological Management & Restoration* **4,** S12-S19.

Anderson, V.J. and K.C. Hodgkinson (1997). Grass-mediated capture of resource flows and the maintenance of banded mulga in a semi-arid woodland. *Australian Journal of Botany* **45,** 331-342.

Armstrong, K.N. and S. Antee (2000). The ghost bat in the Pilbara: 100 years on. *Australian Mammalogy* **22,** 93-101.

Augee, M.L. (2008). Short-beaked Echidna. In: S. van Dyck and R. Strahan (eds) *The Mammals of Australia third edition.* New Holland Publishers (Australia), Sydney.

Australian Koala Foundation (2015). *National Koala Tree Planting List.* Available online at: https://www.savethekoala.com/about-koalas/trees-koalas.

Bacon, P.E., C. Stone, D.L. Binns, D.J. Leslie and D.W. Edwards (1993). Relationships between water availability and *Eucalyptus camaldulensis* growth in a riparian forest. *Journal of Hydrology* **150,** 541-561.

Baker, B.J. and J.M.L. Richardson (2006). The effect of artificial light on male breeding-season behaviour in green frogs, *Rana clamitans melanota*. *Canadian Journal of Zoology* **84,** 1528–1532.

Barber, J.R., K.R. Crooks and K.M. Fristrup (2010). The costs of chronic noise exposure for terrestrial organisms. *Trends in Ecology and Evolution* **25,** 180-189.

Barrett, G., A. Silcocks, S. Barry, R. Cunningham and R. Poulter (2003). The New Atlas of Australian Birds. Birds Australia, Hawthorn East, Victoria.

Ben-Shlomo, R. and C. Kyriacou (2010). Light pulses administered during the circadian dark phase alter expression of cell cycle associated transcripts in mouse brain. *Cancer Genetics and Cytogenetics* **197,** 65--70.

Benyon, R.G., S. Theiveyanathan and T.M. Doody (2006). Impacts of tree plantations on groundwater in south-eastern Australia. *Australian Journal of Botany* **54,** 181-192.

Beyer, G.L., and R.L. Goldingay 2006. The value of nest boxes in the research and management of Australian hollow-using arboreal marsupials. *Wildlife Research* **33,** 161-174.

Braithwaite, R.W. and A.D. Griffiths (1994). Demographic variation and range contraction in the Northern Quoll, *Dasyurus hallucatus* (Marsupialia: Dasyuridae). *Wildlife Research* **21,** 203-207.

Bureau of Meteorology (BOM) (2019). *National Atlas of Groundwater Dependent Ecosystems.* Australian Government, Canberra. Accessed at: http://www.bom.gov.au/water/groundwater/gde/.

Callaghan, J., C. McAlpine, D. Mitchell, J. Thompson, M. Bowen, J. Rhodes, C. de Jong, R. Domalewski and A. Scott (2011). Ranking and mapping koala habitat quality for conservation planning on the basis of indirect evidence of tree-species use: a case study of Noosa Shire, south-eastern Queensland. *Wildlife Research* **38,** 89-102.

Chapman, T.F. (2007). Foods of the Glossy Black-Cockatoo *Calyptorhynchus lathami*. *Australian Field Ornithology* **24,** 30-36.

Comport, S.S., S.J. Ward and W.J. Foley (1996). Home ranges, time budgets and food-tree use in a high-density tropical population of Greater Gliders, *Petauroides volans minor* (Pseudocheiridae: Marsupialia). *Wildlife Research* **23,** 401-419.

Conrad, K., M. Warren, R. Fox, M. Parsons and I. Woiwod (2006). Rapid declines of common, widespread British moths provide evidence of an insect biodiversity crisis. *Biological Conservation* **132,** 279—291.

Cook, P.G. and A.P. O'Grady (2006). Determining soil and ground water use of vegetation from heat pulse, water potential and stable isotope data. *Oecologia* **148,** 97-107.

Cornell Lab of Ornithology (2022). eBird Basic Dataset. Cornell University, Ithaca, New York.

Cristescu, R.H.A. (2011). Fauna recolonisation of mine rehabilitation through the example of arboreal marsupials, with a particular focus on the koala Phascolarctos cinereus. *PhD thesis: School of Biological, Earth and Environmental Sciences*, University of New South Wales.

Cristescu, R.H., J. Rhodes, C. Frére and P.B. Banks (2013). Is restoring flora the same as restoring fauna? Lessons learned from koalas and mining rehabilitation. *Journal of Applied Ecology* **50,** 423-431.

Crome, F.H.J. (1976). Breeding, moult and food of the Squatter Pigeon in north-eastern Queensland. *Australian Wildlife Research* **3,** 45-59.

Crowley, G. (2008). Cockatoo Grass *Alloteropsis semialata* as a Keystone Species in Northern Australia. *Northern Territory Naturalist* **20,** 58-63.

Crowther, M.S., D. Lunney, J. Lemon, E. Stalenberg, R. Wheeler, G. Madani, K.A. Ross and M. Ellis (2013). Climate-mediated habitat selection in an arboreal folivore. *Ecography* **37,** 336-343.

Cunnington, G.M. and L. Fahrig (2010). Plasticity in the vocalizations of anurans in response to traffic noise. *Acta Oecologica* **36,** 463-470.

Czechura, G.V, R.G. Hobson and D.A. Stewart (2010). Distribution, status and habitat of the Red Goshawk *Erythrotriorchis radiatus* in Queensland. *Corella* **35,** 3-10.

Davies, T., J. Bennie and K. Gaston (2012). Street lighting changes the composition of invertebrate communities. *Biology Letters*, e20120216.

Department of Agriculture, Water and the Environment (2017). *Industry Guidelines for Avoiding, Assessing and Mitigating Impacts on EPBC Act Listed Migratory Shorebird Species.* EPBC Act Policy Statement 3.21. Australia Government, Canberra.

Department of Agriculture, Water and the Environment (2022a). *National Recovery Plan for the Koala* Phascolarctos cinereus *(Combined Populaitons of Queensland, New South Wales and the Australian Capital Territory).* Australia Government, Canberra.

Department of Agriculture, Water and the Environment (2022b). Conservation advice for *Phascolarctos cinereus* (Koala) combined populations of Queensland, New South Wales and the Australian Capital Territory. In effect from 12 February 2022.

Department of Climate Change, Energy, the Environment and Water (2022a). Semi-evergreen vine thickets of the Brigalow Belt (North and South) and Nandewar Bioregions. Species Profile and Threats Database. Australian Government, Canberra.

Department of Climate Change, Energy, the Environment and Water (2022b). *Geophaps scripta scripta* — Squatter Pigeon (southern). Species Profile and Threats Database. Australian Government, Canberra.

Department of Climate Change, Energy, the Environment and Water (2022c). *Phascolarctos cinereus* (combined populations of Qld, NSW and the ACT) — Koala (combined populations of Queensland, New South Wales and the Australian Capital Territory). Species Profile and Threats Database. Australian Government, Canberra.

Department of Climate Change, Energy, the Environment and Water (2022d). *Denisonia maculata* — Ornamental Snake. Species Profile and Threats Database. Australian Government, Canberra.

Department of Climate Change, Energy, the Environment and Water (2022e). *Egernia rugosa* — Yakka Skink. Species Profile and Threats Database. Australian Government, Canberra.

Department of Climate Change, Energy, the Environment and Water (2022f). *Rostratula australis* — Australian Painted Snipe. Species Profile and Threats Database. Australian Government, Canberra.

Department of Climate Change, Energy, the Environment and Water (2022g). *Aristida annua*. Species Profile and Threats Database. Australian Government, Canberra.

Department of Climate Change, Energy, the Environment and Water (2022h). *Furina dunmallii* — Dunmall's Snake. Species Profile and Threats Database. Australian Government, Canberra.

Department of Climate Change, Energy, the Environment and Water (2022i). *Lerista allanae* — Allan's Lerista, Retro Slider. Species Profile and Threats Database. Australian Government, Canberra.

Department of Climate Change, Energy, the Environment and Water (2022j). *Dichanthium queenslandicum* — King Blue-grass. Species Profile and Threats Database. Australian Government, Canberra.

Department of Climate Change, Energy, the Environment and Water (2022k). *Dichanthium setosum* — Blue-grass. Species Profile and Threats Database. Australian Government, Canberra.

Department of Climate Change, Energy, the Environment and Water (2022l). *Hirundapus caudacutus* — White-throated Needletail. Species Profile and Threats Database. Australian Government, Canberra.

Department of Environment and Energy (2017). *Industry Guidelines for Avoiding, Assessing and Mitigating Impacts on EPBC Act Listed Migratory Shorebird Species.* EPBC Act Policy Statement 3.21. Australian Government, Canberra.

Department of Environment and Heritage Protection (2014). *Queensland Environmental Offsets Policy Significant Residual Impact Guideline.* Queensland Government, Brisbane.

Department of Environment and Heritage Protection (2016). *Eligibility criteria and standard conditions for mining lease activities—Version 2.0.* Queensland Government, Brisbane.

Department of Environment and Heritage Protection (2017a). *State Government Supported Infrastructure: Koala Conservation Policy.* Queensland Government, Brisbane.

Department of Environment and Heritage Protection (2017b). *Queensland Environmental Offsets Policy (Version 1.4).* Queensland Government, Brisbane.

Department of Environment and Science (2020). *Queensland Environmental Offsets Policy—Version 1.9.* Queensland Government, Brisbane.

Department of Environment and Resource Management (2012). National recovery plan for the red goshawk *Erythrotriorchis radiatus*. Report to the Department of Sustainability, Environment, Water, Population and Communities, Canberra. Queensland Department of Environment and Resource Management, Brisbane.

Department of Industry, Science, Energy and Resources (2020). *National Forest and Sparse Woody Vegetation Data (Version 5.0 – 2020 Release).* Data available at: https://data.gov.au/data/dataset/69d09a6c-df77-439f-8bc7-87822cd520fd.

Department of Natural Resources, Mines and Energy (DNRME) (2019a). Technical summary: terrestrial groundwater-dependent ecosystems in the Surat Cumulative Management Area. Literature review and desktop impact assessment method. Queensland Government, Brisbane.

Department of Natural Resources, Mines and Energy (DNRME) (2019b). Queensland groundwater and surface water monitoring. Queensland Government, Brisbane. Accessed at https://gisservices.information.qld.gov.au/arcgis/rest/services/InlandWaters/GroundAndSurfaceWaterMonitoring/MapServer

Department of Science, Information Technology and Innovation (2015). Queensland Groundwater Dependent Ecosystem Mapping Method v 1.1. State of Queensland, Brisbane.

Department of Sustainability, Environment, Water, Population and Communities (2011). *Draft Referral Guidelines for the Nationally Listed Brigalow Belt Reptiles.* Australian Government, Canberra.

Department of the Environment (2013). *Matters of National Environmental Significance. Significant Impact Guidelines 1.1.* Australian Government, Canberra.

Department of the Environment (2014). *EPBC Act Referral Guidelines for the vulnerable koala (combined populations of Queensland, New South Wales and the Australian Capital Territory),* Commonwealth of Australia.

Department of the Environment (2015a). *Referral guideline for 14 birds listed as migratory under the EPBC Act.* Australian Government, Canberra.

Department of the Environment (2015b). *Wildlife Conservation Plan for Migratory Shorebirds.* Australian Government, Canberra.

Department of the Environment (2016). *EPBC Act Referral Guidelines for the Endangered Northern Quoll* Dasyurus hallucatus. Australian Government, Canberra.

Diete, R.L., K.M. Dixon and P.A. Barden (2016). Predation of pitfall-trapped rodents by the ghost bat, *Macroderma gigas. Australian Mammalogy* **38,** 249-252.

Eamus, D., R. Froend, R. Loomes, G. Hose and B. Murray (2006a). A functional methodology for determining the groundwater regime needed to maintain the health of groundwater-dependent vegetation. *Australian Journal of Botany* **54,** 97-114.

Eamus, D., T. Hatton, P. Cook, C. Colvin (2006b). *Ecohydrology: Vegetation Function, Water and Resource management*. CSIRO Publishing: Australia.

Ellis, W.A.H., A. Melzer, F.N. Carrick and M. Hasegawa (2002). Tree use, diet and home range of the koala (*Phascolarctos cinereus*) at Blair Athol, central Queensland. *Wildlife Research* **29,** 303-311.

Eyre, T.J., D.J. Ferguson, C.L. Hourigan, G.C. Smith, M.T. Mathieson, A.L. Kelly, M.F. Venz, L.D. Hogan and J. Rowland (2018). *Terrestrial Vertebrate Fauna Survey Assessment Guidelines for Queensland.* Version 3.0. Department of Environment and Science, Queensland Government, Brisbane.

Farmer, A. (1993). The effects of dust on vegetation—a review. *Environmental Pollution* **79,** 63-75.

Farrell, R.C.C., D.T. Bell, K. Akilan and J.K. Marshall (1996). Morphological and physiological comparisons of clonal lines of *Eucalyptus camaldulensis.* II. Responses to waterlogging/salinity and alkalinity. *Australian Journal of Plant Physiology* **23,** 509-518.

Fensham, R.J. (1999). Native grasslands of the Central Highlands, Queensland, Australia. Floristics, regional context and conservation. *Rangelands Journal* **21,** 82-103.

Fensham, R.J. and R.J. Fairfax (2007). Drought-related tree death and savanna eucalypts: species susceptibility, soil conditions and root architecture. *Vegetation Science* **18,** 71-80.

Fensham, R.J., J.E. Holman and M.J. Cox (1999). Plant species responses along a grazing disturbance gradient in Australian grassland. *Journal of Vegetation Science* **10,** 77-86.

Fraser, F., V. Lawson, S. Morrison, P. Christophersen, S. McGreggor and M. Rawlinson (2003). Fire management experiment for the declining Partridge Pigeon, Kakadu National Park. *Ecological Management and Restoration* **4,** 94-102.

Gibbons, P., and D. Lindenmayer (2002). Tree hollows and wildlife conservation in Australia. CSIRO Publishing, Collingwood.

Gow, L.J., D.J. Barrett, L.J. Renzullo, S.R. Phinn and A.P. O'Grady (2016). Characterising groundwater use by vegetation using a surface energy balance model and satellite observations of land surface temperature. *Environmental Modelling and Software* **80,** 66-82.

Grigg, A., M. Shelton and B. Mullen (2000). The nature and management of rehabilitated pastures on open-cut coal mines in central Queensland. *Tropical Grasslands* **34,** 242-250.

Hansen, B.D., R.A. Fuller, D. Watkins, D.I. Rogers, R.S. Clemens, M. Newman, E.J. Woehler and D.R. Weller (2017). *Revision of the East Asian-Australasian Flyway Population Estimates for 37 Listed Migratory Shorebird Species.* Report for the Department of the Environment. BirdLife Australia, Melbourne.

Henry, S.R. (1984). Social organisation of the greater glider (*Petauroides volans*) in Victoria. In *Possums and Gliders* (eds A. P. Smith & I. D. Hume), pp. 221-228. Surrey Beatty and Sons, Chipping Norton.

Hill, B.M. and S.J. Ward (2010). *National Recovery Plan for the Northern Quoll,* Dasyurus hallucatus. Department of Natural Resources, Environment, The Arts and Sport, Darwin.

Hoskin, C.J. (2019). Description of three new velvet geckos (Diplodactylidae: *Oedura*) from inland eastern Australia, and redescription of *Oedura monilis* De Vis. *Zootaxa* 4683(2).

Howell, J., A. Laskey and J. Tanner (1954). Bird mortality at airport ceilometers. *The Wilson Bulletin* **66,** 207--215.

Hydrogeologist.com.au (2022). Vulcan Coal Mine EA Amendment Groundwater Impact Assessment. Report prepared for Mining & Energy Technical Services Pty Ltd (METServe).

Jackson, S. M. (2015). Family Pseudocheiridae (Ringtail Possums and Greater Gliders). In *Handbook of the Mammals of the World. Volume 5: Monotremes and Marsupials* (eds R.A. Mittermeier & D.E. Wilson) pp 654–658 (Springer, Barcelona).

Jin, X.M., M.E. Schaepman, J.G. Clevers, Z.B. Su and G. Hu (2011). Groundwater depth and vegetation in the Ejina area, China. *Arid Land Research and Management* **25,** 194-199.

Katerji, N., J.W. van Hoorn, A. Hamdy and M. Mastrorilli (2003). Salinity effect on crop development and yield, analysis of salt tolerance according to several classification methods. *Agricultural Water Management* **62,** 37-66.

Kath, J., K. Reardon-Smith, A.F. Le Brocque. F.J. Dyer, E. Dafny, L. Fritz and M. Batterham (2014). Groundwater decline and tree change in floodplain landscapes: identifying non-linear threshold responses in canopy condition. *Global Ecology and Conservation* **2,** 148-160.

Kearney, M.R., B.A. Wintle and W.P. Porter (2010). Correlative and mechanistic models of species distribution provide congruent forecasts under climate change. *Conservation Letters* **3,** 203-213.

Kehl, J.A. and A. Borsboom (1984). Home ranges, den use and activity patterns in the Greater Glider *Petauroides volans.* In: *Possums and Gliders* (eds. A.P. Smith and I.D. Hume) pp. 229-236. Surrey Beatty: Sydney.

Kempenaers, B., P. Borgström, P. Loës, E. Schlicht and M. Valcu (2010). Artificial night lighting affects dawn song, extra-pair siring success, and lay date in songbirds. *Current Biology* **20,** 1735--1739.

Lawler, I.R., W.J. Foley, B.M. Eschler, D.M. Pass and K. Handasyde (1998). Intraspecific variation in *Eucalyptus* secondary metabolites determines food intake by folivorous marsupials. *Oecologia* **116,** 160-169.

Lewis, M. (2007). Foraging responses of the endangered Gouldian Finch to temporal differences in seed availability in northern Australian savanna grasslands. Pages 218-235 in: Bissonette J.A., Storch I. (eds) *Temporal Dimensions of Landscape Ecology*. Springer, Boston.

Lindenmayer, D.B., M.L. Pope and R.B. Cunningham (2004). Patch use by the greater glider (*Petauroides volans*) in a fragmented forest ecosystem. II. Characteristics of den trees and preliminary data on den-use patterns. *Wildlife Research* **31,** 569-577.

Liu, B., H. Guan, W. Zhao, Y. Yang and S. Li (2017). Groundwater facilitated water-use efficiency along a gradient of groundwater depth in arid northwestern China. *Agriculture and Forest Meteorology* **233,** 235-241.

Longcore, T., C. Rich, P. Mineau, B. MacDonald, D. Bert, L. Sullivan, E. Mutrie, S. Gauthreaux Jr, M. Avery, R. Crawford, A.M. Manville II, E.R. Travis and D. Drake (2012). An estimate of avian mortality at communication towers in the United States and Canada. *PLoS ONE* 7, e34025.

Lv, J., X.-S. Wang, Y. Zhou, K. Qian, L. Wan, D. Eamus and Z. Tao (2012). Groundwater-dependent distribution of vegetation in Hailiutu River catchment, a semi-arid region in China. *Journal of Ecohydrology* **6,** 142-149.

McGregor, D.C., A. Padovan, A. Georges, A. Krokenberger, H.-J. Yoon & K.N. Yougentob (2020). Genetic evidence supports three previously described species of greater glider, *Petauroides volans, P. minor* and *P. armillatus. Scientific Reports* **10,** 19284.

McLendon, T., P.J. Hubbard and D.W. Martin (2008). Partitioning the use of precipitation- and groundwater-derived moisture by vegetation in an arid ecosystem in California. *Journal of Arid Environments* **72,** 986-1001.

Melzer, A., R. Cristescu, W. Ellis, S. Fitzgibbon and G. Manno (2014). The habitat and diet of koalas (*Phascolarctos cinereus*) in Queensland. *Australian Mammalogy* **36,** 189-199.

Mensforth, L.J., P.J. Thorburn, S.D. Tyerman and G.R. Walker (1994). Sources of water used by riparian *Eucalyptus camaldulensis* overlying highly saline groundwater. *Oecologia* **1-2,** 21-28.

Miller, M.W. (2006). Apparent effects of light pollution on singing behaviour of American robins. *The Condor* **108,** 130–139.

Mooney, P.A. and L.P. Pedler (2005). Recovery Plan for the South Australian Subspecies of the Glossy Black-cockatoo (*Calyptorhynchus lathami halmaturinus*): 2005-2010. Department for Environment and Heritage, South Australia.

Moore, B.D. and W.J. Foley (2000). A review of feeding and diet selection in koalas (*Phascolarctos cinereus*). *Australian Journal of Zoology* **48,** 317-333.

Moore, B.D., W.J. Foley, I.R. Wallis, A. Cowling and K.A. Handasyde (2005). *Eucalyptus* foliar chemistry explains selective feeding by koalas. *Biology Letters* **1,** 64-67.

Munks, S.A., R. Corkrey and W.J. Foley (1996). Characteristics of arboreal marsupial habitat in the semi-arid woodlands of northern Queensland. *Wildlife Research* **23,** 185-195.

NAFI (2022). *North Australia and Rangelands Fire Information Website.* Accessed at: https://firenorth.org.au/nafi3/

Neldner, V.J., B.A. Wilson, H.A. Dillewaard, T.S. Ryan, D.W. Butler, W.J.F. McDonald, E.P. Addicott and C.N. Appelman (2019). *Methodology for survey and mapping of regional ecosystems and vegetation communities in Queensland.* Version 5.0. Queensland Herbarium, Queensland Department of Environment and Science, Brisbane.

Nelson, J.L., M. P. Scroggie, L.K. Durkin, J.K. Cripps, D.S.L. Ramsey and L.F. Lumsden (2018). Estimating the density of the Greater Glider in the Strathbogie Ranges, North East Victoria, with an assessment of coupes scheduled for timber harvesting in 2018. Arthur Rylah Institute for Environmental Research Technical Report Series No. 293. Department of Environment, Land, Water and Planning, Heidelberg, Victoria.

Ngugi, M.R. and V.J. Neldner (2015). Two-tiered methodology for the assessment and projection of mine vegetation rehabilitation against mine closure restoration goal. *Ecological Management and Restoration* **16,** 215-223.

Nguyen, N.T., H. Saneoka, R. Suwa and K. Fujita (2009). The interaction among provenances of *Melaleuca leucadendra* (Weeping Paperbark), salt, and aluminium. *Forest Science* **55,** 443-454.

Nichol, S.C., C. Vanpé, J. Sprent, G. Morrow and N.A. Andersen (2011). Spatial ecology of a ubiquitous Australian anteater, the short-beaked echidna (*Tachyglossus aculeatus*). *Journal of Mammalogy* **92,** 101-110.

Nichols, O.G. and C.D. Grant (2007). Vertebrate fauna recolonization of restored bauxite mines—key findings from almost 30 years of monitoring and research. *Restoration Ecology* **15,** S116-S126.

Nolan, R.H., K.A. Fairweather, T. Tarin, N.S. Santini, J. Cleverly, R. Faux and D. Eamus (2017). Divergence in plant water-use strategies in semiarid woody species. *Functional Plant Biology* **44,** 1134-1146.

NSW Scientific Committee (2008). Red Goshawk *Erythrotriorchis radiatus*: Review of Current Information in NSW. Unpublished report arising from the Review of the Schedules of the Threatened Species Conservation Act 1995. NSW Scientific Committee, Hurstville.

O'Grady, A.P., D. Eamus, P.G. Cook and S. Lamontagne (2005). Comparative water use by the riparian trees *Melaleuca argentea* and *Corymbia bella* in the wet-dry tropics of northern Australia. *Tree Physiology* **26,** 219-228.

O'Grady, A.P., P.G. Cook, P. Howe and G. Werren (2006a). Groundwater use by dominant tree species in tropical remnant vegetation communities. *Australian Journal of Botany* **54,** 155-171.

O'Grady, A.P., D. Eamus, P.G. Cook and S. Lamontagne (2006b). Groundwater use by riparian vegetation in the wet-dry tropics of northern Australia. *Australian Journal of Botany* **54,** 145-154.

Phillips, B.L., M.J. Greenlees, G.P. Brown and R. Shine (2009). Predator behaviour and morphology mediates the impact of an invasive species: cane toads and death adders in Australia. *Animal Conservation* **13,** 53-59.

Pollock, A.B. (1999). Notes on status, distribution and diet of Northern Quoll *Dasyurus hallucatus* in the Mackay-Bowen area, mideastern Queensland. *Australian Zoologist* **31,** 388-395.

Poot, H., B. Ens, H. de Vries, M. Donners, M. Wernand and J. Marquenie (2008). Green light for nocturnally migrating birds. *Ecology and Society* **13,** 47 (online) at *http://www.ecologyandsociety.org/vol13/iss2/art47*.

Rice, K.J., S.L. Matzner, W. Byer and J.R. Brown (2004). Patterns of tree dieback in Queensland, Australia: the importance of drought stress and the role of resistance to cavitation. *Oecologia* **139,** 190-198.

Robinson, N., R.J. Harper and K.R.J. Smettem (2006). Soil water depletion by *Eucalyptus* spp. integrated into dryland agricultural systems. *Plant and Soil* **286,** 141-151.

Roman, A., P. Cinzano, G.M. Giacometti, P. Giulini (2000). Light pollution and possible effects on higher plants. *Memoirs of the Societá Astronomica Italiana* **71,** 59-69.

Rotics, S., T. Dayan, O. Levy and N. Kronfeld-Schor (2011). Light masking in the field: an experiment with nocturnal and diurnal spiny mice under semi-natural field conditions. *Chronobiology International* **28,** 70--75.Smith, A.G., C. McAlpine, J.R. Rhodes, L. Seabrook, G. Baxter, D. Lunney and A. Bradley (2012). At what spatial scales does resource selection vary? A case study of koalas in a semi-arid region. *Austral Ecology* **38,** 230-240.

Rumman, R., J. Cleverly, R.H. Nolan, T. Tarin and D. Eamus (2018). Speculations on the application of foliar ^{13}C discrimination to reveal groundwater dependency of vegetation and provide estimates of root depth and rates of groundwater use. *Hydrology and Earth System Sciences* **22,** 4875-4889.

Seaton, R (2014). Survey for the Red Goshawk (*Erythrotriorchis radiatus*) in South East Queensland. *The Sunbird* **44,** 52–59.

Salmon, M., M.G. Tolbert, D.P. Painter, M. Goff and R. Reiners (1995). Behaviour of loggerhead sea turtles on an urban beach. 2. Hatchling orientation. *Journal of Herpetology* **29,** 568-576.

Shannon, G., M.F. McKenna, L.M. Angeloni, K.R. Crooks, K.M. Fristrup, E. Brown, K.A. Warner, M.D. Nelson, C. White, J. Briggs, S. McFarland and G. Wittemyer (2016). A synthesis of two decades of research documenting the effects of noise on wildlife. *Biological Reviews* **91,** 982-1005.

Simon, B.K. (1984). New taxa of and nomenclatural changes in *Aristida* L. (Poaceae) in Australia. *Austrobaileya* **2,** 87-102.

Smith, A.G., C. McAlpine, J.R. Rhodes, L. Seabrook, G. Baxter, D. Lunney, A. Bradley (2013). At what spatial scales does resource selection vary? A case study of koalas in a semi-arid region. *Austral Ecology* **38,** 230-240.

Smith, G.C., and G. Agnew (2002). The value of 'bat boxes' for attracting hollow dependent fauna to farm forestry plantations in southeast Queensland. *Ecological Management and Restoration* **3**: 37-46.

Spain, A.V., D.A. Hinz and M. Tibbett (2010). Colonisation of rehabilitated lands by termites (Dictyoptera), Rio Tinto Alcan Gove bauxite mine, Northern Territory, Australia. *Mine Closure 2010* 437-448.

Stantec (2022). Vulcan South Project Transport Impact Assessment. Prepared by Stantec Australia Pty Ltd, Brisbane, for Vitrinite Pty Ltd.

Sullivan, B.J., W.M. Norris and G.S. Baxter (2003). Low-density koala (*Phascolarctos cinereus*) populations in the mulgalands of wouth-west Queensland. II. Distribution and diet. *Wildlife Research* **30,** 331-338.

Sun, D. and G.R. Dickinson (1995). Salinity effects on tree growth, root distribution and transpiration of *Casuarina cunninghamiana* and *Eucalyptus camaldulensis* planted on a saline site in tropical north Australia. *Forest Ecology and Management* **77,** 127-138.

Tidemann, C.R., D.M. Priddel, J.E. Nelson and J.D. Pettigrew (1985). Foraging behaviour of the Australian ghost bat, *Macroderma gigas* (Microchiroptera: Megadermatidae). *Australian Journal of Zoology* **33,** 705-713.

Toop, J. (1985). Habitat requirements, survival strategies and ecology of the Ghost Bat *Macroderma gigae* Dobson (Microchiroptera: Megadermatidae) in Central Coastal Queensland. *Macroderma* **1,** 37-41.

Threatened Species Scientific Committee (2012). Listing Advice for *Phascolarctos cinereus* (Koala). In effect under the EPBC Act from 2 May 2012, but ceased to be in effect from 11 February 2022.

Threatened Species Scientific Committee (2013). Commonwealth Listing Advice on *Rostula australis* (Australian Painted Snipe).In effect under the EPBC Act from 15 May 2013.

Threatened Species Scientific Committee (2015a). Conservation Advice: *Geophaps scripta scripta,* squatter pigeon (southern). In effect under the EPBC Act from 27 October 2015.

Threatened Species Scientific Committee (2015b). Conservation Advice: *Erythrotriorchis radiatus*, red goshawk. In effect under the EPBC Act from 27 October 2015.

Threatened Species Scientific Committee (2016). Conservation Advice: *Petauroides volans*, greater glider. In effect under the EPBC Act from 25 May 2016.

van der Moezel, P.G., G.V.N. Pearce-Pinto and D.T. Bell (1991). Screening for salt and waterlogging tolerance in *Eucalyptus* and *Melaleuca* species. *Forest Ecology and Management* **40,** 27-37.

van der Ree, R., S.J. Ward & K.A. Handasyde (2004). Distribution and conservation status of possums and gliders in Victoria. In *The Biology of Australian Possums and Gliders* (eds R.L. Goldingay & S.M. Jackson), pp. 91-110. Surrey Beatty and Sons, Sydney.

Walker, B.H., J.L. Langridge and F. McFarlane (2006). Resilience of an Australian savanna grassland to selective and non-selective perturbations. *Australian Journal of Ecology* **22,** 125-135.

Wang, N., J.E. Barrett, C. Bartuska, T.A. Nell, R.K. Schoelhorn and P.E. Hamilton (2003). Effects of low light levels during the dark period on flower development in *Euphorbia pulcherrima*. *Acta Horticulturae* **624,** 185-190.

Wen, L., J. Ling, N. Saintilan and K. Rogers (2009). An investigation of the hydrological requirements of River Red Gum (*Eucalyptus camaldulensis*) Forest, using Classification and Regression Tree modelling. *Ecohydrology* **2,** 143-155.

Woinarski, J.C.Z. and A.J. Ash (2002). Responses of vertebrates to pastoralism, military land use and landscape position in an Australian tropical savanna. *Austral Ecology* **27,** 311-323.

Woinarski, J.C.Z. and C.P. Catterall (2004). Historical changes in bird fauna at Coomooboolaroo, northeastern Australia, from the early years of pastoral settlement (1873) to 1999. *Biological Conservation* **116,** 379-401.

Woinarski, J.C.Z., M. Oakwood, J. Winter, S. Burnett, D. Milne, P. Foster, H. Myles and B. Holmes (2008). Surviving the toads: patterns of persistence of the northern quoll *Dasyurus hallucatus* in Queensland. Report to the Australian Government's Natural Heritage Trust.

Worthington Wilmer, J., L. Hall, E. Barratt and C. Moritz (1999). Genetic structure and male-mediated gene flow in the ghost bat (*Macroderma gigas*). *Evolution* **53,** 1582-1591.

Zolfaghar, S., R. Villalobos-Vega, M. Zeppel, J. Cleverly, R. Rumman, M. Hingee, N. Boulain, Z. Li and D. Eamus (2017). Transpiration of *Eucalyptus* woodlands across a natural gradient of depth-to-groundwater. *Tree Physiology* **37,** 961-975.

APPENDIX A

FAUNA TRAP SITE DESCRIPTIONS

Appendix A Fauna trap site descriptions

Site Name: S1 **Description:** Remnant *Eucalyptus orgadophila* open woodland on clay derived from fine-grained sedimentary rock. **BVG:** 17b **Dates:** 24-28/10/2018 **Latitude, Longitude:** -22.3521, 148.2200	
Site Name: S2 **Description:** Remnant *Acacia harpophylla* open forest with emergent *Eucalyptus cambageana.* **BVG:** 25a **Dates:** 25-29/10/2018 **Latitude, Longitude:** -22.3515, 148.2272	
Site Name: S3 **Description:** Cleared pasture with *Carissa ovata* on clay soil **BVG:** n/a **Dates:** 25-29/10/2018 **Latitude, Longitude:** -22.3557, 148.2396	
Site Name: S4 **Description:** Edge of remnant riparian forest dominated by *Eucalyptus camaldulensis.* **BVG:** 16a/9e **Dates**: 25-29/10/2018 **Latitude, Longitude:** -22.3676, 148.2345	

Site Name: S5 **Description:** Ecotone between remnant *Corymbia tessellaris* forest on a sandy alluvial terrace and *Eucalyptus camaldulensis* and *Bauhinia hookeri* along the creek bank. **BVG:** 16a/9e **Dates:** 28/10-1/11/2018 **Latitude, Longitude:** -22.3749, 148.2401	
Site Name: S6 **Description:** Remnant open forest dominated by *Casuarina cristata* and *Acacia harpophylla* on clay soil. **BVG**: 25a **Dates**: 29/10-2/11/2018 **Latitude, Longitude:** -22.3834, 148.2431	
Site Name: S7 **Description:** Remnant *Eucalyptus populnea* open forest on a sand plain. **BVG:** 17a **Dates:** 29/10-2/11/2018 **Latitude, Longitude:** -22.3890, 148.2448	
Site Name: S8 **Description:** High-value regrowth of *Eucalyptus populnea* on a sand plain. **BVG:** 17a (regrowth) **Dates:** 29/10-2/11/2018 **Latitude, Longitude:** -22.3929, 148.2586	

Site Name: S9 **Description:** Heavily thinned *Eucalyptus crebra* and *Corymbia clarksoniana* woodland on a sand plain. **BVG:** 18b (regrowth) **Dates:** 25-28/3/2019 and 8-12/4/2019 **Latitude, Longitude:** -22.3900, 148.2267 Original trapping session was disrupted by heavy rain and had to be repeated at a later date.	
Site Name: S10 **Description:** Remnant *Eucalyptus populnea* open forest, with some *Eucalyptus melanophloia*, on a sandy alluvial terrace. **BVG:** 17a **Dates:** 26-28/3/2019 and 9-13/4/2019 **Latitude, Longitude**: -22.3757, 148.2155 Original trapping session was disrupted by heavy rain and had to be repeated at a later date.	
Site Name: S11 **Description:** Remnant *Corymbia clarksoniana* and *Eucalyptus crebra* open forest at the base of a rocky sandstone scree slope. **BVG:** 12a **Dates:** 26-28/3/2019 and 9-13/4/2019 **Latitude, Longitude:** -22.3773, 148.2017 Original trapping session was disrupted by heavy rain and had to be repeated at a later date.	
Site Name: S12 **Description:** Remnant *Acacia harpophylla* and *Eucalyptus cambageana* woodland on a clay plain. **BVG:** 25a **Dates:** 27-28/3/2019 and 8-12/4/2019 **Latitude, Longitude:** -22.3769, 148.2384 Original trapping session was disrupted by heavy rain and had to be repeated at a later date.	

Site Name: S13 **Description:** Cleared pasture with scattered *Eucalyptus populnea* on a sand plain. **BVG:** n/a **Dates:** 13-17/4/2019 **Latitude, Longitude:** -22.3761, 148.2588	
Site Name: S14 **Description:** Remnant *Eucalyptus populnea* woodland on a sand plain. **BVG:** 17a **Dates:** 9-13/4/2019 **Latitude, Longitude:** -22.3666, 148.2052	
Site Name: S15 **Description:** Partly thinned woodland dominated by *Eucalyptus crebra* on a low sandstone rise. **BVG:** 18b **Dates:** 12-16/4/2019 **Latitude, Longitude:** -22.3592, 148.1983	
Site Name: S16 **Description:** Remnant *Corymbia aureola* and *Eucalyptus melanophloia* open forest with a shrub layer dominated by *Acacia* spp. on sandstone. **BVG:** 12a **Dates:** 12-16/4/2019 **Latitude, Longitude**: -22.3567, 148.1928	

Site Name: S17 **Description:** Remnant *Eucalyptus orgadophila* open woodland on clay derived from fine-grained sedimentary rock. **BVG:** 17b **Dates:** 13-17/4/2019 **Latitude, Longitude:** -22.3537, 148.2339	
Site Name: S18 **Description:** Remnant open forest dominated by *Acacia rhodoxylon* and *Acacia shirleyi* on sandstone. **BVG:** 24a **Dates:** 1-5/5/2019 **Latitude, Longitude:** -22.3424, 148.2103	
Site Name: S19 **Description:** Remnant open forest dominated by *Acacia shirleyi* on sandstone. **BVG:** 24a **Dates:** 1-5/5/2019 **Latitude, Longitude:** -22.3497, 148.2013	
Site Name: S20 **Description:** Remnant woodland dominated by *Eucalyptus crebra* and *Corymbia clarksoniana*, with a shrub layer dominated by *Alphitonia excelsa, Petalostigma pubescens* and *Acacia burdekensis*, on a sand plain. **BVG:** 18b **Dates**: 1-5/5/2019 **Latitude, Longitude**: -22.3518, 148.2112	

Site Name: S21 **Description:** Remnant *Eucalyptus orgadophila* open woodland on heavy clay soil derived from fine-grained sedimentary rock. **BVG:** 17b **Dates:** 30/4-4/5/2019 **Latitude, Longitude:** -22.3593, 148.2296	
Site Name: S22 **Description:** Remnant open forest dominated by *Eucalyptus crebra, Corymbia clarksoniana* and *Eucalyptus melanophloia*, with a dense shrub layer containing *Alphitonia excelsa, Petalostigma pubescens* and *Acacia burdekensis.* **BVG:** 18b **Dates:** 4-8/5/2019 **Latitude, Longitude:** -22.3306, 148.2124	
Site Name: S23 **Description:** Remnant open forest dominated by *Corymbia tessellaris, Corymbia clarksoniana* and *Eucalyptus crebra* beside a creek lined with *Eucalyptus camaldulensis* and *Melaleuca* spp. **BVG:** 16a/9e **Dates:** 5-9/5/2019 **Latitude, Longitude:** -22.3062, 148.1943	
Site Name: S24 **Description:** Remnant open forest dominated by *Corymbia citriodora, Eucalyptus crebra* and *Corymbia trachyphloia,* with a shrub layer containing *Lysicarpus angustifolius* and *Acacia shirleyi.* **BVG:** 10a **Dates:** 5-9/5/2019 **Latitude, Longitude**: -22.2915, 148.1672	

Site Name: S25 **Description:** Remnant *Acacia shirleyi* open forest, but with many dead trees. **BVG:** 12a **Dates:** 5-9/5/2019 **Latitude, Longitude:** -22.2854, 148.1516	
Site Name: S26 **Description:** Non-remnant open woodland dominated by *E. melanophloia, C. clarksoniana* and *Melaleuca viridiflora* on sandy soil. One of the densest examples of non-remnant habitat. **BVG:** Cleared **Dates:** 23-27/09/2019 **Latitude, Longitude:** -22.2880, 148.1920	
Site Name: S27 **Description:** Remnant open forest dominated by *C. citriodora* on coarse-grained sedimentary rocks. **BVG:** 10a **Dates:** 24-28/09/2019 **Latitude, Longitude:** -22.2860, 148.1471	
Site Name: S28 **Description:** Remnant woodland dominated by *C. citriodora* on coarse-grained sedimentary rocks with dense *Acacia shirleyi* midstorey. **BVG:** 10a **Dates:** 24-28/09/2019 **Latitude, Longitude:** -22.2867, 148.1586	

Site Name: S29 **Description:** Remnant *A. shirleyi* open forest on coarse-grained sedimentary rocks. *C. aureola* also present with a sparse, grassy understorey. **BVG:** 24a **Dates:** 25-29/09/2019 **Latitude, Longitude:** -22.2905, 148.1746	
Site Name: S30 **Description:** High-value regrowth with many dead trees and large amounts of fallen debris. Heavily grazed and very open. Canopy dominated by *C. clarksoniana* and *E. crebra.* **BVG:** 12a **Dates:** 27-1/10/2019 **Latitude, Longitude:** -22.2812, 148.1792	
Site Name: S31 **Description:** High-value regrowth, dominated by *Eucalyptus crebra* with a dense midstorey of *A. burdekensis*, on coarse-grained sedimentary rocks. **BVG:** 12a (regrowth) **Dates:** 27-01/10/2019 **Latitude, Longitude:** -22.2797, 148.1767	
Site Name: S32 **Description:** High-value regrowth *E. crebra* and *C. clarksoniana* woodland on coarse-grained sedimentary rocks. **BVG:** 12a (regrowth) **Dates:** 28-02/10/2019 **Latitude, Longitude:** -22.3098, 148.1940	

Site Name: S33 **Description:** High-value regrowth *E. crebra* woodland with dense midstorey of *Acacia* spp. and *Melaleuca viridiflora*. **BVG:** 18b (regrowth) **Dates:** 28-02/10/2019 **Latitude, Longitude:** -22.3182, 148.1980	
Site Name: S34 **Description:** High-value regrowth dominated by *A. rhodoxylon.* Contained large amounts of fallen debris. **BVG:** 24a (regrowth) **Dates:** 29-03/10/2019 **Latitude, Longitude:** -22.3990, 148.2654	

APPENDIX B

VEGETATION DATA FROM SECONDARY SITES

SECONDARY SITE 1 **11.5.9**



Latitude, Longitude: -22.3307, 148.2130

Community description: Low open forest dominated by *Melaleuca nervosa,* with emergent *Alphitonia excelsa*, on a flat sandy plain. The species composition was similar to nearby RE 11.5.9, except for the absence of an upper stratum of *Eucalyptus crebra.* This was therefore considered to be a variation of 11.5.9.

Dominant species per stratum:

E: *Alphitonia excelsa, Melaleuca nervosa.*
T1: *Acacia burdekensis, Melaleuca nervosa.*
S1: *Acacia burdekensis, Melaleuca nervosa.*
S2: *Erythroxylum australe.*
G: *Perotis rara, Setaria surgens, Cheilanthes sieberi.*

Median (and range) canopy height per stratum: E = 9.2 m (9.0–12.4 m), T1 = 5.2 m (4.2–7.4 m), S1 = 2.25 m (2.0–3.0 m), S2 = 1 m (0.4–1.2 m).

% cover of each stratum (vertical projection along 100 m tape): E = 5.5%; T1 = 62.3%; S1 = 5.7%; S2 <0.1%; **total = 65.7%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

E: *Alphitonia excelsa* = 1 m^2/ha **(total = 1 m^2/ha).**
T1: *Melaleuca nervosa* = 4.17 m^2/ha; *Acacia burdekensis* = 0.67 m^2/ha; *Alphitonia excelsa* = 0.67 m^2/ha **(total = 5.51 m^2/ha).**
S1: *Melaleuca nervosa* = 0.5 m^2/ha; *Acacia burdekensis* = 0.17 m^2/ha **(total = 0.67 m^2/ha).**
S2: *Erythroxylum* < 0.15 m^2/ha **(total < 0.15 m^2/ha).**

Landform: Plain **Slope:** 1° E **Soil:** Brown sand

Disturbance: Nil

Ground cover: Rock = 0%, wood = 3%, bare = 30%, litter = 42%, vegetation = 25%.

Species (percent cover): *Acanthospermum hispidum** (0.1%), *Afrohybanthus stellarioides* (0.1%), *Alloteropsis cimicina* (0.4%), *Alphitonia excelsa* (0.2%), *Aristida holathera* (0.6%), *Bonamia media* (0.1%), *Cheilanthes sieberi* (7%), *Chrysocephalum apiculatum* (0.2%), *Crotalaria medicaginea* (0.1%), *Dactyloctenium radulans* (0.1%), *Desmodium varians* (0.3%), *Emilia sonchifolia** (0.1%), *Eragrostis sororia* (0.1%), *Erythroxylum australe* (0.1%), *Evolvulus alsinoides* (0.1%), *Fimbristylis dichotoma* (0.4%), *Heliotropium peninsulare* (0.1%), *Ipomoea polymorpha* (0.7%), *Melaleuca nervosa* (0.2%), *Murdannia graminea* (0.1%), *Perotis rara* (4%), *Phyllanthus* sp. (Myra Vale J.J. Bruhl+ 1810) (0.2%), *Portulaca filifolia* (0.1%), *Richardia brasiliensis** (0.1%), *Setaria surgens* (5%), *Sida cordifolia** (0.8%), *Spermacoce brachystema* (0.1%), *Stylosanthes hamata** (0.3%), *Stylosanthes scabra** (0.1%), *Tephrosia dietrichiae* (0.1%), *Tricoryne elatior* (0.1%), *Urochloa piligera* (3%), *Zornia muelleriana* subsp. *muelleriana* (0.1%).

SECONDARY SITE 2 **11.5.9**



Latitude, Longitude: -22.3337, 148.2100

Community description: Low woodland dominated by *Eucalyptus melanophloia* on a flat, sandy plain.

Dominant species per stratum:

T1: *Eucalyptus melanophloia.*
T2: *Acacia burdekensis, Eucalyptus melanophloia.*
S1: *Erythroxylum australe, Petalostigma pubescens.*
G: *Alloteropsis cimicina, Aristida calycina* var. *calycina, Eriachne obtusa, Evolvulus alsinoides*

Median (and range) canopy height per stratum: T1 = 6.8 m (5.2–11.4 m), T2 = 4 m (3.2–5 m), S1 = 1.5 m (0.8–2 m).

% cover of each stratum: T1 = 20.2%; T2 = 23.9%; S1 = 5%; **total = 44.6%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Eucalyptus melanophloia* = 4.83 m^2/ha; *Acacia burdekensis* = 0.17 m^2/ha **(total = 5 m^2/ha).**
T2: *Acacia burdekensis* = 1.5 m^2/ha; *Eucalyptus melanophloia* = 0.17 m^2/ha **(total = 1.67 m^2/ha).**
S1: total <0.17 m^2/ha.

Landform: Plain **Slope:** 1°NE **Soil:** Yellow-brown sand

Disturbance: Lightly grazed

Ground cover: Rock = 0%, wood = 1%, bare = 35%, litter = 40%, vegetation = 24%.

Species (percent cover): *Acacia burdekensis* (0.1%), *Afrohybanthus enneaspermus* (0.1%), *Afrohybanthus stellarioides* (0.1%), *Alloteropsis cimicina* (9%), *Alphitonia excelsa* (0.2%), *Alternanthera nana* (0.1%), *Aristida calycina* var. *calycina* (2%), *Chrysopogon fallax* (0.3%), *Digitaria divaricatissima* (0.1%), *Digitaria* sp. A (0.2%), *Eragrostis lacunaria* (0.2%), *Eragrostis sororia* (0.1%), *Eriachne obtusa* (8%), *Eucalyptus melanophloia* (0.1%), *Evolvulus alsinoides* (0.9%), *Fimbristylis dichotoma* (0.6%), *Ipomoea polymorpha* (0.1%), *Melaleuca nervosa* (0.1%), *Murdannia graminea* (0.1%), *Paspalidium rarum* (0.1%), *Petalostigma pubescens* (0.1%), *Phyllanthus carpentariae* (0.1%), *Phyllanthus collinus* (0.1%), *Phyllanthus* sp. (Myra Vale J.J. Bruhl+ 1810) (0.1%), *Portulaca pilosa** (0.1%), *Richardia brasiliensis** (0.1%), *Sida hackettiana* (0.1%), *Sida* sp. (Aramac E.J. Thompson+ JER192) (0.2%), *Stylosanthes scabra** (0.2%), *Tephrosia leptoclada* (0.1%), *Urochloa piligera* (0.1%), *Zornia muelleriana* subsp. *muelleriana* (0.1%).

SECONDARY SITE 3 **11.10.1x1**



Latitude, Longitude: -22.3370, 148.2069

Community description: Low open forest dominated by *Corymbia aureola, Eucalyptus melanophloia* and *Acacia shirleyi* on a low sandstone ridge.

Dominant species per stratum:

T1: *Acacia shirleyi, Corymbia aureola, Eucalyptus melanophloia.*
T2: *Acacia burdekensis.*
S1: *Erythroxylum australe.*
G: *Cleistochloa subjuncea*, *Digitaria diminuta.*

Median (and range) canopy height per stratum: T1 = 9.4 m (8.6–12.4 m), T2 = 5.2 m (3.4–6 m), S1 = 2.4 m (2–2.6 m), S2 = 1 m (0.5–1.5 m).

% cover of each stratum: T1 = 37.6%; T2 = 21.3%; S1 = 6.7%; t**otal = 56.6%**.

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Corymbia aureola* = 2.33 m^2/ha; *Acacia shirleyi* = 1.5 m^2/ha; *Eucalyptus melanophloia* = 1.17 m2/ha **(total = 5 m^2/ha).**
T2: *Acacia burdekensis* = 0.17 m^2/ha; *Acacia shirleyi* = 0.5 m^2/ha; *Alphitonia excelsa* = 0.17 m^2/ha; *Corymbia aureola* = 0.17 m^2/ha; *Eucalyptus melanophloia* = 0.17 m^2/ha **(total = 1.18 m^2/ha).**
S1: *Erythroxylum australe* = 0.33 m^2/ha **(total = 0.33 m^2/ha).**

Landform: Low rocky rise **Slope:** 3°NNE **Soil:** Grey sand

Disturbance: none

Ground cover: Rock = 45%, wood = 7%, bare = 10%, litter = 23%, vegetation = 15%.

Species (percent cover): *Acacia bancroftiorum* (0.1%), *Acacia shirleyi* (0.1%), *Achyranthes aspera* (0.1%), *Afrohybanthus stellarioides* (0.1%), *Alloteropsis imicina* (0.1%), *Alphitonia excelsa* (0.1%), *Aristida benthamii* (0.1%), *Aristida calycina* var. *calycina* (0.1%), *Cheilanthes sieberi* (0.1%), *Chrysopogon fallax* (0.1%), *Cleistochloa subjuncea* (7%), *Corymbia aureola* (0.1%), *Cyanthillium cinereum* (0.1%), *Desmodium macrocarpum* (0.1%), *Digitaria diminuta* (3.6%), *Eragrostis lacunaria* (0.1%), *Eragrostis sororia* (0.1%), *Eriochloa pseudoacrotricha* (0.1%), *Erythroxylum australe* (0.2%), *Eucalyptus melanophloia* (0.1%), *Euphorbia drummondii* (0.1%), *Evolvulus alsinoides* (0.1%), *Fimbristylis dichotoma* (0.1%), *Galactia tenuiflora* (0.1%), *Hibiscus meraukensis* (0.1%), *Ipomoea brownii* (0.2%), *Marsdenia microlepis* (0.1%), *Melinis repens* (0.1%), *Panicum effusum* (0.1%), *Paspalidium gracile* (0.1%), *Petalostigma pubescens* (0.1%), *Phyllanthus carpentariae* (0.1%), *Pseuderanthemum variabile* (0.1%), *Scleria brownii* (0.1%), *Sida* sp. (Musselbrook M.B. Thomas+ MRS437) (0.1%), *Spermacoce brachystema* (0.1%), *Stylosanthes scabra** (0.2%), *Tephrosia juncea* (0.1%), *Themeda triandra* (0.1%), *Ventilago viminalis* (0.1%), *Xenostegia tridentata* (0.1%).

SECONDARY SITE 4 **11.5.9**



Latitude, Longitude: -22.3403, 148.2247

Community description: Low woodland dominated by *Allocasuarina leuhmannii* on a sand plain. It is best considered a variant of 11.5.9 lacking a *Eucalyptus* upper stratum.

Dominant species per stratum:

T1: *Allocasuarina luehmannii.*
T2: *Acacia burdekensis, Allocasuarina luehmannii, Grevillea striata.*
S1: *Allocasuarina luehmannii.*
G: *Eragrostis sororia*, *Chrysopogon fallax*, *Eriachne obtusa*.

Median (and range) canopy height per stratum: T1 = 9.4 (8–11.6 m), T2 = 5 m (4.2–5.6 m), S1 = 2.8 m (1.6–3 m).

% cover of each stratum: T1 = 31.3%, T2 = 20.8%; S1 = 11%; **total = 55.2%**.

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Allocasuarina luehmannii* = 3.83 m^2/ha; *Eucalyptus melanophloia* = 0.17 m^2/ha **(total = 4 m^2/ha).**
T2: *Allocasuarina luehmannii* = 4.5 m^2/ha **(total = 4.5 m^2/ha).**
S1: < 0.17 m^2/ha.

Landform: Slight rise on a sandy plain **Slope:** 2°E **Soil:** Yellow-brown sand

Disturbance: Nil

Ground cover: Rock = 0%, wood = 2%, bare = 34%, litter = 45%, vegetation = 19%.

Species (percent cover): *Allocasuarina luehmannii* (0.4%), *Alternanthera nana* (0.1%), *Aristida calycina* var. *calycina* (0.1%), *Aristida holathera* (0.1%), *Brunoniella australis* (0.1%), *Carissa ovata* (0.1%), *Cheilanthes sieberi* (0.3%), *Chrysopogon fallax* (3.1%), *Commelina lanceolata* (0.1%), *Eragrostis lacunaria* (0.1%), *Eragrostis sororia* (5%), *Eremochloa bimaculata* (0.1%), *Eriachne obtusa* (7%), *Evolvulus alsinoides* (0.8%), *Fimbristylis dichotoma* (0.1%), *Grevillea striata* (0.1%), *Murdannia graminea* (0.4%), *Oldenlandia mitrasacmoides* subsp. *trachymenoides* (0.1%), *Panicum effusum* (0.1%), *Petalostigma pubescens* (0.1%), *Phyllanthus collinus* (0.1%), *Polycarpaea corymbosa* (0.1%), *Portulaca pilosa** (0.1%), *Sida hackettiana* (0.1%), *Sphaeromorphaea australis* (0.1%), *Stylosanthes scabra** (0.1%), *Tephrosia leptoclada* (0.1%).

SECONDARY SITE 5 **11.4.8**



Latitude, Longitude: -22.3424, 148.2219

Community description: Low open forest dominated by *Casuarina cristata* and *Acacia harpophylla* (subdominant), with emergent *Eucalyptus cambageana*, on clay plain.

Dominant species per stratum:

E: *Eucalyptus cambageana.*
T1: *Acacia harpophylla, Casuarina cristata.*
T2: *Acacia harpophylla, Terminalia oblongata.*
S1: *Carissa ovata*.
G: *Ancistrachne uncinata, Paspalidium constrictum*, *Chloris divaricata*, *Cyperus gracilis*.

Median (and range) canopy height per stratum: E = 16 (14.4–16.4 m) T1 = 9.2 m (7.2–11.6 m), T2 = 3.5 m (3.0–4.0 m), S1 = 2 m (1.0–2.5 m).

% cover of each stratum: E = 19%; T1 = 67.1%; T2 = 13.1%; S1 = 4.3%; **total = 78.8%**.

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

E: *Eucalyptus cambageana* = 2.17 **(total = 2.17 m^2/ha).**
T1: *Casuarina cristata* = 5.83 m^2/ha; *Acacia harpophylla* = 1.33 m^2/ha; *Eucalyptus cambageana* = 0.83 m^2/ha; *Terminalia oblongata* = 0.33 m^2/ha. **(total = 8.32 m^2/ha).**
T2: *Acacia harpophylla* =0.33 m^2/ha **(total = 0.33 m^2/ha).**
S1: <0.17 m^2/ha.

Landform: Slight rise on a plain **Slope:** 1°E **Soil:** Reddish-brown sand, but probably texture contrast, with a clay subsoil.

Disturbance: Nil

Ground cover: Rock = 0%, wood = 8%, bare = 4%, litter = 75%, vegetation = 13%.

Species (percent cover): *Abutilon oxycarpum* (0.1%), *Acacia harpophylla* (0.1%), *Alectryon diversifolius* (0.1%), *Ancistrachne uncinata* (1.2%), *Apowollastonia spilanthoides* (0.1%), *Boerhavia pubescens* (0.1%), *Bothriochloa pertusa** (0.1%), *Brunoniella australis* (0.1%), *Bursaria incana* (0.1%), *Capparis lasiantha* (0.1%), *Carissa ovata* (5.5%), *Casuarina cristata* (0.2%), *Cheilanthes sieberi* (0.1%), *Chloris divaricata* (0.9%), *Cymbidium canaliculatum* (0.1%), *Cymbopogon refractus* (0.1%), *Cynanchum viminale* (0.1%), *Cyperus gracilis* (0.7%), *Desmodium varians* (0.1%), *Einadia nutans* (0.1%), *Enchylaena tomentosa* var. *tomentosa* (0.1%), *Enneapogon lindleyanus* (0.1%), *Eremophila mitchellii* (0.1%), *Erythroxylum australe* (0.1%), *Evolvulus alsinoides* (0.1%), *Geijera parviflora* (0.1%), *Grewia retusifolia* (0.1%), *Hibiscus brachysiphonius* (0.1%), *Hibiscus sturtii* (0.1%), *Jasminum didymum* subsp. *lineare* (0.1%), *Nyssanthes erecta* (0.1%), *Parsonsia lanceolata* (0.1%), *Paspalidium constricutum* (0.9%), *Phyllanthus collinus* (0.1%), *Pseuderanthemum variabile* (0.1%), *Sida corrugata* (0.2%), *Solanum ellipticum* (0.1%), *Solanum parvifolium* (0.1%), *Sporobolus scabridus* (0.1%), *Themeda avenacea* (0.1%), *Vachellia bidwillii* (0.1%).

SECONDARY SITE 6 **11.9.2**



Latitude, Longitude: -22.3503, 148.2209

Community description: Woodland dominated by *Eucalyptus orgadophila* and *Corymbia erythrophloia* on clay soil derived from fine-grained sedimentary rock.

Dominant species per stratum:

T1: *Eucalyptus orgadophila.*
T2: *Corymbia erythrophloia*, *Eucalyptus orgadophila*.
S1: *Bursaria incana, Denhamia cunninghamii, Atalaya hemiglauca.*
S2: *Carissa ovata.*
U: *Bothriochloa pertusa*.*

Median (and range) canopy height per stratum: T1 = 12.8 m (10.4–17.6 m), T2 = 5.2 m (4.0–7.0 m), S1 = 1.7 m (1.5–2.1 m), S2 = 0.9 m (0.5–1.2 m).

% cover of each stratum: T1 = 15.6%; T2 = 11.2% S1 = 0.5%, S2 = 3%; **total = 26.9%**.

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Corymbia erythrophloia* = 1.33 m^2/ha; *Eucalyptus crebra* = 0.33 m^2/ha; *Eucalyptus orgadophila* = 0.5 m^2/ha **(total = 4.08 m^2/ha).**
T2: *Corymbia erythrophloia* = 1 m^2/ha **(total = 1 m^2/ha).**
S1: <0.17 m^2/ha).
S2: < 0.17 m^2/ha.

Landform: Low rise **Slope:** 1°N **Soil:** Dark-brown clay

Disturbance: Heavily grazed

Ground cover: Rock = 0%, wood = 0.5%, bare = 10%, litter = 4.2%, vegetation = 85.3%.

Species (percent cover): *Abildgaardia ovata* (0.1%), *Afrohybanthus enneaspermus* (0.1%), *Alloteropsis semialata* (0.1%), *Aristida gracilipes* (0.1%), *Atalaya hemiglauca* (0.1%), *Bothriochloa ewartiana* (0.2%), *Bothriochloa pertusa** (78.9%), *Brunoniella australis* (0.1%), *Carissa ovata* (3%), *Cenchrus ciliaris** (0.1%), *Chrysopogon fallax* (0.1%), *Corymbia erythrophloia* (0.1%), *Cyanthillium cinereum* (0.1%), *Denhamia cunninghamii* (0.1%), *Desmodium varians* (0.1%), *Enneapogon* sp. A (0.1%), *Evolvulus alsinoides* (0.1%), *Fimbristylis dichotoma* (0.1%), *Galactia tenuiflora* (0.1%), *Grewia latifolia* (0.1%), *Heliotropium peninsulare* (0.1%), *Indigofera linifolia* (0.1%), *Indigofera linnaei* (0.1%), *Melhania oblongifolia* (0.1%), *Neptunia gracilis* (0.1%), *Phyllanthus fuernrohrii* (0.1%), *Rhynchosia minima* (0.1%), *Rostellularia adscendens* (0.1%), *Scleria brownii* (0.1%), *Sida hackettiana* (0.1%), *Stylosanthes scabra** (0.3%), *Tephrosia filipes* subsp. *filipes* (0.1%), *Themeda triandra* (0.1%).

SECONDARY SITE 7 **11.10.7**



Latitude, Longitude: -22.3041, 148.1923

Community description: Low woodland dominated by *Corymbia clarksoniana* on a low sandstone rise. The community does not closely match any of the described regional ecosystems, but is closest to 11.10.1 and 11.10.7. Nearby areas of the ridge had *Eucalyptus crebra* and/or *Eucalyptus melanophloia* growing alongside *C. clarksoniana*, so 11.10.7 was considered the best fit for the community.

Dominant species per stratum:

T1: *Corymbia clarksoniana.*
T2: *Acacia flavescens, Acacia burdekensis, Alphitonia excelsa, Petalostigma pubescens.*
S1: *Erythroxylum australe, Leptospermum lamellatum, Petalostigma pubescens.*
G: *Melinis repens*, Digitaria eriantha*, Aristida calycina* var*. calycina.*

Median (and range) canopy height per stratum: T1 = 9.6 m (9.6–10.6 m), T2 = 6.4 m (4.6–6.8 m), S1 = 2.5 m (1–3 m)

% cover of each stratum: T1 = 22.1%; T2 = 13.6%; S1 = 6%; S2 = 11%; **total = 52.4%**.

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Corymbia clarksoniana* = 1.83 m^2/ha **(total = 1.83 m^2/ha).**
T2: *Petalostigma pubescens* = 0.33 m^2/ha; *Corymbia clarksoniana* = 0.33 m^2/ha; *Terminalia porphyrocarpa* = 0.33 m^2/ha; *Alphitonia excelsa* = 0.17 m^2/ha; *Acacia burdekensis* = 0.17 m^2/ha **(total = 1.33 m^2/ha).**
S1: *Erythoxylum australe* = 0.67 m^2/ha **(total = 0.67 m^2/ha).**

Landform: Crest of low sandstone rise **Slope:** 4°NE **Soil:** Light grey-pink sand

Disturbance: Heavily grazed

Ground cover: Rock = 59%, wood = 1%, bare = 15%, litter = 15%, vegetation = 10%.

Species (percent cover): *Acacia flavescens* (0.2%), *Achyranthes aspera* (0.1%), *Afrohybanthus enneaspermus* (0.1%), *Afrohybanthus stellarioides* (0.1%), *Alloteropsis cimicina* (0.5%), *Alphitonia excelsa* (0.1%), *Amaranthus interruptus* (0.1%), *Aristida benthamii* (0.1%), *Aristida calycina* var. *calycina* (1.7%), *Aristida holathera* (0.1%), *Bidens bipinnata** (0.1%), *Bidens pilosa** (0.1%), *Bonamia media* (0.1%), *Chamaecrista rotundifolia** (0.1%), *Cheilanthes sieberi* (0.1%), *Cleome viscosa* (0.1%), *Commelina lanceolata* (0.1%), *Cyperus betchei* (0.1%), *Digitaria eriantha** (3.7%), *Digitaria ramularis* (0.5%), *Dinebra decipiens* var. *decipiens* (0.1%), *Eragrostis spartinoides* (0.2%), *Eriachne mucronata* (0.5%), *Erythroxylum australe* (0.1%), *Euphorbia drummondii* (0.1%), *Evolvulus alsinoides* (0.1%), *Galactia tenuiflora* (0.1%), *Gomphrena celosioides** (0.1%), *Ipomoea brownii* (0.1%), *Larsenaikia ochreata* (0.1%), *Marsdenia microlepis* (0.1%), *Melinis repens** (2.7%), *Pandorea pandorana* (0.1%), *Paspalidium gracile* (0.1%), *Pavetta granitica* (0.3%), *Perotis rara* (0.1%), *Petalostigma pubescens* (0.1%), *Phyllanthus carpentariae* (0.1%), *Phyllanthus collinus* (0.1%), *Planchonella pohlmanniana* (0.1%), *Polycarpaea corymbosa* (0.1%), *Portulaca bicolor* (0.1%), *Portulaca oleracea** (0.1%), *Portulaca pilosa** (0.1%), *Pseuderanthemum variabile* (0.1%), *Setaria surgens* (0.1%), *Sida hackettiana* (0.3%), *Sida* sp. (Musselbrook M.B. Thomas+ MRS437) (0.1%), *Sida spinosa** (0.1%), *Stylosanthes scabra** (0.1%), *Tephrosia filipes* subsp. *filipes* (0.1%), *Urochloa mosambicensis** (0.1%), *Xenostegia tridentata* (0.1%), *Zornia* sp. (0.1%).

SECONDARY SITE 8 **11.10.3**



Latitude, Longitude: -22.3037, 148.1864

Community description: Woodland dominated by *Acacia shirleyi* on sandstone crest.

Dominant species per stratum:

T1: *Acacia shirleyi, Alphitonia excelsa* (subdominant) *Corymbia clarksoniana* (subdominant).
S1: *Erythroxylum australe.*
G: *Alloteropsis cimicina*, *Cleistochloa subjuncea, Urochloa piligera.*

Median (and range) canopy height per stratum: T1 = 11.4 m (9.2–11.4 m), S1 = 3.5 (3.0–4.0 m).

% cover of each stratum: T1 = 36%; S1 = 27%; **total = 60.6%**.

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Acacia shirleyi* = 8.67 m^2/ha; *Corymbia clarksoniana* = 0.83 m^2/ha; *Alphitonia excelsa* = 0.5 m^2/ha **(total = 10.25 m^2/ha).**
S1: *Erythroxylum australe* = 0.5 m^2/ha **(total = 0.33 m^2/ha).**

Landform: Crest of sandstone ridge **Slope:** 1°N **Soil:** Grey sand

Disturbance: Heavily grazed; burn marks indicate a relatively recent fire.

Ground cover: Rock = 38%, wood = 2%, bare = 14%, litter = 32%, vegetation = 14%.

Species (percent cover): *Achyranthes aspera* (0.1%), *Afrohybanthus stellarioides* (0.1%), *Alloteropsis cimicina* (6%), *Alphitonia excelsa* (0.1%), *Alternanthera nana* (0.1%), *Aristida enthamii* (0.5%), *Aristida calycina* var. *calycina* (0.1%), *Bidens bipinnata** (0.1%), *Chamaecrista absus* (0.1%), *Cheilanthes sieberi* (0.1%), *Cleistochloa subjuncea* (0.8%), *Cyanthillium cinereum* (0.1%), *Cyperus betchei* (0.1%), *Digitaria diminuta* (0.1%), *Eragrostis lacunaria* (0.1%), *Erythroxylum australe* (0.5%), *Euphorbia drummondii* (0.1%), *Evolvulus alsinoides* (0.1%), *Galactia tenuiflora* (0.1%), *Hibiscus meraukensis* (0.1%), *Ipomoea brownii* (0.1%), *Marsdenia microlepis* (0.1%), *Melinis repens* (0.2%), *Perotis rara* (0.1%), *Phyllanthus carpentariae* (0.1%), *Portulaca bicolor* (0.1%), *Portulaca pilosa** (0.1%), *Pseuderanthemum variabile* (0.1%), *Ptilotus polystachyus* (0.1%), *Scleria sphacelata* (0.1%), *Sida aprica* (0.1%), *Sida atherophora* (0.1%), *Sida cordifolia** (0.1%), *Sida hackettiana* (0.1%), *Sida spinosa** (0.1%), *Spermacoce brachystema* (0.1%), *Tinospora smilacina* (0.1%), *Urochloa piligera* (2.6%), *Wrightia saligna* (0.1%), *Xenostegia tridentata* (0.1%).

SECONDARY SITE 9 **11.10.3**



Latitude, Longitude: -22.3024, 148.1793

Community description: Low open forest dominated by *Acacia shirleyi*, with emergent *Corymbia citriodora*, on sandstone hillside.

Dominant species per stratum:

E: *Corymbia citriodora.*
T1: *Acacia shirleyi.*
S1: *Acacia shirleyi, Erythroxylum australe.*
G: *Cleistochloa subjuncea.*

Median (and range) canopy height per stratum: T1 = 9.8 m (7.6–9.8 m), S1 = (2.5–3.0 m).

% cover of each stratum: T1 = 52.7; S1 = 6.7; **total = 52.8%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

E: *Corymbia citriodora* = 0.17 m^2/ha **(total = 0.17 m^2/ha).**
T1: *Acacia shirleyi* = 7.5 m^2/ha; *Corymbia clarksoniana* = 0.17 m^2/ha **(total = 7.67 m^2/ha).**
S1: *Acacia shirleyi* <0.17 m^2/ha; *Erythroxylum australe* <0.17 m^2/ha **(total <0.17 m^2/ha).**

Landform: Rocky hillside **Slope:** 20°E **Soil:** Brown sandy-loam with sandstone boulders

Disturbance: Fire scars to 3 m high on tree trunks; lightly grazed.

Ground cover: Rock = 20%, wood = 4.5%, bare = 5%, litter = 10%, vegetation = 61.5%.

Species (percent cover): *Acacia shirleyi* (0.1%), *Alphitonia excelsa* (0.1%), *Aristida benthamii* (0.1%), *Cheilanthes sieberi* (0.1%), *Cleistochloa subjuncea* (60%), *Cyanthillium cinereum* (0.1%), *Digitaria diminuta* (0.1%), *Erythroxylum australe* (0.1%), *Goodenia* sp. (Mt Castletower M.D. Crisp 2753) (0.1%), *Marsdenia microlepis* (0.1%), *Paspalidium gracile* (0.1%), *Persoonia falcata* (0.1%), *Phyllanthus collinus* (0.1%), *Scleria sphacelata* (0.1%), *Sida* sp. (Musselbrook M.B. Thomas+ MRS437) (0.1%), *Solanum parvifolium* (0.1%).

SECONDARY SITE 10 **11.10.1**



Latitude, Longitude: -22.2971, 148.1753

Community description: Open forest dominated by *Corymbia citriodora* on sandstone.

Dominant species per stratum:

T1: *Corymbia citriodora, Corymbia trachyphloia.*
T2: *Acacia shirleyi, Lysicarpus angustifolius.*
S1: *Alphitonia excelsa, Dodonaea lanceolata.*
G: *Cleistochloa subjuncea, Melinis repens*, Scleria sphacelata.*

Median (and range) canopy height per stratum: T1 = 25.6 m (19–28.8 m), T2 = 10 m (9.2–11.8 m), S1 = 1.5 m (1.2–1.5 m).

% cover of each stratum: T1 = 51%; T2 = 45.6%; S1 = 3.6%; **total = 74.3%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Corymbia citriodora* = 2.83 m^2/ha **(total = 2.83 m^2/ha)**
T2: *Lysicarpus angustifolius* = 1.83 m^2/ha; *Acacia shirleyi* = 1 m^2/ha; *Eucalyptus crebra* = 1 m^2/ha; *Bursaria incana* = 0.33 m^2/ha; *Larsenaikia ochreata* = 0.17 m^2/ha; *Corymbia trachyphloia* = 0.17 m^2/ha **(total = 4.5 m^2/ha)**
S1: *Alphitonia excelsa* = 0.17 m^2/ha **(total = 0.17 m^2/ha)**

Landform: Steep foot slope of rocky hill **Slope:** 30°SE **Soil:** Sandy

Disturbance: Nil

Ground cover: Rock = 55%, wood = 1%, bare = 1%, litter = 25%, vegetation = 18%.

Species (percent cover): *Afrohybanthus stellarioides* (0.1%), *Alphitonia excelsa* (0.1%), *Aristida benthamii* (0.2%), *Aristida calycina var. calycina* (0.1%), *Breynia oblongifolia* (0.1%), *Bursaria incana* (0.1%), *Capparis canescens* (0.1%), *Cheilanthes sieberi* (0.1%), *Cleistochloa subjuncea* (9%), *Corymbia citriodora subsp. citriodora* (0.1%), *Corymbia trachyphloia* (0.1%), *Cyanthillium cinereum* (0.1%), *Cyclophyllum coprosmoides* (0.3%), *Cymbopogon obtectus* (0.1%), *Cymbopogon refractus* (0.2%), *Desmodium macrocarpum* (0.1%), *Dodonaea lanceolata* (0.1%), *Eragrostis spartinoides* (0.1%), *Erythroxylum australe* (0.1%), *Euphorbia drummondii* (0.1%), *Euphorbia tannensis* (0.1%), *Evolvulus alsinoides* (0.1%), *Gahnia aspera* (0.1%), *Galactia tenuiflora* (0.1%), *Goodenia* sp. (Mt Castletower M.D. Crisp 2753) (0.1%), *Hovea tholiformis* (0.1%), *Larsenaikia ochreata* (0.1%), *Leptospermum lamellatum* (0.1%), *Lomandra multiflora* (0.1%), *Marsdenia microlepis* (0.1%), *Melinis repens** (2%), *Murdannia graminea* (0.1%), *Oxalis corniculata* (0.1%), *Panicum effusum* (0.1%), *Persoonia amaliae* (0.1%), *Persoonia falcata* (0.1%), *Phyllanthus carpentariae* (0.1%), *Phyllanthus virgatus* (0.1%), *Pseuderanthemum variabile* (0.1%), *Rostellularia adscendens* (0.1%), *Scleria sphacelata* (2.2%), *Sida* sp. (0.1%), *Sida* sp. (Musselbrook M.B. Thomas+ MRS437) (0.1%), *Solanum ellipticum* (0.1%), *Themeda triandra* (0.2%).

SECONDARY SITE 11 **HVR 11.5.9**



Latitude, Longitude: -22.3198, 148.1956

Community description: Open forest dominated by *Eucalyptus crebra* on sand plain.

Dominant species per stratum:

T1: *Eucalyptus crebra, Eucalyptus melanophloia* (subdominant).
S1: *Erythroxylum australe, Petalostigma pubescens.*
G: *Chrysopogon fallax*, *Bothriochloa pertusa**.

Median (and range) canopy height per stratum: T1 =12 m (10–14 m), S1 = 3 m (0.5–3 m).

% cover of each stratum: T1 = 54.7%; **total = 54.7%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Eucalyptus crebra* = 8 m^2/ha; *Eucalyptus melanophloia* = 0.5 m^2/ha; *Corymbia dallachiana* = 0.17 m^2/ha; *Corymbia clarksoniana* = 0.17 m^2/ha **(total = 8.84 m^2/ha)**
S1: *Erythroxylum australe* <0.15 m^2/ha; *Petalostigma pubescens* <0.15 m^2/ha **(total <0.15 m^2/ha)**

Landform: Gently sloping plain **Slope:** 2°S **Soil:** Yellow-grey sand

Disturbance: Previously cleared; regular fire has maintained an open understorey.

Ground cover: Rock = 0%, wood = 1.5%, bare = 40%, litter = 35%, vegetation = 23.5%.

Species: *Afrohybanthus stellarioides* (0.1%), *Alphitonia excelsa* (0.1%), *Alternanthera nana* (0.1%), *Aristida calycina* var. *calycina* (0.1%), *Bothriochloa decipiens* var. *cloncurrensis* (0.3%), *Bothriochloa pertusa** (20%), *Brunoniella australis* (0.1%), *Cenchrus ciliaris** (0.1%), *Chamaecrista absus* (0.1%), *Chloris divaricate* (0.1%), *Chrysopogon fallax* (5%), *Cyanthillium cinereum* (0.1%), *Cyperus fulvus* (0.1%), *Digitaria divaricatissima* (0.1%), *Digitaria* sp. A (0.1%), *Eragrostis sororia* (0.1%), *Eulalia aurea* (0.1%), *Evolvulus alsinoides* (0.1%), *Fimbristylis dichotoma* (0.1%), *Galactia tenuiflora* (0.1%), *Glycine tomentella* (0.1%), *Gomphrena celosioides** (0.1%), *Grewia latifolia* (0.1%), *Ipomoea polymorpha* (0.1%), *Melaleuca nervosa* (0.1%), *Melhania oblongifolia* (0.1%), *Murdannia graminea* (0.1%), *Phyllanthus carpentariae* (0.8%), *Phyllanthus collinus* (0.1%), *Portulaca pilosa** (0.1%), *Rostellularia adscendens* (0.1%), *Scoparia dulcis** (0.1%), *Sida hackettiana* (0.1%), *Sida* sp. (Musselbrook M.B. Thomas+ MRS437) (0.1%), *Sida spinosa** (0.2%), *Stylosanthes scabra** (0.1%), *Urochloa piligera* (0.1%), *Zornia areolata* (0.1%), *Zornia muriculata* subsp. *angustata* (0.1%).

SECONDARY SITE 12 **HVR 11.10.3**



Latitude, longitude: -22.3166, 148.1914

Community description: Low open forest dominated by *Acacia shirleyi*, with emergent *Eucalyptus crebra* and *Eucalyptus exserta*, on a sandstone ridge.

Dominant species per stratum:

E: *Eucalyptus crebra, Eucalyptus exserta.*
T1: *Acacia shirleyi.*
S1: *Erythroxylum australe.*
G: *Cleistochloa subjuncea, Paspalidium caespitosum.*

Median (and range) canopy height per stratum: T1 = 8.2 m (7–9.8 m), S1 = (1.5–4 m).

% cover of each stratum: T1 = 66.8%; S1 = 10%; **total 73.3%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

E: <0.17 m^2/ha)
T1: *Acacia shirleyi* =5.83 m^2/ha; *Eucalyptus exserta* = 1.3 m^2/ha; *Eucalyptus crebra* = 0.67 m^2/ha **(total = 7.8 m^2/ha)**
S1: *Erythroxylum australe* = 0.5 m^2/ha **(total = 0.5 m^2/ha)**

Landform: Ridge top **Slope:** 3°E **Soil:** Grey-brown silty sand

Disturbance: Burnt and probably previously cleared. Mapped as non-remnant.

Ground cover: Rock = 1%, wood = 6%, bare = 31%, litter = 42%, vegetation = 20%.

Species (percent cover): *Acacia shirleyi* (0.1%), *Alloteropsis cimicina* (0.1%), *Alphitonia excelsa* (0.1%), *Alternanthera nana* (0.1%), *Aristida calycina* var. *calycina* (0.8%), *Calotis cuneifolia* (0.1%), *Cenchrus ciliaris** (0.1%), *Cheilanthes sieberi* (0.1%), *Chrysopogon fallax* (0.1%), *Cleistochloa subjuncea* (8%), *Dianella nervosa* (0.1%), *Digitaria diminuta* (0.1%), *Eragrostis lacunaria* (0.2%), *Eriachne obtusa* (0.1%), *Erythroxylum australe* (0.1%), *Eucalyptus crebra* (0.1%), *Evolvulus alsinoides* (0.1%), *Jasminum didymum* subsp. *lineare* (0.1%), *Larsenaikia ochreata* (0.1%), *Marsdenia microlepis* (0.1%), *Opuntia tomentosa** (0.1%), *Panicum effusum* (0.1%), *Paspalidium caespitosum* (5%), *Paspalidium gracile* (0.4%), *Pseuderanthemum variabile* (0.1%), *Sida* sp. (Musselbrook M.B. Thomas+ MRS437) (1%), *Stylosanthes scabra** (0.4%), *Thyridolepis xerophila* (0.1%), *Urochloa mosambicensis** (0.2%).

SECONDARY SITE 13 **11.3.25**



Latitude, Longitude: -22.3866, 148.2619

Community description: Closed forest dominated by *Eucalyptus camaldulensis* and *Melaleuca fluviatilis* along an ephemeral watercourse.

Dominant species per stratum:

T1: *Eucalyptus camaldulensis, Melaleuca fluviatilis.*
T2: *Bauhinia hookeri.*
G: *Megathyrsus maximus* var. *pubiglumis *, Sida rhombifolia*, Bothriochloa pertusa*, Acanthospermum hispidum*, Urochloa mosambicensis*.*

Median (and range) canopy height per stratum: T1 = 24.8 m (15.6–55.8 m), T2 = 5 m.

% cover of each stratum: T1 = 86.9%; T2 = 0.5%; **total = 86.9%**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Eucalyptus camaldulensis* = 5.67 m^2/ha; *Melaleuca fluviatilis* = 6 m^2/ha; *Corymbia tessellaris* = 0.3 m^2/ha **(total = 11.97 m^2/ha)**
T2: *Bauhinia hookeri* = 0.3 m^2/ha **(total = 0.3 m^2/ha)**

Landform: Creek bank **Slope:** 0° **Soil:** Brown clay

Disturbance: Grazed and with very high weed densities.

Ground cover: Rock = 0%, wood = 1%, bare = 5%, litter = 7%, vegetation = 87%.

Species (percent cover): *Acanthospermum hispidum** (8%), *Achyranthes aspera* (0.1%), *Afrohybanthus stellarioides* (0.1%), *Alloteropsis cimicina* (0.1%), *Bauhinia hookeri* (0.1%), *Bidens bipinnata** (0.1%), *Bothriochloa pertusa** (30%), *Calyptocarpus vialis** (0.1%), *Carissa ovata* (0.1%), *Cenchrus ciliaris** (0.1%), *Chloris virgata** (0.1%), *Commelina diffusa* (0.1%), *Crinum arenarium* (0.1%), *Cynodon dactylon** (3%), *Datura leichhardtii** (0.1%), *Digitaria eriantha** (2%), *Echinochloa colona** (1%), *Eragrostis elongata* (0.1%), *Eucalyptus camaldulensis* (0.1%), *Ficus opposita* (0.1%), *Gomphrena celosioides** (0.1%), *Ipomoea plebia* (0.1%), *Malvastrum coromandelianum** (0.1%), *Megathyrsus maximus* var. *pubiglumis** (4%), *Melinis repens** (0.1%), *Parthenium hysterophorus** (0.2%), *Perotis rara* (0.1%), *Phyllanthus virgatus* (0.1%), *Portulaca pilosa** (0.1%), *Scoparia dulcis** (0.1%), *Senna occidentalis** (0.1%), *Sida cordifolia** (0.3%), *Sida rhombifolia** (8%), *Sida spinosa** (0.1%), *Solanum ellipticum* (0.1%), *Stachytarpheta jamaicensis** (0.1%), *Stylosanthes hamata** (0.1%), *Urochloa mosambicensis** (20%), *Verbesina encelioides** (0.1%), *Xanthium occidentale** (0.2%), *Zornia muriculata* subsp. *angustata* (0.1%).

SECONDARY SITE 14 **Non-remnant**



Latitude, Longitude: -22.3909, 148.2546

Community description: Open pasture derived from cleared *Eucalyptus populnea* dominated woodland.

Dominant species per stratum:

T1: *Eucalyptus populnea.*
S1: *Atalaya hemiglauca, Carissa ovata, Eucalyptus populnea.*
G: *Cenchrus ciliaris, Bothriochloa pertusa, Urochloa mosambicensis*

Median (and range) canopy height per stratum: T1 = 10 m (8–15.2 m), S1 = 2.5 m (1.5–4 m).

% cover of each stratum: T1 < 0.1%; S1 = 1.9%; **total = 1.9%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Persoonia falcata* = 0.75 m^2/ha; *Eucalyptus populnea* = 0.5 m^2/ha **(total = 1.25 m^2/ha)**
S1: *Atalaya hemiglauca* <0.15 m^2/ha, *Carissa ovata* <0.15 m^2/ha, *Eucalyptus populnea* <0.15 m^2/ha **(total = <0.15 m^2/ha)**

Landform: Plain **Slope:** 0° **Soil:** Dark-brown silt

Disturbance: Cleared, weed-infested and heavily grazed.

Ground cover: Rock = 0%, wood = 0.2%, bare = 10%, litter = 1%, vegetation = 88.8%.

Species: *Alternanthera nana* (0.1%), *Apowollastonia spilanthoides* (0.1%), *Atalaya hemiglauca* (0.1%), *Boerhavia pubescens* (0.1%), *Bothriochloa ewartiana* (0.1%), *Bothriochloa pertusa** (0.1%), *Capparis lasiantha* (0.1%), *Carissa ovata* (0.2%), *Cenchrus ciliaris** (65%), *Chrysopogon fallax* (0.1%), *Crotalaria juncea** (0.1%), *Cyanthillium cinereum* (0.1%), *Digitaria eriantha** (0.1%), *Enteropogon ramosus* (0.1%), *Eucalyptus populnea* (0.1%), *Fimbristylis dichotoma* (0.1%), *Galactia tenuiflora* (0.1%), *Gomphrena celosioides** (0.1%), *Grewia retusifolia* (0.1%), *Indigofera colutea* (0.1%), *Indigofera linnaei* (0.1%), *Neptunia gracilis* (0.1%), *Panicum effusum* (0.1%), *Parsonsia lanceolata* (0.1%), *Phyllanthus virgatus* (0.1%), *Portulaca pilosa** (0.1%), *Rhynchosia minima* (0.1%), *Sida hackettiana* (0.1%), *Sida spinosa** (0.1%), *Sphaeromorphaea australis* (0.1%), *Sporobolus caroli* (0.1%), *Stylosanthes hamata** (0.1%), *Stylosanthes humilis** (0.1%), *Stylosanthes scabra** (0.1%), *Urochloa mosambicensis** (10%).

SECONDARY SITE 15 **Regrowth 11.5.3**



Latitude, Longitude: -22.3939, 148.25

Community description: Low open forest dominated by *Eucalyptus populnea* on a sand plain.

Dominant species per stratum:

T1: *Eucalyptus populnea*.
T2: *Eucalyptus populnea*.
S1: *Carissa ovata*.
G: *Bothriochloa pertusa*, Sida hackettiana*

Median (and range) canopy height per stratum: T1 = 9.8 m (9.6–12 m), S1 = 1.6 m (1.4–2.5 m).

% cover of each stratum: T1 = 62.9%; S1 = 7%; **total = 66.2%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Eucalyptus populnea* = 8.17 m^2/ha; *Corymbia clarksoniana* = 0.33 m^2/ha; *Persoonia falcata* = 0.16 m^2/ha **(total = 8.66 m^2/ha)**
T2: *Eucalyptus populnea* <0.17 m^2/ha **(total <0.17 m^2/ha)**
S1: *Carissa ovata* <0.17 m^2/ha **(total < 0.17 m^2/ha)**

Landform: Plain **Slope:** 1°SW **Soil:** Yellow-brown loam.

Disturbance: Previously cleared and not quite old enough to qualify as high-value regrowth?; heavily grazed.

Ground cover: Rock = 0%, wood = 1%, bare = 53%, litter = 32%, vegetation = 14%.

Species (percent cover): *Abutilon oxycarpum* (0.1%), *Alternanthera denticulata* (0.1%), *Alternanthera nana* (0.1%), *Apowollastonia spilanthoides* (0.1%), *Aristida calycina* var. *calycina* (0.1%), *Boerhavia pubescens* (0.1%), *Bothriochloa pertusa** (8.6%), *Brunoniella australis* (0.1%), *Carissa ovata* (0.1%), *Cenchrus ciliaris** (0.1%), *Chrysopogon fallax* (0.1%), *Cyperus gracilis* (0.1%), *Enteropogon ramosus* (0.1%), *Eremophila debilis* (0.1%), *Eucalyptus populnea* (0.1%), *Evolvulus alsinoides* (0.1%), *Glycine* sp. (Mackay S.B. Andrews+ 43) (0.1%), *Gomphrena celosioides** (0.1%), *Grewia latifolia* (0.1%), *Grewia retusifolia* (0.6%), *Owenia acidula* (0.1%), *Phyllanthus collinus* (0.1%), *Portulaca oleracea** (0.1%), *Rhynchosia minima* (0.1%), *Sida hackettiana* (1.4%), *Sida spinosa** (0.1%), *Solanum ellipticum* (0.1%), *Sporobolus caroli* (0.1%), *Stylosanthes scabra** (0.1%), *Urochloa mosambicensis** (0.8%).

SECONDARY SITE 16 **11.5.3**



Latitude, Longitude: -22.3920, 148.2295

Community description: Open forest dominated by *Eucalyptus populnea* on sandy soils.

Dominant species per stratum:

T1: *Eucalyptus populnea.*
T2: *Corymbia clarksoniana, Eucalyptus populnea.*
G: *Cenchrus ciliaris*.*

Median (and range) canopy height per stratum: T1 = 14.2 m (13.4–18 m), T2 = 7.2 m (0.4–7.2 m), S1 = 3 m (2.0–4.0 m).

% cover of each stratum: T1 = 52.2%; T2 = 45.6%; **total = 72%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Eucalyptus populnea* = 5.17 m^2/ha **(total = 5.17 m^2/ha)**
T2: *Eucalyptus populnea* = 4.25 m^2/ha; *Corymbia clarksoniana* = 0.5 m^2/ha **(total = 4.75 m^2/ha)**

Landform: Plain on low rise **Slope:** 2°S **Soil:** Yellow-brown sand

Disturbance: Grazed and dominated by weed understorey.

Ground cover: Rock = 0%, wood = 1.5%, bare = 20%, litter = 30%, vegetation = 48.5%.

Species (percent cover): *Acanthospermum hispidum** (0.1%), *Achyranthes aspera* (0.1%), *Afrohybanthus enneaspermus* (0.1%), *Alphitonia excelsa* (0.1%), *Alternanthera nana* (0.1%), *Archidendropsis basaltica* (0.1%), *Aristida calycina* var. *calycina* (0.1%), *Aristida holathera* (0.1%), *Aristolochia thozetii* (0.1%), *Boerhavia pubescens* (0.1%), *Bonamia media* (0.5%), *Bothriochloa pertusa** (0.5%), *Breynia oblongifolia* (0.1%), *Brunoniella australis* (0.1%), *Calotis cuneifolia* (0.1%), *Capparis canescens* (0.1%), *Capparis lasiantha* (0.1%), *Cenchrus ciliaris** (42%), *Chrysopogon fallax* (0.1%), *Clerodendrum tomentosum* (0.1%), *Cyanthillium cinereum* (0.1%), *Dactyloctenium radulans* (0.1%), *Dysphania melanocarpa* forma *melanocarpa* (0.1%), *Enneapogon lindleyanus* (0.1%), *Enteropogon ramosus* (0.1%), *Eragrostis lacunaria* (0.1%), *Eragrostis sororia* (0.1%), *Evolvulus alsinoides* (0.1%), *Fimbristylis dichotoma* (0.1%), *Galactia tenuiflora* (0.1%), *Glycine* sp. (Mackay S.B. Andrews+ 43) (0.1%), *Glycine tomentella* (0.1%), *Gomphrena celosioides** (0.1%), *Grewia retusifolia* (0.1%), *Ipomoea polymorpha* (0.1%), *Parsonsia lanceolata* (0.1%), *Phyllanthus collinus* (0.1%), *Portulaca filifolia* (0.1%), *Rostellularia adscendens* (0.1%), *Setaria surgens* (0.1%), *Sida cordifolia** (0.1%), *Sida hackettiana* (0.1%), *Sida spinosa** (0.1%), *Stylosanthes hamata** (0.1%), *Stylosanthes humilis** (0.1%), *Urochloa mosambicensis** (1%), *Ventilago viminalis* (0.1%), *Zornia areolata* (0.1%), *Zornia muelleriana* subsp. *muelleriana* (0.1%).

SECONDARY SITE 17 **11.5.9**



Latitude, Longitude: -22.3839, 148.2236

Community description: Low open woodland dominated by *Corymbia clarksoniana*. Despite the absence of *Eucalyptus crebra*, it otherwise resembles regional ecosystem 11.5.9 in structure and floristics of the lower strata. A small number of sandstone boulders suggests that it might be 11.10.7 instead of 11.5.2, but the land form was otherwise a sandy plain.

Dominant species per stratum:

T1: *Corymbia clarksoniana.*
T2: *Acacia burdekensis, Alphitonia excelsa.*
S1: *Melaleuca nervosa.*
G: *Melinis repens*, Perostis rara, Alloteropsis cimicina, Aristida calycina* var. *calycina.*

Median (and range) canopy height per stratum: T1 =9.6 m (8.6–12.2 m), T2 = 6.4 m (5.4–7 m), S1 = 3.0 m (2.0–4.0 m).

% cover of each stratum: T1 = 3.7%; T2 = 14.3%; S1 = 10.7%; t**otal = 26.6%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Corymbia clarksoniana* = 1.5 m^2/ha **(total = 1.5 m^2/ha)**
T2: *Acacia burdekensis* = 0.83 m^2/ha; *Alphitonia excelsa* = 0.33 m^2/ha; *Petalostigma pubescens* = 0.17 m^2/ha; *Bursaria incana* = 0.17 m^2/ha **(total = 1.5 m^2/ha)**
S1: *Melaleuca nervosa* = 1.5 m^2/ha **(total = 1.5 m^2/ha)**

Landform: Low sandy plateau **Slope:** 2°N **Soil:** Yellow-brown coarse sand with scattered sandstone boulders.

Disturbance: Lightly grazed.

Ground cover: Rock = 1%, wood = 2%, bare = 45%, litter = 22%, vegetation = 30%.

Species: *Acacia burdekensis* (0.1%), *Acanthospermum hispidum** (0.1%), *Afrohybanthus stellarioides* (0.1%), *Alloteropsis cimicina* (2%), *Alphitonia excelsa* (0.1%), *Aristida calycina* var. *calycina* (3%), *Bonamia media* (0.1%), *Chamaecrista absus* (0.1%), *Chrysopogon fallax* (0.1%), *Cleome tetrandra* var. *tetrandra* (0.1%), *Cyanthillium cinereum* (0.1%), *Dactyloctenium radulans* (0.9%), *Digitaria eriantha** (0.6%), *Dysphania melanocarpa* forma *melanocarpa* (0.1%), *Eragrostis lacunaria* (0.1%), *Eragrostis sororia* (0.1%), *Erythroxylum australe* (0.1%), *Fimbristylis dichotoma* (0.1%), *Glycine tomentella* (0.1%), *Goodenia glabra* (0.1%), *Heliotropium peninsulare* (0.1%), *Indigofera colutea* (0.1%), *Ipomoea polymorpha* (0.1%), *Melaleuca nervosa* (0.1%), *Melinis repens** (9%), *Paspalidium rarum* (0.1%), *Perotis rara* (3.7%), *Phyllanthus* sp. (Myra Vale J.J. Bruhl+ 1810) (0.1%), *Portulaca bicolor* (0.2%), *Psydrax oleifolia* (0.1%), *Setaria surgens* (0.1%), *Sida cordifolia** (0.1%), *Sida hackettiana* (1.3%), *Spermacoce brachystema* (0.1%), *Stylosanthes hamata** (0.1%), *Stylosanthes scabra** (0.4%), *Tribulopis angustifolia* (0.1%), *Urochloa mosambicensis** (1%), *Urochloa piligera* (5%), *Zornia* sp. (0.1%).

SECONDARY SITE 18 **11.5.3**



Latitude, Longitude: -22.3767, 148.2250

Community description: Woodland dominated by *Eucalyptus populnea* on a sand plain.

Dominant species per stratum:

T1: *Corymbia dallachiana.*
T2: *Alphitonia excelsa, Acacia burdekensis, Eucalyptus populnea, Melaleuca nervosa.*
S1: *Erythroxylum australe.*
G: *Alloteropsis cimicina, Chrysopogon fallax, Eragrostis speciosa*, *Perotis rara, Sida hackettiana, Urochloa piligera.*

Median (and range) canopy height per stratum: T1 = 16.6 m (12.8–17.2 m), T2 = 6.4 m (6.0–7.2 m), S1 = 1.8 m (1.0–2.0 m).

% cover of each stratum: T1 = 2%; T2 = 45.4%; S1 = 4.4%; **total = 51.4%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Acacia burdekensis* = 2.33 m^2/ha; *Eucalyptus populnea* = 1.67 m^2/ha; *Corymbia dallachiana* = 0.3 m^2/ha; *Corymbia clarksoniana* = 0.17 m^2/ha **(total = 4.47 m^2/ha)**
T2: *Melaleuca nervosa* = 4.83 m^2/ha; *Alphitonia excelsa* = 0.67 m^2/ha; **(total = 5.5 m^2/ha)**
S1: *Erythroxylum australe* <0.15 m^2/ha **(total <0.15 m^2/ha)**

Landform: Low sandy plateau. **Slope:** 2°N **Soil:** Yellow-brown sand with scattered boulders.

Disturbance: Light grazing.

Ground cover: Rock = 0.5%, wood = 2%, bare = 40%, litter = 23%, vegetation = 33.5%.

Species (percent cover): *Acanthospermum hispidum** (0.1%), *Afrohybanthus enneaspermus* (0.1%), *Afrohybanthus stellarioides* (0.1%), *Alloteropsis cimicina* (7.1%), *Alphitonia excelsa* (0.1%), *Alternanthera nana* (0.1%), *Aristida calycina* var. *calycina* (0.1%), *Cheilanthes sieberi* (0.1%), *Chrysopogon fallax* (8.1%), *Cyanthillium cinereum* (0.1%), *Desmodium filiforme* (0.1%), *Digitaria minima* (0.1%), *Eragrostis spartinoides* (0.1%), *Eragrostis speciosa* (2.1%), *Evolvulus alsinoides* (0.1%), *Fimbristylis dichotoma* (0.1%), *Ipomoea polymorpha* (0.1%), *Melaleuca nervosa* (0.1%), *Murdannia graminea* (0.1%), *Perotis rara* (8%), *Phyllanthus collinus* (0.1%), *Phyllanthus* sp. (Myra Vale J.J. Bruhl+ 1810) (0.1%), *Portulaca filifolia* (1.2%), *Portulaca pilosa** (0.1%), *Setaria surgens* (0.1%), *Sida cordifolia** (0.1%), *Sida hackettiana* (2.1%), *Sida spinosa** (0.1%), *Stylosanthes hamata** (0.1%), *Stylosanthes scabra** (0.1%), *Tephrosia leptoclada* (0.1%), *Tribulopis angustifolia,* (0.1%), *Urochloa piligera* (2.2%), *Zornia* sp. (0.1%).

SECONDARY SITE 19 **11.4.8**



Latitude, Longitude: -22.3772, 148.2379

Community description: Woodland dominated by *Acacia harpophylla* and *Eucalyptus cambageana* on a clay plain.

Dominant species per stratum:

T1: *Acacia harpophylla, Eucalyptus cambageana.*
S1: *Eremophila mitchellii, Ventilago viminalis.*
S2: *Carissa ovata.*
G: *Cenchrus ciliaris*, Chloris ventricosa, Urochloa mosambicensis*.*

Median (and range) canopy height per stratum: T1 = 11.6 m (10.6–14.6 m), S1 = 5.5 m (5.0–6.0 m), S2 = 1 m (0.5–1.6 m).

% cover of each stratum: T1 = 27.7%; S1 = 5.4%; S2 = 33.2%; **total = 53.8%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Acacia harpophylla* = 5.67 m^2/ha; *Eucalyptus cambageana* = 1.67 m^2/ha **(total = 7.34 m^2/ha)**
S1: *Eremophila mitchellii* = 0.3 m^2/ha; *Flindersia dissosperma* = 0.17 m^2/ha **(total = 0.47 m^2/ha)**
S2: *Carissa ovata* <0.15 m^2/ha **(total <0.15 m^2/ha)**

Landform: Plain **Slope:** 1°E **Soil:** Grey-brown sandy-clay, possibly heavier subsoil. No gilgais.

Disturbance: Grazed; numerous dead trees.

Ground cover: Rock = 0%, wood = 1%, bare = 20%, litter = 20%, vegetation = 59%.

Species (percent cover): *Abutilon oxycarpum* var. *incanum* (0.3%), *Acacia harpophylla* (0.6%), *Achyranthes aspera* (0.1%), *Alternanthera nana* (0.8%), *Ancistrachne uncinata* (0.1%), *Aristida gracilipes* (0.5%), *Atalaya hemiglauca* (0.1%), *Boerhavia pubescens* (0.1%), *Bothriochloa pertusa** (0.5%), *Brunoniella australis* (0.1%), *Capparis lasiantha* (0.1%), *Carissa ovata* (37%), *Cassia brewsteri* (0.1%), *Cenchrus ciliaris** (5%), *Cheilanthes sieberi* (0.1%), *Chloris divaricata* (6%), *Desmodium varians* (0.1%), *Ehretia membranifolia* (0.1%), *Einadia nutans* (0.1%), *Einadia nutans* subsp. *linifolia* (0.1%), *Eragrostis lacunaria* (1%), *Eremophila mitchellii* (0.1%), *Evolvulus alsinoides* (0.1%), *Grewia latifolia* (0.1%), *Harrisia martinii** (0.1%), *Jacquemontia paniculata* (0.1%), *Maireana microphylla* (0.1%), *Melhania oblongifolia* (0.1%), *Nyssanthes erecta* (0.1%), *Opuntia tomentosa** (0.1%), *Owenia acidula* (0.1%), *Parsonsia lanceolata* (0.1%), *Parthenium hysterophorus** (0.5%), *Paspalidium caespitosum* (0.1%), *Paspalidium distans* (0.1%), *Phyllanthus virgatus* (0.1%), *Portulaca oleracea** (0.1%), *Portulaca pilosa** (0.1%), *Pseuderanthemum variabile* (0.1%), *Salsola australis* (0.1%), *Sida hackettiana* (0.1%), *Sida rohlenae* (0.1%), *Sporobolus caroli* (0.4%), *Urochloa mosambicensis** (3%), *Urochloa piligera* (0.1%), *Ventilago viminalis* (0.1%).

SECONDARY SITE 20 **HVR 11.5.3**



Latitude, Longitude: -22.3787, 148.2139

Community description: Open forest dominated by *Eucalyptus populnea* on a sand plain.

Dominant species per stratum:

T1: *Eucalyptus populnea.*
T2: *Eucalyptus populnea.*
S1: *Eucalyptus populnea, Erythroxylum australe.*
G: *Bothriochloa pertusa*, Aristida calycina* var. *calycina, Fimbristylis dichotoma.*

Median (and range) canopy height per stratum: T1 = 14.8 m (10.0–15.6 m), T2 = 3.0 m (2.5–4.0 m), S1 = 1.0 m (0.5–1.5 m).

% cover of each stratum: T1 = 58.4%; T2 = 2.1%; S1 = 1.6%; **total = 60.5%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Eucalyptus populnea* = 12.17 m^2/ha **(total = 12.17 m^2/ha)**
T2: *Eucalyptus populnea* < 0.17 **(total < 0.17 m^2/ha)**
S1: *Erythroxylum australe* < 0.17 **(total < 0.17 m^2/ha)**

Landform: Plain **Slope:** 1°NE **Soil:** Yellow-brown sand

Disturbance: Previously cleared; heavily grazed.

Ground cover: Rock = 0%, wood = 2%, bare = 40%, litter = 20%, vegetation = 38%.

Species (percent cover): *Alloteropsis cimicina* (0.1%), *Alphitonia excelsa* (0.1%), *Alternanthera denticulata* (0.1%), *Alternanthera nana* (0.1%), *Apowollastonia spilanthoides* (0.1%), *Aristida calycina* var. *calycina* (1%), *Boerhavia pubescens* (0.1%), *Bothriochloa pertusa** (26.6%), *Carissa ovata* (0.1%), *Cenchrus ciliaris** (0.3%), *Cheilanthes sieberi* (0.1%), *Chloris divaricata* (3%), *Chloris virgata** (0.1%), *Chrysopogon fallax* (0.1%), *Cyanthillium cinereum* (0.1%), *Cyperus fulvus* (0.1%), *Digitaria longiflora* (0.1%), *Enneapogon lindleyanus* (0.1%), *Eragrostis lacunaria* (1%), *Eragrostis leptostachya* (0.1%), *Eragrostis sororia* (0.1%), *Eremophila debilis* (0.1%), *Erythroxylum australe* (0.1%), *Eucalyptus populnea* (0.1%), *Euphorbia drummondii* (0.1%), *Fimbristylis dichotoma* (2%), *Gomphrena celosioides** (0.1%), *Grewia latifolia* (0.1%), *Ipomoea polymorpha* (0.1%), *Melhania oblongifolia* (0.1%), *Murdannia graminea* (0.1%), *Opuntia tomentosa** (0.1%), *Panicum effusum* (0.1%), *Phyllanthus collinus* (0.1%), *Phyllanthus* sp. (Myra Vale J.J. BruhlJ.J. Bruhl+ 1810) (0.1%), *Portulaca filifolia* (0.1%), *Portulaca pilosa** (0.1%), *Rhynchosia minima* (0.1%), *Rostellularia adscendens* (0.1%), *Sida hackettiana* (0.1%), *Sida spinosa** (0.1%), *Stylosanthes scabra** (0.1%), *Urochloa mosambicensis** (0.1%), *Vittadinia pustulata* (0.1%), *Zornia areolata* (0.1%).

SECONDARY SITE 21 **11.3.25**



Latitude, Longitude: -22.3736, 148.2149

Community description: Open forest dominated by *Corymbia tessellaris, Melaleuca fluviatilis, Eucalyptus camaldulensis* and *Casuarina cunninghamiana* on the banks of an ephemeral watercourse.

Dominant species per stratum:

T1: *Casuarina cunninghamiana, Corymbia tessellaris, Eucalyptus camaldulensis, Melaleuca fluviatilis.*
S1: *Bauhinia hookeri, Lophostemon grandiflorus.*
G: *Megathyrsus maximus* var. *pubiglumis*, Bothriochloa ewartiana.*

Median (and range) canopy height per stratum: T1 = 24.2 m (21.8–24.4 m), S1 = 5.0 m (3.0–9.6 m).

% cover of each stratum: T1 = 62.4%; S1 = 46.9%; **total = 95.5%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Corymbia tessellaris* = 4.33 m^2/ha; *Melaleuca fluviatilis* = 3.17 m^2/ha; *Casuarina cunninghamiana* = 1.17 m^2/ha; *Eucalyptus camaldulensis* = 1.17 m^2/ha; *Cassia brewsteri* = 0.17 m^2/ha **(total = 10.01 m^2/ha).**
S1: *Bauhinia hookeri* = 0.67 m^2/ha; *Casuarina cunninghamiana* = 0.17 m^2/ha; *Lophostemon grandiflorus* = 0.17 m^2/ha; *Melaleuca fluviatilis* = 0.17 m^2/ha **(total = 1.18 m^2/ha).**

Landform: Creek bank **Slope:** 40°N **Soil:** Yellow sand

Disturbance: High weed densities.

Ground cover: Rock = 0%, wood = 1%, bare = 3%, litter = 30%, vegetation = 66%.

Species (percent cover): *Abutilon guineense** (0.1%), *Acacia salicina* (0.1%), *Acanthospermum hispidum** (0.1%), *Achyranthes aspera* (0.1%), *Afrohybanthus enneaspermus* (0.1%), *Ageratum conyzoides** (0.1%), *Ajuga australis* (0.1%), *Alloteropsis cimicina* (0.1%), *Bauhinia hookeri* (0.1%), *Bidens pilosa** (0.1%), *Bothriochloa ewartiana* (7%), *Bothriochloa pertusa** (0.2%), *Calyptocarpus vialis* (0.1%), *Cenchrus ciliaris** (0.1%), *Chamaecrista absus* (0.1%), *Cheilanthes sieberi* (0.1%), *Chloris virgata** (0.1%), *Clematicissus opaca* (0.1%), *Clerodendrum floribundum* (0.1%), *Commelina diffusa* (0.7%), *Crotalaria mitchellii* (0.1%), *Cyanthillium cinereum* (0.2%), *Cynodon dactylon** (0.1%), *Cyperus gracilis* (0.1%), *Cyperus leiocaulon* (0.1%), *Digitaria ammophila* (0.1%), *Digitaria eriantha** (0.2%), *Dysphania melanocarpa* forma *melanocarpa* (0.1%), *Emilia sonchifolia** (0.1%), *Euphorbia hirta** (0.1%), *Ficus opposita* (0.1%), *Glycine tomentella* (0.7%), *Grewia retusifolia* (0.1%), *Heteropogon contortus* (0.1%), *Ipomoea plebia* (0.1%), *Lomandra longifolia* (0.1%), *Megathyrsus maximus* var. *pubiglumis** (52%), *Melaleuca fluviatilis* (0.1%), *Oxalis corniculata* (0.1%), *Parthenium hysterophorus** (0.1%), *Pimelea sericostachya* (0.3%), *Rostellularia adscendens* (0.1%), *Senna occidentalis** (0.1%), *Setaria surgens* (0.1%), *Sida cordifolia** (0.1%), *Sida rhombifolia* (0.1%), *Stephania japonica* (0.1%), *Stylosanthes hamata** (0.1%), *Stylosanthes humilis** (0.1%), *Tinospora smilacina* (0.1%), *Tridax procumbens** (0.1%), *Urochloa foliosa* (0.1%), *Urochloa mosambicensis** (0.1%), *Xanthium occidentale** (0.1%).

SECONDARY SITE 22 **HVR 11.5.9**



Latitude, Longitude: -22.3761, 148.2097

Community description: Woodland dominated by *Eucalyptus melanophloia* on a sand plain.

Dominant species per stratum:

T1: *Eucalyptus melanophloia.*
T2: *Melaleuca nervosa.*
S1: *Melaleuca nervosa.*
G: *Chrysopogon fallax, Bothriochloa pertusa*, Perotis rara, Alloteropsis cimicina.*

Median (and range) canopy height per stratum: T1 = 10.2 m (8.0–11.8 m), T2 = 5.2 m (4.6–5.6 m), S1 = 1.6 m (1.0–2.4 m).

% cover of each stratum: T1 = 37%; T2 < 0.1%; S1 < 0.1%; **total = 37%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Eucalyptus melanophloia* = 9.83 m^2/ha **(total = 9.83 m^2/ha)**
T2: *Melaleuca nervosa* = 0.83 m^2/ha **(total = 0.83 m^2/ha)**
S1: total < 0.17 m^2/ha

Landform: Slight rise. **Slope:** 3°N **Soil:** Yellow sand.

Disturbance: Previously cleared but probably very old regrowth; heavily grazed.

Ground cover: Rock = 0%, wood = 1%, bare = 30%, litter = 18%, vegetation = 51%.

Species (percent cover): *Acanthospermum hispidum** (0.1%), *Alloteropsis cimicina* (8%), *Aristida inaequiglumis* (0.1%), *Bonamia media* (0.1%), *Bothriochloa pertusa** (28%), *Chrysopogon fallax* (8%), *Dactyloctenium radulans* (0.1%), *Digitaria longiflora* (0.1%), *Eragrostis sororia* (0.1%), *Eragrostis speciosa* (0.1%), *Eucalyptus melanophloia* (0.1%), *Fimbristylis dichotoma* (0.1%), *Galactia tenuiflora* (0.1%), *Heliotropium peninsulare* (0.1%), *Ipomoea polymorpha* (0.1%), *Melaleuca nervosa* (0.1%), *Paspalidium rarum* (0.1%), *Perotis rara* (1%), *Phyllanthus* sp. (Myra Vale.J. Bruhl+ 1810) (0.1%), *Phyllanthus virgatus* (0.1%), *Portulaca pilosa** (0.1%), *Setaria surgens* (0.2%), *Sida hackettiana* (0.2%), *Stylosanthes hamata** (3.5%), *Stylosanthes scabra** (0.1%), *Tribulopis angustifolia* (0.1%), *Urochloa piligera* (0.1%), *Zornia muelleriana* subsp. *muelleriana* (0.1%).

SECONDARY SITE 23 **11.9.2**



Latitude, Longitude: -22.3641, 148.2071

Community description: Open forest dominated by *Eucalyptus orgadophila* on clay soil derived from fine-grained sedimentary rock.

Dominant species per stratum:

T1: *Eucalyptus orgadophila.*
T2: *Acacia excelsa, Corymbia erythrophloia.*
S1: *Erythroxylum australe, Ventilago viminalis.*
G: *Bothriochloa pertusa*, Enneapogon* sp., *Jaquemontia paniculata*, *Melhania oblongifolia*

Median (and range) canopy height per stratum: T1 = 17.6 m (12.4–18.2 m), T2 = 7.6 m (6.8–8.6 m), S1 = 2.3 m (2.0–3.0 m).

% cover of each stratum: T1 = 69.6%; T2 = 5%; S1 = 4.9%; **total = 75.1%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Eucalyptus orgadophila* = 6.5 m^2/ha; *Acacia excelsa* = 2.5 m^2/ha **(total = 9 m^2/ha)**
T2: *Bursaria incana* = 0.17 m^2/ha; *Corymbia erythrophloia* = 0.33 m^2/ha **(total = 0.5 m^2/ha)**
S1: total < 0.17 m^2/ha

Landform: Low rise. **Slope:** 12°S **Soil:** Dark-brown clay-loam imbedded sandstone.

Disturbance: Lightly grazed

Ground cover: Rock = 0.1%, wood = 0.7%, bare = 25%, litter = 55%, vegetation = 19.2%.

Species (percent cover): *Acacia excelsa* (0.1%), *Afrohybanthus enneaspermus* (0.1%), *Aristida gracilipes* (0.5%), *Aristida holathera* (0.1%), *Atalaya hemiglauca* (0.1%), *Bothriochloa ewartiana* (0.4%), *Bothriochloa pertusa** (9%), *Brunoniella australis* (0.1%), *Bursaria incana* (0.1%), *Carissa ovata* (0.4%), *Cassytha filiformis* (0.4%), *Cenchrus ciliaris** (0.3%), *Enneapogon* sp. A (2%), *Eucalyptus orgadophila* (0.1%), *Euphorbia drummondii* (0.1%), *Eustrephus latifolius* (0.1%), *Glycine tomentella* (0.1%), *Heteropogon contortus* (0.1%), *Indigofera linifolia* (0.1%), *Indigofera linnaei* (0.1%), *Jacquemontia paniculata* (1%), *Lomandra multiflora* (0.1%), *Melhania oblongifolia* (1.6%), *Melinis repens* (0.1%), *Ocimum caryophyllinum* (0.6%), *Peripleura hispidula* var. *setosa* (0.1%), *Phyllanthus maderaspatensis* (0.1%), *Psydrax oleifolia* (0.1%), *Rostellularia adscendens* (0.4%), *Scleria brownii* (0.1%), *Sida hackettiana* (0.1%), *Stylosanthes hamata** (0.1%), *Stylosanthes scabra** (0.1%), *Themeda triandra* (0.1%), *Urochloa foliosa* (0.1%), *Vachellia bidwillii* (0.1%), *Ventilago viminalis* (0.1%).

SECONDARY SITE 24 **11.10.1x1**



Latitude, Longitude: -22.3566, 148.1916

Community description: Woodland dominated by *Corymbia aureola* on a low sandstone rise.

Dominant species per stratum:

T1: *Corymbia aureola, Eucalyptus crebra, Eucalyptus melanophloia.*
T2: *Acacia curvinervia, Acacia burdekensis.*
S1: *Erythroxylum australe.*
G: *Alloteropsis cimicina, Melinis repens*.*

Median (and range) canopy height per stratum: T1 = 13.8 m (10.8–15.2 m), T2 = 5.6 m (4.0–6.0 m), S1 = 2.5 m (1.0–3.0 m).

% cover of each stratum: T1 = 33.6%; T2 = 62%; S1 = 15.1%; **total = 84.9%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Corymbia aureola* = 2.83 m^2/ha; *Alphitonia excelsa* = 1 m^2/ha; *Acacia burdekensis* = 0.5 m^2/ha; *Eucalyptus crebra* = 0.33 m^2/ha; *Eucalyptus melanophloia* = 0.17 m^2/ha; *Petalostigma pubescens* = 0.17 m^2/ha; **(total = 5 m^2/ha)**
T2: *Acacia curvinervia* = 3 m^2/ha; *Corymbia aureola* = 1 m^2/ha; *Eucalyptus melanophloia* = 0.17 m^2/ha; **(total = 4.17 m^2/ha)**
S1: *Erythroxylum australe* = 1 m^2/ha **(total = 1 m^2/ha)**

Landform: Rocky hillside. **Slope:** 9°NE **Soil:** Yellow-grey sand

Disturbance: Grazed

Ground cover: Rock = 28%, wood = 1.5%, bare = 33%, litter = 20%, vegetation = 17.5%.

Species (percent cover): *Acacia bancroftiorum* (0.1%), *Acacia curvinervia* (0.1%), *Acacia dietrichiana* (0.1%), *Alloteropsis cimicina* (8%), *Alphitonia excelsa* (0.1%), *Aristida calycina* var. *calycina* (0.1%), *Bonamia media* (0.1%), *Chamaecrista absus* (0.1%), *Cheilanthes sieberi* (0.1%), *Cleistochloa subjuncea* (0.1%), *Corymbia aureola* (0.1%), *Eragrostis lacunaria* (0.1%), *Erythroxylum australe* (0.1%), *Euphorbia bifida* (0.1%), *Euphorbia drummondii* (0.1%), *Evolvulus alsinoides* (0.1%), *Galactia tenuiflora* (0.1%), *Heliotropium peninsulare* (0.1%), *Hibiscus meraukensis* (0.1%), *Ipomoea brownii* (0.1%), *Ipomoea plebia* (0.1%), *Larsenaikia ochreata* (0.1%), *Melinis repens** (1.5%), *Phyllanthus carpentariae* (0.1%), *Sida hackettiana* (0.1%), *Sida spinosa** (0.1%), *Spermacoce brachystema* (0.1%), *Stylosanthes scabra** (0.1%), *Tephrosia filipes* subsp. *filipes* (0.1%), *Tinospora smilacina* (0.1%), *Urochloa piligera* (5.1%), *Xenostegia tridentata* (0.1%).

SECONDARY SITE 25 **Non-remnant**



Latitude, Longitude: -22.3597, 148.1994

Community description: Pasture with scattered *Eucalyptus crebra* on sand plain. Area was likely to formerly have been regional ecosystem 11.5.9.

Dominant species per stratum:

T1: *Eucalyptus crebra, Grevillea striata.*
S1: *Archidendropsis basaltica, Atalaya hemiglauca.*
G: *Urochloa mosambicensis*, Chloris barbata*.*

Median (and range) canopy height per stratum: T1 = 14.8 m (12.4–19 m), S1 = 2.0 m (0.5–4.0 m).

% cover of each stratum: T1 < 0.1%, S1 = 3.4; **total = 3.4%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Eucalyptus crebra* = 3 m^2/ha **(total = 3 m^2/ha).**
S2: *Archidendropsis basaltica* = 0.17 m^2/ha; *Atalaya hemiglauca* = 0.17 m^2/ha **(total = 0.34 m^2/ha).**

Landform: Low rise on sand plain **Slope:** 2°SSE **Soil:** Yellow-sand

Disturbance: Previously cleared, and probably thinned since; heavily grazed.

Ground cover: Rock = 0%, wood = 0.2%, bare = 49.8%, litter = 18%, vegetation = 32%.

Species (percent cover): *Acanthospermum hispidum** (0.1%), *Alloteropsis cimicina* (0.1%), *Alphitonia excelsa* (0.1%), *Alternanthera nana* (0.1%), *Archidendropsis basaltica* (0.1%), *Aristida calycina* var. *calycina* (0.1%), *Bothriochloa pertusa** (0.9%), *Brunoniella australis* (0.1%), *Cenchrus ciliaris** (0.4%), *Chamaecrista absus* (0.1%), *Cheilanthes sieberi* (0.1%), *Chloris barbata** (6.1%), *Chrysopogon fallax* (0.1%), *Cyanthillium cinereum* (0.1%), *Dactyloctenium radulans* (0.1%), *Digitaria ciliaris* (0.1%), *Dysphania melanocarpa* forma *melanocarpa* (0.1%), *Einadia nutans* (0.1%), *Enteropogon ramosus* (0.1%), *Eragrostis lacunaria* (0.1%), *Evolvulus alsinoides* (0.1%), *Fimbristylis dichotoma* (0.8%), *Gomphrena celosioides** (0.1%), *Indigofera colutea* (0.1%), *Ipomoea polymorpha* (0.1%), *Murdannia graminea* (0.1%), *Perotis rara* (0.1%), *Petalostigma pubescens* (0.1%), *Phyllanthus* sp. (Myra Vale.J. Bruhl+ 1810) (0.1%), *Portulaca pilosa** (0.1%), *Sida cordifolia** (0.1%), *Sida spinosa** (0.1%), *Stylosanthes scabra** (1%), *Urochloa mosambicensis** (20%).

SECONDARY SITE 26 **11.5.3**



Latitude, Longitude: -22.3707, 148.2025

Community description: Open forest dominated by *Eucalyptus populnea* on a sand plain.

Dominant species per stratum:

T1: *Eucalyptus populnea.*
T2: *Acacia excelsa, Eremophila mitchellii, Ventilago viminalis.*
S1: *Carissa ovata, Erythroxylum australe.*
G: *Bothriochloa pertusa*, Aristida gracilipes*, *Cyperus gracilis.*

Median (and range) canopy height per stratum: T1 = 15.6 m (11–16.6 m), T2 = 7.2 m (5.2–9.0 m), S1 = 1.8 m (1.4–2.5 m).

% cover of each stratum: T1 = 53.3%; T2 = 17%; S1 = 49.5%; **total = 88.4%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Eucalyptus populnea* = 8.67 m^2/ha; *Acacia excelsa* = 0.33 m^2/ha **(total = 9 m^2/ha)**
T2: *Eremophila mitchellii* = 3.33 m^2/ha; *Ventilago viminalis* = 2.33 m^2/ha; *Alphitonia excelsa* = 0.17 m^2/ha **(total = 5.83 m^2/ha)**
S1: *Erythroxylum australe* = 0.17 m^2/ha **(total = 0.17 m^2/ha)**

Landform: Plain. Supposed to be land zone 3, but there was no noticeable terrace. It was a high bank from the creek up to the plain.

Slope: 0° **Soil:** Fine yellow-grey sand

Disturbance: Grazed

Ground cover: Rock = 0%, wood = 2%, bare = 31%, litter = 52%, vegetation = 15%.

Species (percent cover): *Abutilon oxycarpum* (0.1%), *Abutilon oxycarpum* var. *incanum* (0.1%), *Acacia excelsa* (0.1%), *Achyranthes aspera* (0.1%), *Alternanthera denticulata* (0.1%), *Alternanthera nana* (0.1%), *Aristida calycina* var. *calycina* (0.1%), *Aristida gracilipes* (4%), *Atalaya hemiglauca* (0.1%), *Boerhavia pubescens* (0.2%), *Bonamia media* (0.1%), *Bothriochloa pertusa** (3.7%), *Breynia oblongifolia* (0.1%), *Capparis lasiantha* (0.1%), *Carissa ovata* (1%), *Cassia brewsteri* (0.1%), *Cenchrus ciliaris** (0.2%), *Chloris divaricata* (0.1%), *Cyanthillium cinereum* (0.1%), *Cyperus gracilis* (1.7%), *Einadia nutans* (0.2%), *Enneapogon lindleyanus* (0.1%), *Eragrostis lacunaria* (0.2%), *Eremophila mitchellii* (0.1%), *Erythroxylum australe* (0.1%), *Eucalyptus populnea* (0.1%), *Evolvulus alsinoides* (0.1%), *Galactia tenuiflora* (0.1%), *Gomphrena celosioides** (0.1%), *Grewia retusifolia* (0.1%), *Malvastrum americanum** (0.1%), *Melhania oblongifolia* (0.2%), *Nyssanthes erecta* (0.1%), *Parsonsia lanceolata* (0.3%), *Phyllanthus collinus* (0.1%), *Portulaca oleracea** (0.1%), *Salsola australis* (0.1%), *Sida hackettiana* (0.1%), *Sida spinosa** (0.2%), *Sporobolus caroli* (0.1%), *Tribulus terrestris** (0.1%), *Ventilago viminalis* (0.1%).

SECONDARY SITE 27 **Non-remnant**



Latitude, Longitude: -22.3803, 148.2550

Community description: Open pasture with scattered *Eucalyptus populnea*

Dominant species per stratum:

T1: *Eucalyptus populnea.*
S1: *Cassia brewsteri.*
G: *Bothriochloa pertusa*, Urochloa mosambicensis*, Fimbristylis dichotoma.*

Median (and range) canopy height per stratum: T1 = 9.1 m (7.2–24.6 m), S1 = 1.5 m (1.0–4.0 m).

% cover of each stratum: T1 = 8.2%; S1 = 2.1%; **total = 10.3%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Eucalyptus populnea* =1.17 m^2/ha **(total = 1.17 m^2/ha)**.
S1: *Corymbia tessellaris* = 0.17 m^2/ha **(total = 0.17 m^2/ha)**.

Landform: Plain **Slope:** 1°S **Soil:** Dark-brown clay with sand

Disturbance: Cleared and heavily grazed; high weed density.

Ground cover: Rock = 0%, wood = 0.5%, bare = 10%, litter = 5%, vegetation = 84.5%.

Species (percent cover): *Aristida calycina* var. *calycina* (0.1%), *Bothriochloa pertusa** (76%), *Cassia brewsteri* (0.1%), *Cenchrus ciliaris** (1.1%), *Chrysopogon fallax* (0.1%), *Crinum arenarium* (0.1%), *Dactyloctenium radulans* (0.1%), *Digitaria diminuta* (0.1%), *Eragrostis sororia* (0.1%), *Fimbristylis dichotoma* (2%), *Gomphrena celosioides** (0.1%), *Grewia retusifolia* (0.1%), *Heteropogon contortus* (0.5%), *Indigofera colutea* (0.1%), *Ipomoea polymorpha* (0.1%), *Murdannia graminea* (0.1%), *Neptunia gracilis* (0.1%), *Owenia acidula* (0.1%), *Oxalis corniculata* (0.1%), *Phyllanthus virgatus* (0.1%), *Portulaca pilosa** (0.1%), *Salsola australis* (0.1%), *Sida hackettiana* (0.1%), *Sida spinosa** (0.1%), *Sphaeromorphaea australis* (0.1%), *Stylosanthes hamata** (0.1%), *Stylosanthes scabra** (0.5%), *Urochloa mosambicensis** (2%), *Zornia muriculata* subsp. *angustata* (0.1%), *Zornia* sp. (0.1%).

SECONDARY SITE 28 **11.3.2**



Latitude, Longitude: -22.3819, 148.2465

Community description: Woodland dominated by *Eucalyptus populnea* on alluvial flats beside a watercourse.

Dominant species per stratum:

T1: *Eucalyptus populnea, Eucalyptus melanophloia* (subdominant).
T2: *Cassia brewsteri.*
S1: *Carissa ovata.*
G: *Cenchrus ciliaris*, Bothriochloa pertusa*.*

Median (and range) canopy height per stratum: T1 =22 m (15–24 m), T2 = 7.0 m (6.4–9.0 m), S1 = 1.5 m (0.5–2.5 m).

% cover of each stratum: T1 = 30.2%; T2 = 6.4%; S1 = 8.8%; **total = 38.4%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Eucalyptus populnea* = 3.83 m^2/ha; *Eucalyptus camaldulensis* = 0.33 m^2/ha; *Acacia excelsa* = 0.67 m^2/ha; *Eucalyptus melanophloia* = 0.83 **(total = 5.66 m^2/ha).**
T2: *Eucalyptus populnea* = 0.5 m^2/ha; *Cassia brewsteri* = 1 m^2/ha; *Ventilago viminalis* = 0.5 m^2/ha; *Corymbia erythrophloia* = 0.17 m^2/ha; *Bauhinia hookeri* = 0.33 m^2/ha; *Eucalyptus melanophloia* = 0.5 m^2/ha **(total = 3 m^2/ha)**.
S1 < 0.17 m^2/ha

Landform: Plain **Slope:** 1°SW **Soil:** Brown sand.

Disturbance: Grazed; very high weed cover.

Ground cover: Rock = 0%, wood = 1%, bare = 20%, litter = 8%, vegetation = 71%.

Species (percent cover): *Afrohybanthus enneaspermus* (0.1%), *Alternanthera nana* (0.1%), *Aristida calycina var. calycina* (0.1%), *Aristida gracilipes* (0.1%), *Atalaya hemiglauca* (0.1%), *Bothriochloa ewartiana* (0.1%), *Bothriochloa pertusa** (9%), *Capparis lasiantha* (0.1%), *Carissa ovata* (0.5%), *Cenchrus ciliaris** (55%), *Cheilanthes sieberi* (0.1%), *Chrysopogon fallax* (0.5%), *Cymbidium canaliculatum* (0.1%), *Cyperus fulvus* (0.1%), *Cyperus gracilis* (0.1%), *Desmodium macrocarpum* (0.1%), *Eragrostis sororia* (0.1%), *Eucalyptus melanophloia* (0.1%), *Eucalyptus populnea* (0.1%), *Evolvulus alsinoides* (0.1%), *Fimbristylis dichotoma* (2%), *Grewia retusifolia* (0.1%), *Harrisia martinii** (0.1%), *Heteropogon contortus* (0.1%), *Jacquemontia paniculata* (0.1%), *Melhania oblongifolia* (0.1%), *Opuntia tomentosa** (0.1%), *Oxalis corniculata* (0.1%), *Panicum effusum* (0.1%), *Phyllanthus virgatus* (0.1%), *Portulaca pilosa** (0.1%), *Sida cordifolia** (0.1%), *Sida hackettiana* (0.1%), *Sida spinosa** (0.1%), *Stylosanthes scabra** (0.6%), *Urochloa mosambicensis** (0.1%), *Zornia muriculata* subsp. *angustata* (0.4%).

SECONDARY SITE 29 **11.4.9**



Latitude, Longitude: -22.3827, 148.2447

Community description: Woodland dominated by *Acacia harpophylla* and *Casuarina cristata* on a clay plain.

Dominant species per stratum:

T1: *Acacia harpophylla, Casuarina cristata.*
T2: *Bauhinia hookeri, Eremophila mitchellii, Terminalia oblongata.*
S1: *Acacia harpophylla, Bauhinia hookeri, Carissa ovata.*
G: *Cenchrus ciliaris*.*

Median (and range) canopy height per stratum: T1 =16.4 m (15.2–16.8 m), T2 = 6.2 m (5.0–10.6 m), S1 = 1.0 m (0.5–2.0 m).

% cover of each stratum: T1 = 40.6%; T2 = 26.2%; S1 = 58.8%; **total = 72.8%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Acacia harpophylla* = 2.83 m^2/ha; *Bauhinia carroniii* = 0.33 m^2/ha **(total = 3.16 m^2/ha)**.
T2: *Eremophila mitchellii* = 1.33 m^2/ha; *Bauhinia carronii* = 0.83 m^2/ha; *Casuarina cristata* = 0.5 m^2/ha; *Ventilago viminalis* = 0.83 m^2/ha **(total = 3.49 m^2/ha)**.
S1: *Bauhinia carronii* = 1 m^2/ha; *Casuarina cristata* = 0.5 m^2/ha **(total = 1.5 m^2/ha)**.

Landform: Plain **Slope:** 1°S **Soil:** Dark-brown clay with thin surface covering of sand; shallow gilgais.

Disturbance: Minimal.

Ground cover: Rock = 0%, wood = 7%, bare = 12%, litter = 50%, vegetation = 31%.

Species (percent cover): *Abutilon oxycarpum* var. *incanum* (0.2%), *Alectryon diversifolius* (0.1%), *Alternanthera denticulata* (0.1%), *Amaranthus interruptus* (0.1%), *Amaranthus viridis** (0.1%), *Apophyllum anomalum* (0.1%), *Bauhinia hookeri* (0.1%), *Boerhavia pubescens* (0.1%), *Brunoniella australis* (0.1%), *Carissa ovata* (19.5%), *Cenchrus ciliaris** (8%), *Cheilanthes sieberi* (0.1%), *Cyperus concinnus* (0.1%), *Cyperus gracilis* (0.1%), *Cyperus perangustus* (0.1%), *Dactyloctenium radulans* (0.1%), *Echinochloa colona** (0.1%), *Ehretia membranifolia* (0.1%), *Eragrostis pilosa** (0.1%), *Eriochloa crebra* (0.1%), *Geijera parviflora* (0.1%), *Ipomoea plebia* (0.1%), *Malvastrum americanum** (0.1%), *Marsdenia viridiflora* subsp. *viridiflora* (0.1%), *Owenia acidula* (0.1%), *Parsonsia lanceolata* (0.1%), *Parthenium hysterophorus** (0.1%), *Plumbago zeylanica* (0.1%), *Portulaca oleracea** (0.1%), *Salsola australis* (0.1%), *Senna coronilloides* (0.1%), *Sporobolus caroli* (0.1%), *Sporobolus scabridus* (0.1%), *Tribulus terrestris** (0.1%), *Urochloa foliosa* (0.1%), *Ventilago viminalis* (0.1%).

SECONDARY SITE 30 **11.3.2**



Latitude, Longitude: -22.3672, 148.2353

Community description: Open woodland dominated by *Eucalyptus populnea* on sandy alluvial flat.

Dominant species per stratum:

T1: *Corymbia tessellaris, Eucalyptus populnea.*
T2: *Acacia salicina, Cassia brewsteri.*
S1: *Capparis canescens, Eucalyptus populnea.*
G: *Cenchrus ciliaris*.*

Median (and range) canopy height per stratum: T1 =11.6 m (11.0–19.2 m), T2 = 7.4 m (6.4–8.4 m), S1 = 1.5 m (1.0–3.0 m).

% cover of each stratum: T1 = 15%; T2 = 20.1%; S1 = 2.9%; **total = 32.9%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Eucalyptus populnea* = 6.33 m^2/ha; *Corymbia dallachiana* = 0.33 m^2/ha **(total = 6.66 m^2/ha)**.
T2: *Eucalyptus populnea* = 1.33 m^2/ha; *Corymbia dallachiana* = 0.17 m^2/ha; *Corymbia tessellaris* = 0.5 m^2/ha; *Acacia salicina* = 0.33 m^2/ha; *Cassia brewsteri* = 0.5 m^2/ha **(total = 2.83 m^2/ha).**

Landform: Plain **Slope:** 0° **Soil:** Yellow-brown sand.

Disturbance: Grazed; high weed densities.

Ground cover: Rock = 0%, wood = 1%, bare = 30%, litter = 25%, vegetation = 44%.

Species (percent cover): *Acacia salicina* (0.1%), *Afrohybanthus enneaspermus* (0.1%), *Alphitonia excelsa* (0.1%), *Aristida calycina* var. *calycina* (0.1%), *Aristida gracilipes* (0.1%), *Boerhavia pubescens* (0.1%), *Bonamia media* (0.1%), *Bothriochloa ewartiana* (0.1%), *Bothriochloa pertusa** (0.1%), *Capparis canescens* (0.1%), *Capparis lasiantha* (0.1%), *Carissa ovata* (0.1%), *Cassia brewsteri* (0.1%), *Cenchrus ciliaris** (40.3%), *Chrysopogon fallax* (0.1%), *Crinum arenarium* (0.1%), *Cyanthillium cinereum* (0.1%), *Eremophila mitchellii* (0.1%), *Eucalyptus populnea* (0.1%), *Evolvulus alsinoides* (0.1%), *Fimbristylis dichotoma* (0.1%), *Glycine tomentella* (0.1%), *Gomphrena celosioides** (0.1%), *Grewia retusifolia* (0.1%), *Harrisia martinii** (0.1%), *Hibiscus sturtii* (0.1%), *Indigofera colutea* (0.1%), *Indigofera linnaei* (0.1%), *Melhania oblongifolia* (0.1%), *Oxalis corniculata* (0.1%), *Parsonsia lanceolata* (0.1%), *Phyllanthus virgatus* (0.1%), *Portulaca filifolia* (0.1%), *Rostellularia adscendens* (0.1%), *Sida hackettiana* (0.1%), *Sida spinosa** (0.1%), *Stylosanthes humilis** (0.1%), *Stylosanthes scabra** (0.1%).

SECONDARY SITE 31 **11.9.2**



Latitude, Longitude: -22.3656, 148.2267

Community description: Open woodland dominated by *Eucalyptus orgadophila* on a clay plain derived from fine-grained sedimentary rock.

Dominant species per stratum:

T1: *Eucalyptus orgadophila.*
T2: *Cassia brewsteri, Vachellia bidwillii, Ventilago viminalis.*
S1: *Carissa ovata.*
G: *Cenchrus ciliaris*, Bothriochloa pertusa*.*

Median (and range) canopy height per stratum: T1 =13.4 m (9.4–15 m), T2 = 6.2 m (5.2–6.6 m), S1 = 1.5 m (0.5–2.5 m).

% cover of each stratum: T1 = 6%; T2 < 0.1%, S1 < 0.1%; **total = 6%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Eucalyptus orgadophila* = 2 m^2/ha **(total = 2 m^2/ha)**.
T2: *Vachellia bidwillii* = 0.33 m^2/ha; *Atalaya hemiglauca* = 0.17 m^2/ha; *Acacia salicina* = 0.17 m^2/ha **(total = 0.67 m^2/ha)**.
S1: < 0.17 m^2/ha

Landform: Plain **Slope:** 2°S **Soil:** Spongy, dark-brown clay-loam.

Disturbance: Many dead trees; heavily grazed; high weed densities.

Ground cover: Rock = 0%, wood = 0%, bare = 10%, litter = 7%, vegetation = 83%.

Species (percent cover): *Acacia salicina* (0.1%), *Atalaya hemiglauca* (0.1%), *Boerhavia pubescens* (0.1%), *Bothriochloa ewartiana* (0.1%), *Bothriochloa pertusa** (76.8%), *Camptacra barbata* (0.3%), *Cenchrus ciliaris** (2%), *Cleome viscosa* (0.1%), *Cyperus rotundus** (0.1%), *Datura leichhardtii** (0.1%), *Digitaria eriantha** (0.1%), *Euphorbia bifida* (0.1%), *Glycine* sp. (Mackay S.B.Andrews+ 43) (0.1%), *Indigofera linifolia* (0.1%), *Lomandra multiflora* (0.1%), *Malvastrum americanum** (0.1%), *Neptunia gracilis* (0.4%), *Parthenium hysterophorus** (0.1%), *Phyllanthus maderaspatensis* (0.1%), *Polymeria pusilla* (0.1%), *Portulaca oleracea** (0.1%), *Rhynchosia minima* (0.1%), *Sida pleiantha* (0.1%), *Sida spinosa** (0.3%), *Stylosanthes scabra** (0.1%), *Tephrosia* sp. B (0.1%), *Tribulus terrestris** (0.1%), *Urochloa mosambicensis** (1%).

SECONDARY SITE 32 **11.5.9**



Latitude, Longitude: -22.3618, 148.217

Community description: Open woodland dominated by *Eucalyptus crebra* and *Corymbia dallachiana* (subdominant) on a sand plain. A small number of sandstone rocks were present, but otherwise the landform was a sand plain.

Dominant species per stratum:

T1: *Corymbia dallachiana, Eucalyptus crebra.*
S1: *Melaleuca nervosa.*
G: *Chrysopogon fallax, Bothriochloa pertusa, Bothriochloa bladhii*

Median (and range) canopy height per stratum: T1 = 13.8 m (12.0–14.4 m), S1 = 0.6 m (0.5–2.5 m).

% cover of each stratum: T1 = 7.8%; S1 = 6.7%; **total = 14.5%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Eucalyptus crebra* = 3 m^2/ha; *Corymbia dallachiana* = 1.67 m^2/ha; *Grevillea striata* = 0.17 m^2/ha **(total = 4.84 m^2/ha)**
S1: <0.17 m^2/ha)

Landform: Low rise on plain. **Slope:** 3°W **Soil:** Dark, yellow-brown sand.

Disturbance: Minimal.

Ground cover: Rock = 0.2%, wood = 0%, bare = 40%, litter = 18%, vegetation = 41.8%.

Species: *Alloteropsis cimicina* (0.4%), *Apowollastonia spilanthoides* (0.1%), *Aristida benthamii* (0.1%), *Aristida calycina* var. *calycina* (0.4%), *Aristida holathera* (0.1%), *Bonamia media* (0.1%), *Bothriochloa pertusa** (30%), *Brunoniella australis* (0.1%), *Cenchrus ciliaris** (0.1%), *Chamaecrista absus* (0.1%), *Chrysopogon fallax* (5%), *Corymbia dallachiana* (0.1%), *Dactyloctenium radulans* (0.1%), *Digitaria divaricatissima* (0.1%), *Eragrostis sororia* (0.1%), *Eriachne mucronata* (0.1%), *Evolvulus alsinoides* (0.1%), *Fimbristylis dichotoma* (0.1%), *Glycine tomentella* (0.1%), *Grewia retusifolia* (0.1%), *Heteropogon contortus* (2%), *Indigofera linnaei* (0.1%), *Ipomoea polymorpha* (0.1%), *Melaleuca nervosa* (0.1%), *Melhania oblongifolia* (0.1%), *Murdannia graminea* (0.3%), *Parthenium hysterophorus** (0.1%), *Perotis rara* (0.1%), *Petalostigma pubescens* (0.1%), *Phyllanthus collinus* (0.1%), *Portulaca pilosa** (0.1%), *Sida hackettiana* (0.1%), *Spermacoce brachystema* (0.1%), *Stylosanthes scabra** (0.7%), *Tephrosia leptoclada* (0.1%), *Urochloa mosambicensis** (0.1%), *Urochloa piligera* (0.1%).

SECONDARY SITE 33 **Non-remnant**



Latitude, Longitude: -22.3607, 148.2331

Community description: Open cleared pasture in what was formerly open *Eucalyptus orgadophila* woodland (regional ecosystem 11.9.2).

Dominant species per stratum:

T1: *Corymbia erythrophloia, Eucalyptus orgadophila.*
S1: *Cassia brewsteri.*
G: *Bothriochloa pertusa*.*

Median (and range) canopy height per stratum: E = 6.8 m (6.8 – 7.8 m), T1 = 1.5 m (0.5 – 2.5 m).

% cover of each stratum: T1 = 1%; S1 = 11.9%; **total = 12.9%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Corymbia erythrophloia* = 0.33 m^2/ha; *Eucalyptus orgadophila* = 0.17 m^2/ha **(total = 0.5 m^2/ha)**
S1: <0.15 m^2/ha

Landform: Low rise. **Slope:** 3°SE **Soil:** Dark brown clay-loam.

Disturbance: Cleared and heavily grazed.

Ground cover: Rock = 0%, wood = 0.1%, bare = 10%, litter = 5%, vegetation = 84.9%.

Species (percent cover): *Abutilon guineense** (0.1%), *Acacia salicina* (0.1%), *Archidendropsis basaltica* (0.2%), *Bothriochloa pertusa** (82%), *Brunoniella australis* (0.1%), *Capparis lasiantha* (0.1%), *Carissa ovata* (0.6%), *Cassia brewsteri* (0.1%), *Cenchrus ciliaris** (0.1%), *Clerodendrum floribundum* (0.1%), *Dactyloctenium radulans* (0.1%), *Digitaria eriantha** (0.1%), *Eulalia aurea* (0.1%), *Euphorbia bifida* (0.1%), *Eustrephus latifolius* (0.1%), *Galactia tenuiflora* (0.1%), *Glycine tomentella* (0.1%), *Heliotropium cunninghamii* (0.1%), *Indigofera linifolia* (0.2%), *Indigofera linnaei* (0.1%), *Ipomoea plebia* (0.1%), *Macroptilium atropurpureum** (0.1%), *Neptunia gracilis* (0.1%), *Parthenium hysterophorus** (0.1%), *Phyllanthus maderaspatensis* (0.1%), *Polymeria pusilla* (0.1%), *Portulaca filifolia* (0.1%), *Psydrax oleifolia* (0.1%), *Rhynchosia minima* (0.1%), *Sida hackettiana* (0.1%), *Sida pleiantha* (0.1%), *Sida spinosa** (0.1%), *Stylosanthes scabra** (0.1%), *Tragus australianus* (0.1%), *Urochloa mosambicensis** (0.1%), *Urochloa piligera* (0.1%).

SECONDARY SITE 34 **11.4.8**



Latitude, Longitude: -22.3446, 148.2355

Community description: Tall shrubland dominated by *Acacia harpophylla*, with scattered emergent *Acacia harpophylla* and *Eucalyptus cambageana*.

Dominant species per stratum:

E: *Acacia harpophylla, Eucalyptus cambageana.*
T1: *Acacia harpophylla.*
S1: *Acacia harpophylla, Carissa ovata.*
G: *Cenchrus ciliaris*.*

Median (and range) canopy height per stratum: E = 12 m (11.2–13.2 m), T1 = 4.0 m (3.0–5.4 m), S1 = 1.0 m (0.5–1.5 m).

% cover of each stratum: E = 4%; T1 = 41.1%; S1 = 26.5%; **total = 53.5%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

E: *Acacia harpophylla* = 0.3 m^2/ha; *Eucalyptus cambageana* = 0.3 m^2/ha; *Bauhinia carronii* = 0.3 m^2/ha **(total = 1 m^2/ha)**.
T1: *Acacia harpophylla* = 5.33 m^2/ha **(total = 5.33 m^2/ha)**.
S1: <0.17 m^2/ha.

Landform: Plain **Slope:** 0° **Soil:** Dark brown clay-loam; no gilgais; some surface pebbles.

Disturbance: Very few large trees and these were mostly dead. Most of the living vegetation was relatively young regrowth (DBH < 5 cm).

Ground cover: Rock = 0.1%, wood = 1%, bare = 30%, litter = 48.9%, vegetation = 20%.

Species (percent cover): *Abutilon oxycarpum* (0.1%), *Abutilon oxycarpum* var. *incanum* (0.1%), *Acacia harpophylla* (2%), *Apophyllum anomalum* (0.1%), *Boerhavia pubescens* (0.1%), *Brunoniella australis* (0.1%), *Capparis lasiantha* (0.1%), *Carissa ovata* (8%), *Cenchrus ciliaris** (8%), *Cheilanthes sieberi* (0.1%), *Chloris divaricata* (0.1%), *Cyanthillium cinereum* (0.1%), *Cyperus gracilis* (0.1%), *Enchylaena tomentosa* var. *tomentosa* (0.1%), *Eragrostis lacunaria* (0.1%), *Evolvulus alsinoides* (0.1%), *Harrisia martinii** (0.1%), *Paspalidium distans* (0.1%), *Phyllanthus virgatus* (0.1%), *Portulaca filifolia* (0.1%), *Portulaca oleracea** (0.1%), *Solanum esuriale* (0.1%), *Terminalia oblongata* (0.1%).

SECONDARY SITE 35 **11.5.9**



Latitude, Longitude: -22.3336, 148.2134

Community description: Closed scrub dominated by *Melaleuca nervosa* and *Acacia burdekensis,* with emergent *Corymbia clarksoniana*, on a sand plain. Resembles regional ecosystem 11.5.9 but with a very dense mid-storey. Presumably drainage is impeded by texture contrast soil or shallow bedrock.

Dominant species per stratum:

E: *Corymbia clarksoniana.*
T1: *Acacia burdekensis, Melaleuca nervosa.*
S1: *Alphitonia excelsa, Melaleuca nervosa.*
G: *Eriochloa crebra, Perotis rara, Sida hackettiana, Setaria surgens, Alloteropsis cimicina.*

Median (and range) canopy height per stratum: E = 15.2 m (13.8–16.8 m), T1 = 4.0 m (3.5–4.8 m), S1 = 2.0 m (1.0–2.5 m).

% cover of each stratum: E < 0.1%; T1 = 84.3%; S1 = 16.6%; **total = 90.6%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

E: *Corymbia clarksoniana* = 0.17 m^2/ha **(total = 0.17 m^2/ha)**.
T1: *Melaleuca nervosa* = 6.67 m^2/ha; *Acacia burdekensis* = 6.3 m^2/ha; *Alphitonia excelsa* = 0.67 m^2/ha **(total = 13.64 m^2/ha)**.
S1: *Acacia burdekensis* = 0.33 m^2/ha; *Melaleuca nervosa* =0.33 m^2/ha **(total = 0.66 m^2/ha)**.

Landform: Plain. **Slope:** 1°N **Soil:** Grey sand.

Disturbance: Nil.

Ground cover: Rock = 0%, wood = 2%, bare = 10%, litter = 50%, vegetation = 38%.

Species (percent cover): *Acacia burdekensis* (0.1%), *Afrohybanthus stellarioides* (0.1%), *Alloteropsis cimicina* (4%), *Alphitonia excelsa* (0.3%), *Bidens pilosa** (0.1%), *Bonamia media* (0.1%), *Cassytha filiformis* (0.1%), *Cheilanthes sieberi* (0.1%), *Chrysocephalum apiculatum* (0.1%), *Cleome tetrandra* var. *tetrandra* (0.1%), *Crotalaria medicaginea* (0.1%), *Dactyloctenium radulans* (0.1%), *Desmodium filiforme* (0.1%), *Dysphania melanocarpa* forma *melanocarpa* (0.1%), *Emilia sonchifolia** (0.1%), *Eriochloa crebra* (9%), *Fimbristylis dichotoma* (0.1%), *Galactia tenuiflora* (0.1%), *Glycine tomentella* (0.1%), *Indigofera colutea* (0.1%), *Ipomoea polymorpha* (0.4%), *Melaleuca nervosa* (0.1%), *Perotis rara* (3%), *Petalostigma pubescens* (0.1%), *Portulaca pilosa** (0.1%), *Richardia brasiliensis** (0.1%), *Setaria surgens* (9%), *Sida cordifolia** (0.3%), *Sida hackettiana* (1.6%), *Spermacoce brachystema* (0.1%), *Tribulopis angustifolia* (0.1%), *Urochloa piligera* (8%), *Zornia muelleriana* subsp. *muelleriana* (0.1%).

SECONDARY SITE 36 **11.10.3**



Latitude, Longitude: -22.3434, 148.2104

Community description: Low open forest dominated by *Acacia shirleyi* and *Acacia rhodoxylon*, with emergent *Corymbia clarksoniana*, on the crest of a sandstone rise.

Dominant species per stratum:

E: *Corymbia clarksoniana.*
T1: *Acacia rhodoxylon, Acacia shirleyi.*
S1: *Erythroxylum australe.*
G: *Cleistochloa subjuncea, Alloteropsis cimicina, Thyridolepis xerophila.*

Median (and range) canopy height per stratum: E = 15.2 m (12.2–15.6 m), T1= 5.6 m (5.2–5.6 m), S1 = 2.0 m (1.5–3.5 m).

% cover of each stratum: E = 21.1%; T1 = 58.6%; S1 = 4.3%; **total = 68.5%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

E: *Corymbia clarksoniana* = 1.33 m^2/ha **(total = 1.33 m^2/ha)**.
T1: *Acacia shirleyi* = 6 m^2/ha; *Acacia rhodoxylon* = 2.5 m^2/ha; *Lysicarpus angustifolius* = 0.17 m^2/ha; *Corymbia clarksoniana* = 0.17 m^2/ha; *Alphitonia excelsa* = 0.17 m^2/ha **(total = 9.0 m^2/ha)**.
S1: <0.17 m^2/ha.

Landform: Crest **Slope:** 2°NE **Soil:** Yellow-grey sand.

Disturbance: Nil.

Ground cover: Rock = 0%, wood = 4%, bare = 20%, litter = 65%, vegetation = 11%.

Species (percent cover): *Acacia rhodoxylon* (0.1%), *Acacia shirleyi* (0.2%), *Afrohybanthus stellarioides* (0.1%), *Alloteropsis cimicina* (1.5%), *Alphitonia excelsa* (0.1%), *Aristida calycina* var. *calycina* (0.1%), *Cheilanthes sieberi* (0.6%), *Cleistochloa subjuncea* (2%), *Digitaria diminuta* (0.1%), *Eragrostis lacunaria* (0.1%), *Eragrostis sororia* (0.1%), *Larsenaikia ochreata* (0.1%), *Lysicarpus angustifolius* (0.1%), *Murdannia graminea* (0.1%), *Sida hackettiana* (0.1%), Sida sp. (Musselbrook M.B. Thomas+ MRS437) (0.1%), *Stylosanthes scabra** (0.1%), *Thyridolepis xerophila* (5.3%), *Zornia muelleriana* subsp. *muelleriana* (0.1%).

SECONDARY SITE 37 **11.10.1x1**



Latitude, Longitude: -22.3471, 148.1894

Community description: Woodland dominated by *Corymbia aureola* on a low sandstone rise.

Dominant species per stratum:

T1: *Corymbia aureola*
T2: *Alphitonia excelsa, Acacia flavescens.*
S1: *Erythroxylum australe.*
G: *Melinis repens, Alloteropsis cimicina.*

Median (and range) canopy height per stratum: T1 = 13 m (10.2–14.8 m), T2 = 3.8 m (3.4–5 m), S1 = 1.5 m (0.5–2.5 m).

% cover of each stratum: T1 = 32.8%; T2 = 19.5%; S1 = 3.6%; **total = 45.3%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Corymbia aureola* = 4.33 m^2/ha; *Eucalyptus melanophloia* = 0.33 m^2/ha; *Corymbia clarksoniana* = 0.17 m^2/ha; *Larsenaikia ochreata* = 0.17 m^2/ha **(total = 5 m^2/ha)**
T2: *Alphitonia excelsa* = 1.33 m^2/ha; *Acacia flavescens* = 1.33 m^2/ha; *Acacia burdekensis* = 0.33 m^2/ha; **(total = 2.99 m^2/ha)**
S1: <0.15 m^2/ha

Landform: Low rise **Slope:** 3°S **Soil:** Yellow-grey sand with large sandstone boulders.

Disturbance: Grazed.

Ground cover: Rock = 9%, wood = 4%, bare = 33%, litter = 19%, vegetation = 35%.

Species (percent cover): *Acacia burdekensis* (0.1%), *Afrohybanthus stellarioides* (0.1%), *Alloteropsis cimicina* (2%), *Alphitonia excelsa* (0.4%), *Aristida calycina* var. *calycina* (0.1%), *Aristida holathera* (0.1%), *Bidens bipinnata** (0.1%), *Bonamia media* (0.1%), *Breynia oblongifolia* (0.1%), *Chamaecrista absus* (0.6%), *Commelina lanceolata* (0.1%), *Corymbia aureola* (0.1%), *Cyperus betchei* (0.1%), *Digitaria longiflora* (0.1%), *Eragrostis sororia* (0.1%), *Eriochloa crebra* (2%), *Erythroxylum australe* (0.1%), *Evolvulus alsinoides* (0.1%), *Glycine tomentella* (0.1%), *Hibiscus meraukensis* (0.1%), *Ipomoea brownii* (0.1%), *Ipomoea plebia* (0.1%), *Ipomoea polymorpha* (0.1%), *Larsenaikia ochreata* (0.1%), *Lomandra longifolia* (1%), *Melinis repens* (20%), *Oxalis corniculata* (0.1%), *Phyllanthus virgatus* (0.1%), *Portulaca filifolia* (0.1%), *Setaria surgens* (0.1%), *Sida hackettiana* (0.8%), *Sida spinosa** (0.1%), *Stylosanthes scabra** (0.1%), *Tephrosia filipes* subsp. *filipes* (0.1%), *Tinospora smilacina* (0.1%), *Trema tomentosa* (0.5%), *Tribulopis angustifolia* (0.1%), *Urochloa piligera* (4%), *Xanthorrhoea johnsonii* (0.7%), *Xenostegia tridentata* (0.1%).

SECONDARY SITE 38 **11.10.7**



Latitude, Longitude: -22.3411, 148.1925

Community description: Open forest dominated by *Eucalyptus crebra* on a flat terrace of a sandstone slope.

Dominant species per stratum:

T1: *Eucalyptus crebra, Corymbia clarksoniana* (subdominant), *Corymbia dallachiana* (subdominant).
T2: *Acacia burdekensis, Alphitonia excelsa, Petalostigma pubescens.*
S1: *Petalostigma pubescens.*
G: *Chrysopogon fallax, Aristida calycina* var. *calycina, Bothriochloa pertusa*.*

Median (and range) canopy height per stratum: T1 = 15 m (13.6–22 m), T2 = 8.0 m (3.6–9.2 m), S1 = 1.5 m (0.5–1.5 m).

% cover of each stratum: T1 = 75.2%; T2 = 11.5%; S1 = 7.7%; **total = 77.7%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Eucalyptus crebra* = 5.5 m^2/ha; *Corymbia clarksoniana* = 0.33 m^2/ha; *Corymbia dallachiana* = 0.33 m^2/ha; *Acacia burdekensis* = 0.17 m^2/ha. **(total = 6.33 m^2/ha)**
T2: *Petalostigma pubescens* = 0.33 m^2/ha; *Eucalyptus crebra* = 0.17 m^2/ha; *Corymbia dallachiana* = 0.17 m^2/ha; *Alphitonia excelsa* = 0.17 m^2/ha; **(total =0.84 m^2/ha)**
S1: <0.15 m^2/ha

Landform: Terrace of sandstone slope. **Slope:** 3°E **Soil:** Yellow-grey sand with no rocks.

Disturbance: Numerous dead trees.

Ground cover: Rock = 0%, wood = 0.5%, bare = 35%, litter = 30%, vegetation = 34.5%.

Species (percent cover): *Afrohybanthus stellarioides* (0.1%), *Alphitonia excelsa* (0.1%), *Aristida calycina* var. *calycina* (4%), *Bothriochloa pertusa** (19%), *Breynia oblongifolia* (0.1%), *Cenchrus ciliaris** (0.4%), *Chamaecrista absus* (0.1%), *Chrysopogon fallax* (8%), *Cyperus fulvus* (0.1%), *Digitaria divaricatissima* (0.1%), *Eragrostis sororia* (0.1%), *Eriochloa crebra* (0.1%), *Eucalyptus crebra* (0.1%), *Evolvulus alsinoides* (0.1%), *Fimbristylis dichotoma* (0.1%), *Glycine sp.* (Mackay S.B.Andrews+ 43) (0.1%), *Grewia retusifolia* (0.3%), *Heliotropium peninsulare* (0.1%), *Marsdenia microlepis* (0.1%), *Panicum effusum* (0.4%), *Petalostigma pubescens* (0.1%), *Phyllanthus carpentariae* (0.1%), *Phyllanthus collinus* (0.1%), *Pseuderanthemum variabile* (0.1%), *Scoparia dulcis** (0.1%), *Sida hackettiana* (0.3%), *Sida spinosa** (0.1%), *Stylosanthes scabra** (0.1%).

SECONDARY SITE 39 **11.10.1**



Latitude, Longitude: -22.2909, 148.1633

Community description: Open forest dominated by *Corymbia citriodora, Corymbia trachyphloia* and *Lysicarpus angustifolius* on a steep, sandstone hillside.

Dominant species per stratum:

T1: *Corymbia citriodora, Corymbia trachyphloia, Lysicarpus angustifolius.*
T2: *Lysicarpus angustifolius, Corymbia trachyphloia*
S1: *Acacia dietrichiana, Lysicarpus angustifolius.*
G: *Cleistochloa subjuncea, Scleria sphacelata, Digitaria diminuta, Goodenia* sp. (Mt Castletower M.D. Crisp 2753).

Median (and range) canopy height per stratum: T1 =11.8 m (10.4–18.2 m), T2 = 4.0 m (3.0–5.2 m), S1 = 1.5 m (0.5 – 2.0 m).

% cover of each stratum: T1 = 49.8%; T2 = 8.8%; S1 = 5.2%; **total = 56.6%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Lysicarpus angustifolius* = 4.67 m^2/ha; *Corymbia trachyphloia* = 1.67 m^2/ha; *Acacia shirleyi* = 1.5 m^2/ha; *Corymbia citriodora* = 0.83 m^2/ha; *Eucalyptus crebra* = 0.33 m^2/ha **(total = 9 m^2/ha)**.
T2: *Corymbia trachyphloia* = 0.33 m^2/ha; *Lysicarpus angustifolius* = 0.17 m^2/ha; *Larsenaikia ochreata* = 0.17 m^2/ha **(total = 0.67 m^2/ha)**.
S1: <0.15 m^2/ha.

Landform: Steep rocky slope. **Slope:** 38°S **Soil:** Grey sand with abundant sandstone.

Disturbance: Regular but not recent fire.

Ground cover: Rock = 30%, wood = 0.5%, bare = 1%, litter = 40%, vegetation = 28.5%.

Species (percent cover): *Acacia dietrichiana* (0.1%), *Acacia flavescens* (0.1%), *Afrohybanthus stellarioides* (0.1%), *Alternanthera nana* (0.1%), *Aristida calycina* var. *calycina* (0.1%), *Aristida gracilipes* (0.1%), *Calotis cuneifolia* (0.1%), *Cheilanthes sieberi* (0.1%), *Cleistochloa subjuncea* (13.5%), *Coelospermum reticulatum* (0.1%), *Commelina lanceolata* (0.1%), *Coronidium oxylepis* (0.1%), *Corymbia trachyphloia* (0.4%), *Cyanthillium cinereum* (0.1%), *Cymbopogon obtectus* (0.5%), *Cyperus betchei* (0.1%), *Daviesia filipes* (0.1%), *Desmodium rhytidophyllum* (0.1%), *Digitaria diminuta* (3%), *Eragrostis spartinoides* (0.1%), *Eriachne obtusa* (0.1%), *Evolvulus alsinoides* (0.1%), *Fimbristylis dichotoma* (0.1%), *Goodenia* sp. (Mt Castletower M.D. Crisp 2753) (4%), *Hovea tholiformis* (0.1%), *Larsenaikia ochreata* (0.1%), *Lysicarpus angustifolius* (0.9%), *Oxalis corniculata* (0.1%), *Panicum effusum* (0.3%), *Persoonia falcata* (0.1%), *Phyllanthus collinus* (0.1%), *Pomax umbellata* (0.1%), *Scleria sphacelata* (2%), *Setaria surgens* (0.1%), *Sorghum leiocladum* (0.1%), *Tephrosia* sp. A (0.1%), *Xanthorrhoea johnsonii* (1%), *Zornia* sp. (0.1%).

SECONDARY SITE 40 **11.10.7**



Latitude, Longitude: -22.2930, 148.1505

Community description: Woodland dominated by *Eucalyptus crebra* and *Eucalyptus melanophloia* growing on a low terrace on a sandstone slope.

Dominant species per stratum:

T1: *Eucalyptus crebra, Eucalyptus melanophloia, Acacia shirleyi.*
T2: *Petalostigma pubescens, Acacia burdekensis.*
S1: *Eucalyptus crebra*
G: *Aristida calycina* var. *calycina, Chrysopogon fallax, Eriochloa crebra.*

Median (and range) canopy height per stratum: T1 = 12.8 m (9.2–14.6 m), T2 = 5.6 m (4.0–7.0 m), S1 = 2 m (0.5–3.0 m).

% cover of each stratum: T1 = 23%; T2 = 8.7%; S1 = 5.1%; **total = 33.7%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Eucalyptus crebra* = 2.67 m^2/ha; *Eucalyptus melanophloia* = 1.83 m^2/ha; *Acacia shirleyi* = 0.5 m^2/ha; *Corymbia dallachiana* = 0.17 m^2/ha **(total = 5.17 m^2/ha)**
T2: *Petalostigma pubescens* = 1 m^2/ha; *Acacia burdekensis* = 0.5 m^2/ha **(total = 1.5 m^2/ha)**
S1: < 0.17 m^2/ha

Landform: Ledge on foot slope of sandstone ridge. **Slope:** 6°ESE **Soil:** Grey-brown sand with no outcropping rock.

Disturbance: Lightly grazed.

Ground cover: Rock = 0%, wood = 1%, bare = 59%, litter = 20%, vegetation = 20%.

Species (percent cover): *Acacia burdekensis* (0.1%), *Afrohybanthus stellarioides* (0.1%), *Alphitonia excelsa* (0.1%), *Aristida calycina* var. *calycina* (4%), *Cenchrus ciliaris** (0.1%), *Chamaecrista absus* (0.1%), *Cheilanthes sieberi* (0.1%), *Chrysopogon fallax* (6.5%), *Corymbia dallachiana* (0.1%), *Cyanthillium cinereum* (0.1%), *Digitaria brownii* (0.1%), *Digitaria diminuta* (0.1%), *Digitaria* sp. A (0.4%), *Eragrostis leptostachya* (0.1%), *Eragrostis sororia* (0.5%), *Eriochloa crebra* (5%), *Erythroxylum australe* (0.1%), *Eucalyptus crebra* (0.1%), *Eucalyptus melanophloia* (0.1%), *Evolvulus alsinoides* (0.1%), *Fimbristylis dichotoma* (0.1%), *Lobelia purpurascens* (0.1%), *Melinis repens** (0.1%), *Murdannia graminea* (0.1%), *Panicum effusum* (0.1%), *Petalostigma pubescens* (0.1%), *Phyllanthus collinus* (0.1%), *Phyllanthus* sp. (Myra Vale J.J. Bruhl+ 1810) (0.1%), *Rostellularia adscendens* (0.1%), *Sida cordifolia** (0.1%), *Sida hackettiana* (0.2%), *Sida spinosa** (0.3%), *Stylosanthes scabra** (0.2%), *Themeda triandra* (0.1%), *Urochloa mosambicensis** (0.1%), *Zornia muelleriana* subsp. *muelleriana* (0.1%).

SECONDARY SITE 41 **11.10.1**



Latitude, Longitude: -22.2933, 148.1519

Community description: Open forest dominated by *Corymbia citriodora* on a rocky sandstone foot slope.

Dominant species per stratum:

T1: *Corymbia citriodora, Eucalyptus crebra* (subdominant).
T2: *Corymbia citriodora, Corymbia trachyphloia, Eucalyptus crebra.*
S1: *Acacia flavescens, Acacia burdekensis.*
G: *Cymbopogon refractus, Themeda triandra, Melinis repens*.*

Median (and range) canopy height per stratum: T1 = 24.4 m (23–25.8 m), T2 = 11 m (8.4–13 m), S1 = 2.5 m (0.6–4 m).

% cover of each stratum: T1 = 46.2%; T2 = 30.2%; S1 = 14.1%; **total = 69.6%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Corymbia citriodora* = 3.17 m^2/ha; *Eucalyptus crebra* = 0.67 m^2/ha **(total = 3.84 m^2/ha)**.
T2: *Eucalyptus crebra* = 4.67 m^2/ha; *Corymbia trachyphloia* = 0.33 m^2/ha **(total = 5 m^2/ha)**.
S1: < 0.17 m^2/ha

Landform: Rocky foot slope next to gully **Slope:** 18°E **Soil:** Grey-brown sand with sandstone boulders

Disturbance: Few weeds and light grazing.

Ground cover: Rock = 35%, wood = 0.5%, bare = 10%, litter = 31.5%, vegetation = 23%.

Species (percent cover): *Acacia burdekensis* (0.1%), *Acacia macradenia* (0.2%), *Afrohybanthus stellarioides* (0.1%), *Alphitonia excelsa* (0.3%), *Aristida benthamii* (0.1%), *Aristida spuria* (0.1%), *Breynia oblongifolia* (0.1%), *Brunoniella australis* (0.1%), *Capparis canescens* (0.1%), *Cenchrus ciliaris** (0.2%), *Cheilanthes sieberi* (0.1%), *Chrysopogon fallax* (0.1%), *Coelospermum reticulatum* (0.1%), *Corymbia citriodora* subsp. *citriodora* (0.1%), *Crotalaria montana* (0.1%), *Cyanthillium cinereum* (0.1%), *Cymbopogon refractus* (8.4%), *Dichanthium sericeum* (0.1%), *Enneapogon lindleyanus* (0.1%), *Eriochloa pseudoacrotricha* (0.1%), *Erythroxylum australe* (0.1%), *Eucalyptus crebra* (0.1%), *Eucalyptus melanophloia* (0.1%), *Eustrephus latifolius* (0.1%), *Glycine tomentella* (0.1%), *Grewia latifolia* (0.1%), *Hakea lorea* (0.1%), *Indigofera australis* (0.1%), *Larsenaikia ochreata* (0.1%), *Marsdenia microlepis* (0.1%), *Melhania oblongifolia* (0.1%), *Melinis repens** (2%), *Panicum effusum* (0.1%), *Persoonia falcata* (0.1%), *Petalostigma pubescens* (0.1%), *Phyllanthus virgatus* (0.1%), *Pterocaulon ciliosum* (0.1%), *Pycnospora lutescens* (0.1%), *Rostellularia adscendens* (0.1%), *Scleria sphacelata* (0.1%), *Sida spinosa** (0.1%), *Solanum ellipticum* (0.1%), *Stylosanthes scabra** (0.1%), *Tephrosia juncea* (0.1%), *Themeda triandra* (8%).

SECONDARY SITE 42 **11.10.3**



Latitude, Longitude: -22.2988, 148.1585

Community description: Low open forest dominated by *Acacia shirleyi*, with emergent *Corymbia aureola*, on a terrace of a sandstone ridge.

Dominant species per stratum:

E: *Corymbia aureola.*
T1: *Acacia shirleyi.*
S1: *Alphitonia excelsa, Erythroxylum australe.*
G: *Cleistochloa subjuncea, Eriachne obtusa, Thyridolepis xerophila*

Median (and range) canopy height per stratum: E = 13.2 m (11.8–13.6 m), T1 = 9.8 m (5.6–10.4 m), S1 = 1.5 m (1.0–1.5 m).

% cover of each stratum: E = 21.5%; T1 = 58.2%; S1 = 1.4%; t**otal = 70.7%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

E: *Acacia shirleyi* = 0.5 m^2/ha; *Corymbia aureola* = 0.83 m^2/ha **(total = 1.33 m^2/ha)**.
T1: *Acacia shirleyi* = 5.83 m^2/ha **(total = 5.83 m^2/ha)**.
S1: <0.15 m^2/ha.

Landform: Ledge of sandstone ridge. **Slope:** 8°N **Soil:** Pink-grey sand with many small rocks.

Disturbance: Recent fire seems to have resulted in many large dead *A. shirleyi*.

Ground cover: Rock = 5%, wood = 8%, bare = 28%, litter = 35%, vegetation = 24%.

Species (percent cover): *Acacia shirleyi* (0.1%), *Afrohybanthus stellarioides* (0.1%), *Alphitonia excelsa* (0.1%), *Aristida calycina* var. *calycina* (0.1%), *Aristida gracilipes* (0.1%), *Cheilanthes sieberi* (0.1%), *Cleistochloa subjuncea* (17.7%), *Digitaria diminuta* (0.1%), *Eragrostis sororia* (0.1%), *Eriachne obtusa* (4%), *Marsdenia microlepis* (0.1%), *Pseuderanthemum variabile* (0.1%), *Scleria sphacelata* (0.1%), *Solanum parvifolium* (0.1%), *Thyridolepis xerophila* (1%), *Wrightia saligna* (0.1%).

SECONDARY SITE 43 **HVR 11.5.9**



Latitude, Longitude: -22.2852, 148.1759

Community description: Woodland dominated by *Eucalyptus crebra* on a sand plain.

Dominant species per stratum:

T1: *Eucalyptus crebra.*
T2: *Ventilago viminalis, Grevillea parallela, Acacia excelsa.*
S1: *Erythroxylum australe.*
G: *Cenchrus ciliaris*, Bothriochloa pertusa*.*

Median (and range) canopy height per stratum: T1 = 14.8 m (11.2–17.4 m), T2 = 7.8 m (7.4–9.2 m), S1 = 2.0 m (1.0–3.0 m).

% cover of each stratum: T1 = 22.5%; T2 = 16.9%; S1 = 16%; **total = 43.9%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Eucalyptus crebra* = 3.33 m^2/ha; *Grevillea striata* = 0.17 m^2/ha; *Acacia excelsa* = 0.17 m^2/ha **(total = 3.67 m^2/ha)**.
T2: *Ventilago viminalis* = 1.67 m^2/ha *Corymbia dallachiana* = 1.33 m^2/ha; *Corymbia clarksoniana* = 1.17 m^2/ha; **(total = 4.17 m^2/ha)**.
S1: <0.15 m^2/ha.

Landform: Sandy foot slope **Slope:** 2°N **Soil:** Yellow sand

Disturbance: Heavily grazed; evidence of heavy thinning of vegetation; probably previously cleared.

Ground cover: Rock = 0%, wood = 0.5%, bare = 45%, litter = 30%, vegetation = 24.5%.

Species (percent cover): *Acacia excelsa* (0.1%), *Alphitonia excelsa* (0.1%), *Alternanthera nana* (0.1%), *Aristida calycina* var. *calycina* (0.1%), *Boerhavia pubescens* (0.1%), *Bothriochloa pertusa** (2%), *Capparis canescens* (0.1%), *Cenchrus ciliaris** (18.5%), *Chamaecrista absus* (0.1%), *Chrysopogon fallax* (0.1%), *Clerodendrum floribundum* (0.1%), *Commelina lanceolata* (0.1%), *Dianella nervosa* (0.1%), *Digitaria longiflora* (0.1%), *Eragrostis lacunaria* (0.1%), *Eragrostis spartinoides* (0.1%), *Erythroxylum australe* (0.3%), *Eucalyptus crebra* (0.1%), *Evolvulus alsinoides* (0.1%), *Fimbristylis dichotoma* (0.1%), *Flindersia dissosperma* (0.1%), *Galactia tenuiflora* (0.1%), *Harrisia martinii** (0.1%), *Jacquemontia paniculata* (0.1%), *Melhania oblongifolia* (0.1%), *Murdannia graminea* (0.1%), *Parsonsia lanceolata* (0.4%), *Phyllanthus collinus* (0.1%), *Portulaca oleracea** (0.1%), *Portulaca pilosa** (0.1%), *Pseuderanthemum variabile* (0.1%), *Rostellularia adscendens* (0.1%), *Sida spinosa** (0.1%), *Stylosanthes scabra** (0.1%), *Urochloa mosambicensis** (0.1%), *Ventilago viminalis* (0.1%), *Vittadinia pustulata* (0.1%).

SECONDARY SITE 44 **11.10.1x1**



Latitude, Longitude: -22.2774, 148.1604

Community description: Low woodland dominated by *Corymbia aureola* on a sandstone plateau. Mapped as high-value regrowth, but is probably remnant and naturally stunted by the lack of topsoil. It is improbable that it would have been cleared considering the difficult terrain.

Dominant species per stratum:

T1: *Corymbia aureola.*
S1: *Acacia bancroftiorum, Acacia flavescens, Acacia burdekensis.*
G: *Cleistochloa subjuncea, Melinis repens*

Median (and range) canopy height per stratum: T1 = 9.6 m (6.4–10.4 m), S1 = 2.5 m (0.5–3.5 m).

% cover of each stratum: T1 = 26.2%; S1 = 40.7%; **total = 62.1%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Corymbia aureola* = 5 m^2/ha; *Terminalia porphyrocarpa* = 0.17 m^2/ha **(total = 5.17 m^2/ha)**.
S1: *Acacia shirleyi* = 0.17 m^2/ha; *Acacia flavescens* = 0.17 m^2/ha **(total = 0.34 m^2/ha)**.

Landform: Rocky plateau. **Slope:** 12°W **Soil:** Quartz/white sand.

Disturbance: Lightly grazed; many large dead trees appear to have been killed by a severe historical fire. This may be why the site appeared to be non-remnant from aerial imagery.

Ground cover: Rock = 35%, wood = 0.5%, bare = 5%, litter = 43%, vegetation = 17%.

Species (percent cover): *Acacia bancroftiorum* (0.1%), *Acacia burdekensis* (0.2%), *Acacia dietrichiana* (0.1%), *Acacia flavescens* (0.3%), *Acacia shirleyi* (0.2%), *Afrohybanthus stellarioides* (0.1%), *Alphitonia excelsa* (0.1%), *Aristida benthamii* (0.8%), *Cheilanthes sieberi* (0.1%), *Cleistochloa subjuncea* (12%), *Corymbia aureola* (0.1%), *Digitaria diminuta* (0.2%), *Eragrostis spartinoides* (0.1%), *Eriachne obtusa* (0.1%), *Erythroxylum australe* (0.4%), *Euphorbia drummondii* (0.1%), *Evolvulus alsinoides* (0.1%), *Galactia tenuiflora* (0.1%), *Hovea tholiformis* (0.3%), *Larsenaikia ochreata* (0.1%), *Lomandra longifolia* (0.1%), *Melinis repens* (1%), *Panicum effusum* (0.1%), *Solanum ellipticum* (0.1%), *Urochloa piligera* (0.1%).

SECONDARY SITE 45 **HVR 11.10.3**



Latitude, Longitude: -22.2905, 148.1883

Community description: Open forest dominated by *Acacia shirleyi*, with emergent *Eucalyptus crebra* and *Corymbia clarksoniana*, on a low sandstone ridge.

Dominant species per stratum:

E: *Eucalyptus crebra, Corymbia clarksoniana.*
T1: *Acacia shirleyi.*
S1: *Erythroxylum australe***.**
G: *Alloteropsis cimicina, Melinis repens*.*

Median (and range) canopy height per stratum: E = 12.8 m; T1 = 10.6 m (7.4–11.6 m), S1 = 3.0 m (1.0–4.0 m).

% cover of each stratum: E < 0.1%; T1 = 74.2%; S1 = 12%; **total = 76.7%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

E: *Corymbia clarksoniana* = 0.17 m^2/ha **(total = 0.17 m^2/ha)**.
T1: *Acacia shirleyi* = 14.67 m^2/ha **(total = 14.67 m^2/ha)**.
S1: <0.15 m^2/ha.

Landform: Low ridge. **Slope:** 15°S **Soil:** Pink-grey sand with lots of gravel.

Disturbance: Previously cleared; much dumped rubbish.

Ground cover: Rock = 5%, wood = 1%, bare = 20%, litter = 67%, vegetation = 7%.

Species (percent cover): *Acacia shirleyi* (0.1%), *Alloteropsis cimicina* (3.9%), *Alphitonia excelsa* (0.1%), *Aristida calycina* var. *calycina* (0.1%), *Calotis cuneifolia* (0.1%), *Capparis canescens* (0.1%), *Cheilanthes sieberi* (0.1%), *Cyanthillium cinereum* (0.1%), *Digitaria diminuta* (0.1%), *Eragrostis lacunaria* (0.1%), *Erythroxylum australe* (0.1%), *Harrisia martinii** (0.1%), *Melinis repens* (1%), *Paspalidium gracile* (0.1%), *Portulaca filifolia* (0.1%), *Portulaca oleracea** (0.1%), *Pseuderanthemum variabile* (0.1%), *Ptilotus polystachyus* (0.1%), *Sida* sp. (Musselbrook M.B. Thomas+ MRS437) (0.4%), *Urochloa mosambicensis** (0.1%).

SECONDARY SITE 46 **11.3.25**



Latitude, Longitude: -22.3061, 148.1946

Community description: Closed forest dominated by *Eucalyptus camaldulensis* and *Melaleuca leucadendra* on the bank of an ephemeral watercourse.

Dominant species per stratum:

T1: *Eucalyptus camaldulensis, Melaleuca leucadendra.*
T2: *Alphitonia excelsa.*
S1: *Ficus opposita.*
G: *Bidens pilosa*, Megathyrsus maximus* var. *pubiglumis*, Acanthospermum hispidum*, Richardia brasiliensis*.*

Median (and range) canopy height per stratum: T1 = 21 m (18.4–21.2 m), T2 = 10.8 m (9.2–11 m), S1 = 2.5 m (1.0–4.0 m).

% cover of each stratum: T1 = 87.3%; T2 = 18.8%; S1 = 30.7%; **total = 87.7%**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Melaleuca leucadendra* = 9.83 m^2/ha; *Eucalyptus camaldulensis* = 8 m^2/ha; *Corymbia clarksoniana* = 0.5 m^2/ha **(total = 18.5 m^2/ha)**.
T2: *Alphitonia excelsa* = 0.33 m^2/ha; *Flindersia australis* =0.17 m^2/ha **(total = 0.5 m^2/ha)**.
S1: *Acacia macradenia* = 0.17 m^2/ha; *Ficus opposita* = 0.17 m^2/ha **(total = 0.33 m^2/ha)**.

Landform: Creek bank. **Slope:** 0° **Soil:** Sand.

Disturbance: Very high weed densities.

Ground cover: Rock = 0%, wood = 1%, bare = 15%, litter = 60%, vegetation = 24%.

Species (percent cover): *Acacia macradenia* (0.1%), *Acanthospermum hispidum** (3%), *Ageratum conyzoides** (0.4%), *Albizia canescens* (0.1%), *Alternanthera nana* (0.1%), *Aristolochia thozetii* (0.1%), *Bidens pilosa** (7%), *Bothriochloa pertusa** (0.6%), *Cenchrus ciliaris** (0.1%), *Clerodendrum floribundum* (0.1%), *Commelina diffusa* (0.1%), *Crinum arenarium* (0.1%), *Crotalaria mitchellii* (0.1%), *Crotalaria pallida** (0.1%), *Cryptostegia grandiflora** (0.1%), *Cyanthillium cinereum* (0.1%), *Cyperus gracilis* (0.1%), *Dactyloctenium radulans* (0.1%), *Desmodium filiforme* (0.1%), *Digitaria brownii* (0.1%), *Digitaria eriantha** (0.2%), *Echinochloa colona** (0.1%), *Emilia sonchifolia** (0.2%), *Erythrina vespertilio* (0.1%), *Eucalyptus camaldulensis* (0.1%), *Ficus opposita* (3%), *Ipomoea plebia* (0.1%), *Juncus usitatus* (0.1%), *Lomandra longifolia* (0.1%), *Macroptilium atropurpureum** (0.1%), *Megathyrsus maximus* var. *pubiglumis** (1.4%), *Parthenium hysterophorus** (0.1%), *Passiflora foetida** (0.7%), *Richardia brasiliensis** (3%), *Scoparia dulcis** (0.1%), *Senna occidentalis** (0.1%), *Sida cordifolia** (1%), *Sida hackettiana* (0.1%), *Sida rhombifolia* (0.2%), *Urochloa mosambicensis** (0.5%), *Xanthium occidentale** (0.1%).

SECONDARY SITE 47 **HVR 11.5.3**



Latitude, Longitude: -22.3940, 148.2580

Community description: Woodland dominated by *Eucalyptus populnea* on sand plain. A very small amount of sandstone present at the surface, but otherwise is land zone 5.

Dominant species per stratum:

T1: *Eucalyptus populnea.*
T2: *Alphitonia excelsa, Cassia brewsteri, Melaleuca nervosa.*
S1: *Erythroxylum australe.*
G: *Alloteropsis cimicina, Eriochloa crebra, Sida hackettiana, Stylosanthes scabra*.*

Median (and range) canopy height per stratum: T1 = 15.2 m (11.6–16 m), T2 = 6.6 m (6.2–8.6 m), S1 = 2.5 m (1.0–4.2 m).

% cover of each stratum: T1 = 31.1%; T2 = 16.4%; S1 = 0.6; **total = 44.9%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Eucalyptus populnea* = 6.83 m^2/ha **(total = 6.83 m^2/ha)**.
T2: *Cassia brewsteri* = 0.5 m^2/ha; *Alphitonia excelsa* = 1.67 m^2/ha **(total = 2.17 m^2/ha)**.
S1: <0.15 m^2/ha.

Landform: Plain **Slope:** 1°N **Soil:** Yellow-grey sand.

Disturbance: Previously cleared; grazed.

Ground cover: Rock = 0.1%, wood =0.5%, bare = 45%, litter = 25%, vegetation = 29.4%.

Species (percent cover): *Acacia burdekensis* (0.1%), *Acacia salicina* (0.1%), *Afrohybanthus enneaspermus* (0.1%), *Alloteropsis cimicina* (13%), *Alphitonia excelsa* (0.1%), *Aristida calycina* var. *calycina* (0.1%), *Aristida holathera* (0.9%), *Bonamia media* (0.1%), *Carissa ovata* (0.1%), *Cenchrus ciliaris** (0.4%), *Cheilanthes sieberi* (0.1%), *Chrysopogon fallax* (0.3%), *Desmodium filiforme* (0.1%), *Digitaria divaricatissima* (0.2%), *Digitaria eriantha** (0.1%), *Diospyros humilis* (0.1%), *Eragrostis lacunaria* (0.1%), *Eragrostis sororia* (0.2%), *Eragrostis speciosa* (0.1%), *Eriachne mucronata* (0.1%), *Eriochloa crebra* (6%), *Erythroxylum australe* (0.3%), *Eucalyptus populnea* (0.1%), *Euphorbia bifida* (0.1%), *Evolvulus alsinoides* (0.1%), *Fimbristylis dichotoma* (0.1%), *Ipomoea polymorpha* (0.1%), *Melinis repens* (0.1%), *Perotis rara* (0.2%), *Phyllanthus collinus* (0.2%), *Phyllanthus* sp. (Myra Vale J.J. Bruhl+ 1810) (0.2%), *Phyllanthus virgatus* (0.1%), *Portulaca filifolia* (0.1%), *Portulaca oleracea** (0.1%), *Sida hackettiana* (2%), *Sida spinosa** (0.1%), *Stylosanthes hamata** (0.1%), *Stylosanthes scabra** (2%), *Tephrosia leptoclada* (0.2%), *Urochloa mosambicensis** (0.1%), *Zornia* sp. (0.7%)**.**

SECONDARY SITE 48 **11.5.3**



Latitude, Longitude: -22.3895, 148.2367

Community description: Woodland dominated by *Eucalyptus populnea* on a sand plain.

Dominant species per stratum:

T1: *Eucalyptus populnea.*
T2: *Vachellia bidwillii, Eucalyptus populnea.*
S1: *Carissa ovata.*
G: *Scoparia dulcis*, Heteropogon contortus, Fimbristylis dichotoma, Bothriochloa pertusa*, Cenchrus ciliaris*, Urochloa mosambicensis*.*

Median (and range) canopy height per stratum: T1 = 16.8 m (11.6–19.8 m), T2 = 4.2 m (2.8–6.8 m), S1 = 1.0 m (0.5–1.5 m).

% cover of each stratum: T1 = 44.2%; T2 = 3%; S1 = 12.7%; **total = 45.3%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Eucalyptus populnea* = 14.67 m^2/ha; *Corymbia clarksoniana* = 0.33 m^2/ha; *Eucalyptus crebra* = 0.17 m^2/ha; *Eucalyptus melanophloia* = 0.17 m^2/ha **(total = 15.34 m^2/ha)**
T2: *Corymbia dallachiana* = 0.17 m^2/ha; *Cassia brewsteri* = 0.17 m^2/ha; *Vachellia bidwillii* = 0.17 m^2/ha **(total = 0.51 m^2/ha)**
S1: < 0.15 m^2/ha

Landform: Plain. **Slope:** 0° **Soil:** Fine grey-brown sand.

Disturbance: Grazed.

Ground cover: Rock = 0%, wood =0.8%, bare = 25%, litter = 35%, vegetation = 39.2%.

Species (percent cover): *Achyranthes aspera* (0.1%), *Afrohybanthus enneaspermus* (0.1%), *Afrohybanthus stellarioides* (0.1%), *Alphitonia excelsa* (0.1%), *Alternanthera nana* (0.1%), *Aristida calycina* var. *calycina* (0.4%), *Boerhavia pubescens* (0.1%), *Bothriochloa ewartiana* (0.2%), *Bothriochloa pertusa** (4%), *Carissa ovata* (2%), *Cenchrus ciliaris** (5%), *Chamaecrista absus* (0.1%), *Chrysopogon fallax* (0.8%), *Crotalaria juncea** (0.1%), *Cyanthillium cinereum* (0.1%), *Cynodon dactylon** (0.1%), *Cyperus fulvus* (0.1%), *Cyperus gracilis* (0.1%), *Desmodium filiforme* (0.1%), *Enteropogon ramosus* (0.2%), *Eragrostis sororia* (0.1%), *Eriochloa crebra* (0.3%), *Eucalyptus populnea* (0.1%), *Euphorbia drummondii* (0.1%), *Evolvulus alsinoides* (0.1%), *Fimbristylis dichotoma* (3%), *Glycine tomentella* (0.1%), *Grewia retusifolia* (0.2%), *Heteropogon contortus* (3%), *Indigofera colutea* (0.1%), *Ipomoea plebia* (0.1%), *Malvastrum americanum** (0.1%), *Melinis repens* (0.5%), *Phyllanthus collinus* (0.1%), *Polygala triflora* (0.1%), *Scoparia dulcis** (5%), *Sida hackettiana* (0.2%), *Sida spinosa** (0.8%), *Spermacoce brachystema* (0.1%), *Stylosanthes scabra** (2%), *Urochloa mosambicensis** (9%), *Vachellia bidwillii* (0.1%), *Zornia areolata* (0.1%).

SECONDARY SITE 49 **11.4.8**



Latitude, Longitude: -22.3526, 148.2236

Community description: Open forest dominated by *Acacia harpophylla* and *Casuarina cristata*, with emergent *Eucalyptus cambageana*, on a clay plain.

Dominant species per stratum:

E: *Eucalyptus cambageana*.
T1: *Acacia harpophylla*, *Casuarina cristata*, *Terminalia oblongata.*
T2: *Acacia harpophylla*, *Terminalia oblongata.*
S1: *Carissa ovata, Terminalia oblongata.*
G: *Paspalidium caespitosum*, *Eragrostis lacunaria*.

Median (and range) canopy height per stratum: E = 20.4 m (18.4–24.6 m); T1 = 12.8 m (12.2–16.6 m), T2 = 5.0 m (4.8–5.8 m), S1 = 1.5 m (0.5–3.0 m).

% cover of each stratum: E = 10.6%; T1 = 56.5%; T2 = 12%; S1 = 43.1%; **total = 83.4%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

E: *Eucalyptus cambageana* = 0.5 m^2/ha **(total = 0.5 m^2/ha)**.
T1: *Casuarina cristata* = 4.67 m^2/ha; *Acacia harpophylla* = 4.5 m^2/ha; *Terminalia oblongata* = 3 m^2/ha; *Eucalyptus cambageana* = 0.67 m^2/ha; *Ventilago viminalis* = 0.17 m^2/ha **(total = 13.01 m^2/ha)**.
T2: <0.17 m^2/ha.
S1: <0.17 m^2/ha.

Landform: Plain. **Slope:** 2°NE **Soil:** Brown clay loam with some surface pebbles. No obvious gilgais.

Disturbance: Grazed.

Ground cover: Rock = 0.1%, wood = 1%, bare = 24%, litter = 38%, vegetation = 36.9%.

Species (percent cover): *Abutilon oxycarpum* (0.1%), *Aristida calycina* var. *calycina* (0.1%), *Bothriochloa pertusa** (0.1%), *Brunoniella australis* (0.1%), *Carissa ovata* (0.1%), *Casuarina cristata* (31.4%), *Cenchrus ciliaris** (0.1%), *Chloris divaricata* (0.1%), *Chrysopogon fallax* (0.1%), *Cymbopogon refractus* (0.1%), *Cynanchum viminale* (0.1%), *Desmodium varians* (0.1%), *Enneapogon* sp. A (0.1%), *Eragrostis lacunaria* (0.4%), *Eremophila mitchellii, Erythroxylum australe, Evolvulus alsinoides, Flindersia dissosperma, Glycine* sp. (Mackay S.B. Andrews+ 43), *Grewia latifolia* (0.1%), *Hibiscus sturtii* (0.1%), *Jacquemontia paniculata* (0.1%), *Jasminum didymum* subsp. *lineare* (0.1%), *Melhania oblongifolia* (0.1%), *Ocimum caryophyllinum* (0.1%), *Paspalidium caespitosum* (0.1%), *Phyllanthus virgatus* (0.1%), *Rhynchosia minima* (0.1%), *Scleria brownii* (0.2%), *Terminalia oblongata* (2%).

SECONDARY SITE 50 **11.10.8**



Latitude, Longitude: -22.2892, 148.1563.
Community description: Low closed forest (semi-evergreen microphyll vine-thicket) dominated by *Planchonella pubescens*, *Geijera salicifolia*, *Gossia bidwillii* and *Hovea longipes* in a sheltered sandstone gorge.

Dominant species per stratum:

E: *Acacia shirleyi, Lophostemon suaveolens, Euroschinus falcatus.*
T1: *Planchonella pubescens, Geijera salicifolia, Drypetes deplanchei, Acronychia laevis, Psydrax odorata.*
S1: *Hovea longipes, Alyxia ruscifolia, Gossia bidwillii.*
G: *Ancistrachne uncinata.*

Median (and range) canopy height per stratum: E =11 m (10–13 m); T1 = 5 m (4–6 m); S1 = 1.5 m (1–2 m).

% cover of each stratum: E = 46.8%; T1 =64.7%; S1 = 30.4%; **total = 92.4%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

E: *Acacia shirleyi* = 0.83 m^2/ha; *Alectryon connatus* = 0.17 m^2/ha; *Bursaria incana* = 0.33 m^2/ha; *Euroschinus falcata* = 0.5 m^2/ha; *Ficus rubiginosa* = 0.17 m^2/ha; *Pleiogynium timoriense* **=** 0.33 m^2/ha; (**total = 2.33 m^2/ha)**.
T1: *Planchonella pubescens* = 3.17 m^2/ha; *Geijera salicifolia* = 2.67 m^2/ha; *Gossia bidwillii* = 1.5 m^2/ha; *Ehretia membranifolia* = 0.5 m^2/ha; *Exocarpos latifolius* = 0.67 m^2/ha; *Drypetes deplanchei* = 0.17 m^2/ha; *Psydrax odorata* subsp. *buxifolia* = 0.17 m^2/ha; **(total = 8.85 m^2/ha)**.
S1: *Hovea longipes* = 1.33 m^2/ha; *Psydrax odorata* subsp. *buxifolia* = 0.67 m^2/ha **(total = 2 m^2/ha)**.

Landform: Rocky gorge. **Slope:** 45°ESE **Soil:** Abundant sandstone boulders.

Disturbance: nil.

Ground cover: Rock = 70%, bare = 2%, litter = 20%, vegetation = 8%.

Species (percent cover): *Abutilon oxycarpum* (0.1%), *Acacia burdekensis* (0.1%), *Acacia shirleyi* (0.1%), *Acronychia laevis* (0.1%), *Alectryon connatus* (0.1%), *Alphitonia excelsa* (0.1%), *Alyxia ruscifolia* (0.7%), *Amyema conspicua* (0.1%), *Ancistrachne uncinata* (0.5%), *Bidens bipinnata** (0.1%), *Bursaria incana* (0.1%), *Capparis lasiantha* (0.1%), *Cassytha filiformis* (0.1%), *Cheilanthes nudiuscula* (0.2%), *Cissus oblonga* (0.1%), *Cleistochloa subjuncea* (0.7%), *Commelina diffusa* (0.2%), *Cyanthillium cinereum* (0.2%), *Deeringia amaranthoides* (0.1%), *Dinebra decipiens* var. *decipiens* (0.1%), *Diospyros humilis* (0.1%), *Drypetes deplanchei* (0.3%), *Ehretia membranifolia* (0.1%), *Exocarpos latifolius* (0.3%), *Ficus rubiginosa* (0.1%), *Gahnia aspera* (0.1%), *Geijera salicifolia* (0.1%), *Gossia bidwillii* (0.2%), *Harrisia martinii** (0.1%), *Hovea longipes* (0.3%), *Jasminum didymum* subsp. *racemosum* (0.1%), *Jasminum simplicifolium* subsp. *australiense* (0.1%), *Larsenaikia ochreata* (0.2%), *Lophostemon suaveolens* (0.1%), *Myrsine variabilis* (0.1%), *Parsonsia lanceolata* (0.1%), *Pavetta granitica* (0.1%), *Planchonella pubescens* (0.1%), *Plectranthus parviflorus* (0.2%), *Pleiogynium timoriense* (0.1%), *Psydrax odorata* subsp. *buxifolia* (0.1%), *Richardia brasiliensis** (0.1%), *Scleria brownii* (0.1%), *Scleria sphacelata* (0.1%), *Scoparia dulcis** (0.1%), *Secamone elliptica* (0.1%), *Setaria surgens* (0.1%), *Sida hackettiana* (0.1%), *Solanum ellipticum* (0.1%), *Tetrastigma nitens* (0.1%), *Trema tomentosa* (0.1%), *Trophis scandens* (0.1%).

SECONDARY SITE 51 **11.10.7**



Date: 1 April 2020

Latitude, Longitude: -22.2798, 148.1368

Community description: *Eucalyptus crebra* open woodland situated on a terrace of a sandstone slope.

Dominant species per stratum:

T1: *Eucalyptus crebra, Eucalyptus melanophloia* (sub-dominant).
S1: *Acacia burdekensis.*
G: *Bothriochloa pertusa*, Chrysopogon fallax*

Median (and range) canopy height per stratum: T1 = 15.8 m (12.3-16 m), S1 = 2.6 m (2.1-8.2 m).

% cover of each stratum (vertical projection along 100 m tape): T1 = 15.2 %, S1 < 0.1%; **total = 15.2%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Eucalyptus crebra* = 3.33 m^2/ha **(total = 3.33 m^2/ha).**

Landform: Terrace of a sandstone slope. **Slope:** 1°W **Soil:** Grey-brown sandy clay.

Disturbance: Many dead trees; high weed density.

Ground cover: rock = 1.5%, litter = 20.5%, bare = 18%, vegetation = 60%.

Species (percent cover): *Acacia burdekensis* (0.1%), *Alloteropsis cimicina* (0.1%), *Alphitonia excelsa* (0.1%), *Alternanthera nana* (0.1%), *Aristida calycina* var. *calycina* (0.1%), *Bothriochloa bladhii* (0.1%), *Bothriochloa decipiens* var. *decipiens* (2%), *Bothriochloa pertusa** (48%), *Brunoniella australis* (0.1%), *Cenchrus ciliaris** (0.1%), *Chrysopogon fallax* (5.5%), *Crotalaria juncea* (0.1%), *Cyanthillium cinereum* (0.1%), *Cyperus fulvus* (0.1%), *Dactyloctenium radulans* (0.1%), *Dichanthium sericeum* (0.1%), *Digitaria ammophila* (0.1%), *Digitaria papposa* (0.5%), *Enteropogon acicularis* (0.1%), *Eragrostis sororia* (0.1%), *Eucalyptus crebra* (0.1%), *Eulalia aurea* (0.1%), *Fimbristylis dichotoma* (0.1%), *Galactia tenuiflora* (0.1%), *Ipomoea polymorpha* (0.1%), *Lobelia concolor* (0.1%), *Marsdenia microlepis* (0.1%), *Melhania oblongifolia* (0.1%), *Melinis repens** (0.1%), *Panicum effusum* (0.1%), *Parthenium hysterphorus** (0.1%), *Phyllanthus virgatus* (0.1%), *Rhynchosia minima* (0.1%), *Sida hackettiana* (0.3%), *Sida rohlenae* subsp. *rohlenae* (0.1%), *Sporobolus caroli* (0.1%), *Stylosanthes scabra** (0.1%), *Themeda triandra* (0.2%), *Tragus australianus* (0.1%), *Urochloa mosambicensis** (0.1%), *Zornia muelleriana* subsp. *muelleriana* (0.1%).

SECONDARY SITE 52 **11.10.1**



Date: 2 April 2020

Latitude, Longitude: -22.2728, 148.1414

Community description: Open forest dominated by *Corymbia citriodora* on sandstone.

Dominant species per stratum:

T1: *Corymbia citriodora, Eucalyptus crebra* (sub-dominant).
T2: *Acacia shirleyi, Alphitonia excelsa, Corymbia citriodora.*
S1: *Acacia bancroftiorum, Acacia flavescens, Erythroxylum australe.*
G: *Cleistochloa subjuncea, Scleria sphacelata.*

Median (and range) canopy height per stratum: T1 = 18.8 m (16.8-21.6 m), T2 = 8.8 m (6.8-10.2 m), S1 = 2 m (1.1-3.6 m).

% cover of each stratum (vertical projection along 100 m tape): T1 = 42.1%, T2 =18.1%, S1 = 23.8%; **total = 73.7%.**

Basal area (using a Bitterlich gauge, measured at three points along the transect)**:**

T1: *Corymbia aureola* = 0.17 m^2/ha; *Corymbia citriodora* = 5.67 m^2/ha **(total = 5.83 m^2/ha).**
T2: *Acacia shirleyi* = 0.83 m^2/ha; *Euroschinus falcata* = 0.17 m^2/ha **(total = 1 m^2/ha).**
S1: *Erythroxylum australe* **=** 0.17 m^2/ha; **(total = 0.17 m^2/ha).**

Landform: Crest of hill slope. **Slope:** 20°S **Soil:** Coarse sand.

Disturbance: Minimal.

Ground cover: rock = 61.8%, litter = 18%, bare = 0.5%, vegetation = 19.7%.

Species (percent cover): *Acacia bancroftiorum* (0.1%), *Acacia flavescens* (0.1%), *Amyema congener* (0.1%), *Blumea axillaris* (0.1%), *Breynia oblongifolia* (0.1%), *Bursaria incana* (0.1%), *Cassytha filiformis* (0.1%), *Cleistochloa subjuncea* (13%), *Clerodendrum floribundum* (0.1%), *Corymbia citriodora* subsp. *citriodora* (0.1%), *Cyanthillium cinereum* (0.1%), *Cyclophyllum coprosmoides* (0.3%), *Cymbopogon obtectus* (0.1%), *Desmodium rhytidophyllum* (0.1%), *Digitaria ramularis* (0.1%), *Dinebra decipiens* var. *decipiens* (0.1%), *Erythroxylum australe* (0.1%), *Euphorbia bifida* (0.1%), *Euphorbia tannensis* (0.1%), *Evolvulus alsinoides* (0.1%), *Galactia tenuiflora* (0.1%), *Goodenia* sp. (Mt Castletower M.D. Crisp 2753) (0.1%), *Hibiscus meraukensis* (0.1%), *Indigofera pratensis* (0.1%), *Ipomoea brownii* (0.1%), *Jasminum didymum* subsp. *lineare* (0.1%), *Marsdenia microlepis* (0.1%), *Melinis repens** (0.1%), *Oxalis corniculata* (0.1%), *Pandorea pandorana* (0.1%), *Parsonsia lanceolata* (0.1%), *Persoonia falcata* (0.1%), *Petalostigma pubescens* (0.1%), *Phyllanthus carpentariae* (0.1%), *Phyllanthus virgatus* (0.1%), *Scleria sphacelata* (3%), *Setaria surgens* (0.1%).

APPENDIX C

FLORA AND FAUNA RECORDED DURING SURVEYS

Appendix C1 Flora recorded during field surveys

Family	Scientific Name	Common Name	Percentage of secondary sites in each regional ecosystem containing the species												
			11.3.2	11.3.25	11.4.8	11.4.9	11.5.3	11.5.9	11.9.2	11.10.1	11.10.3	11.10.7	11.10.8	11.10.13	Non-remnant
Acanthaceae	*Brunoniella australis*	Blue Trumpet	0	0	100	100	29	33	67	33	0	0	0	0	50
Acanthaceae	*Pseuderanthemum variabile*	Pastel Flower; Love Flower	0	0	50	0	0	11	0	33	80	67	0	20	0
Acanthaceae	*Rostellularia adscendens*	Pink Tongues	50	33	0	0	29	22	67	67	0	33	0	0	0
Aizoaceae	*Portulaca bicolor*		0	0	0	0	0	11	0	0	20	33	0	0	0
Aizoaceae	*Portulaca filifolia*		50	0	25	0	57	11	0	0	20	0	0	20	25
Aizoaceae	*Portulaca oleracea**	Common Purslane	0	0	50	100	43	11	33	0	20	33	0	0	0
Aizoaceae	*Portulaca pilosa**	Pink Purslane	50	33	25	0	29	78	0	0	20	33	0	0	75
Aizoaceae	*Trianthema portulacastrum**	Black Pigweed	0	0	0	0	0	0	0	0	0	0	0	0	0
Amaranthaceae	*Achyranthes aspera*	Devil's Horsewhip; Chaff Flower	0	67	25	0	43	0	0	0	20	33	0	20	0
Amaranthaceae	*Alternanthera denticulata*	Lesser Joyweed	0	0	0	100	43	0	0	0	0	0	0	0	0
Amaranthaceae	*Alternanthera nana*	Hairy Joyweed	50	33	25	0	86	44	0	33	40	0	0	0	50
Amaranthaceae	*Alternanthera pungens**	Khaki Weed	0	0	0	0	0	0	0	0	0	0	0	0	0
Amaranthaceae	*Amaranthus interruptus*		0	0	0	100	0	0	0	0	0	33	0	0	0
Amaranthaceae	*Amaranthus viridis**	Green Amaranth	0	0	0	100	0	0	0	0	0	0	0	0	0
Amaranthaceae	*Deeringia amaranthoides*	Redberry; Shrubby Deeringia	0	0	0	0	0	0	0	0	0	0	100	0	0
Amaranthaceae	*Gomphrena celosioides**	Gomphrena Weed	50	33	0	0	57	11	0	0	0	33	0	0	75
Amaranthaceae	*Nyssanthes erecta*		0	0	50	0	14	0	0	0	0	0	0	0	0
Amaranthaceae	*Ptilotus polystachyus*		0	0	0	0	0	0	0	0	40	0	0	0	0
Amaryllidaceae	*Crinum arenarium*	Field Lily	50	67	0	0	0	0	0	0	0	0	0	0	25
Anacardiaceae	*Euroschinus falcata*	Ribbonwood	0	0	0	0	0	0	0	0	0	0	0	0	0
Anacardiaceae	*Pleiogynium timoriense*	Burdekin Plum	0	0	0	0	0	0	0	0	0	0	100	0	0

Family	Scientific Name	Common Name	Percentage of secondary sites in each regional ecosystem containing the species												
			11.3.2	11.3.25	11.4.8	11.4.9	11.5.3	11.5.9	11.9.2	11.10.1	11.10.3	11.10.7	11.10.8	11.10.13	Non-remnant
Apiaceae	*Platysace valida*		0	0	0	0	0	0	0	0	0	0	0	0	0
Apocynaceae	*Alstonia constricta*	Bitter Bark; Quinine Bush	0	0	0	0	0	0	0	0	0	0	0	0	0
Apocynaceae	*Alyxia ruscifolia*	Chain Fruit	0	0	0	0	0	0	0	0	0	0	100	0	0
Apocynaceae	*Carissa ovata*	Conkerberry; Currant Bush	100	33	100	100	71	11	67	0	0	0	0	0	50
Apocynaceae	*Cryptostegia grandiflora**	Rubber Vine	0	33	0	0	0	0	0	0	0	0	0	0	0
Apocynaceae	*Cynanchum viminale*	Caustic Vine	0	0	50	0	0	0	0	0	0	0	0	0	0
Apocynaceae	*Marsdenia microlepis*		0	0	0	0	0	0	0	67	80	67	0	20	0
Apocynaceae	*Marsdenia viridiflora* subsp. *viridiflora*	Native Pear	0	0	0	100	0	0	0	0	0	0	0	0	0
Apocynaceae	*Parsonsia lanceolata*	Rough Silkpod	50	0	50	100	29	11	0	0	0	0	100	0	25
Apocynaceae	*Secamone elliptica*	Corky Milk Vine	0	0	0	0	0	0	0	0	0	0	100	0	0
Apocynaceae	*Wrightia saligna*	Milk Wood	0	0	0	0	0	0	0	0	40	0	0	0	0
Aristolochiaceae	*Aristolochia thozetii*	Australian Native Dutchman's Pipe	0	33	0	0	14	0	0	0	0	0	0	0	0
Asteraceae	*Acanthospermum hispidum**	Bristly Star Bur; Goat's Head	0	100	0	0	29	33	0	0	0	0	0	0	25
Asteraceae	*Ageratum conyzoides**	Billygoat Weed	0	67	0	0	0	0	0	0	0	0	0	0	0
Asteraceae	*Apowollastonia spilanthoides*		0	0	25	0	29	11	0	0	0	0	0	0	25
Asteraceae	*Bidens bipinnata**	Bipinnate Cobbler's Pegs	0	33	0	0	0	0	0	0	20	33	100	20	0
Asteraceae	*Bidens pilosa**	Cobbler's Pegs	0	67	0	0	0	11	0	0	0	33	0	0	0
Asteraceae	*Calotis cuneifolia*	Purple Burr-daisy	0	0	0	0	14	0	0	33	40	0	0	0	0
Asteraceae	*Calyptocarpus vialis*	Creeping Cinderella Weed	0	67	0	0	0	0	0	0	0	0	0	0	0
Asteraceae	*Camptacra barbata*		0	0	0	0	0	0	33	0	0	0	0	0	0
Asteraceae	*Centipeda minima*	Spreading Sneezeweed	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae	*Chrysocephalum apiculatum*	Billy Buttons	0	0	0	0	0	22	0	0	0	0	0	0	0

Family	Scientific Name	Common Name	Percentage of secondary sites in each regional ecosystem containing the species												
			11.3.2	11.3.25	11.4.8	11.4.9	11.5.3	11.5.9	11.9.2	11.10.1	11.10.3	11.10.7	11.10.8	11.10.13	Non-remnant
Asteraceae	*Coronidium oxylepis*	Pointed Everlasting Daisy	0	0	0	0	0	0	0	33	0	0	0	0	0
Asteraceae	*Cyanthillium cinereum*	Vernonia	50	67	25	0	71	22	33	100	60	33	100	20	50
Asteraceae	*Eclipta prostrata**	False Daisy; Eclipta	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae	*Emilia sonchifolia**	Tassel Flower; Emilia	0	67	0	0	0	22	0	0	0	0	0	0	0
Asteraceae	*Erigeron bonariensis**		0	13	0	0	0	0	0	0	0	0	0	0	0
Asteraceae	*Parthenium hysterophorus**	Parthenium Weed	0	100	25	100	0	11	33	0	0	0	0	0	25
Asteraceae	*Peripleura hispidula* var. *setosa*		0	0	0	0	0	0	33	0	0	0	0	0	0
Asteraceae	*Pterocaulon ciliosum*		0	0	0	0	0	0	0	33	0	0	0	0	0
Asteraceae	*Sonchus oleraceus**	Common Sowthistle	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae	*Sphaeromorphaea australis*	Spreading Nut-heads	0	0	0	0	0	11	0	0	0	0	0	0	50
Asteraceae	*Tridax procumbens**	Tridax Daisy	0	33	0	0	0	0	0	0	0	0	0	0	0
Asteraceae	*Verbesina encelioides**	Golden Crownbeard; Butter Daisy	0	33	0	0	0	0	0	0	0	0	0	0	0
Asteraceae	*Vittadinia pustulata*		0	0	0	0	14	11	0	0	0	0	0	0	0
Asteraceae	*Xanthium occidentale**	Noogoora Burr	0	100	0	0	0	0	0	0	0	0	0	0	0
Bignoniaceae	*Pandorea pandorana*	Wonga Vine	0	0	0	0	0	0	0	0	0	33	0	0	0
Boraginaceae	*Ehretia membranifolia*	Peach Bush; Weeping Koda	0	0	25	100	0	0	0	0	0	0	100	0	0
Boraginaceae	*Heliotropium cunninghamii*		0	0	0	0	0	0	0	0	0	0	0	0	25
Boraginaceae	*Heliotropium peninsulare*		0	0	0	0	0	33	33	0	0	33	0	20	0
Brassicaceae	*Cardamine hirsuta**	Hairy Bittercress	0	0	0	0	0	0	0	0	0	0	0	0	0
Byttneriaceae	*Hannafordia shanesii*		0	0	0	0	0	0	0	0	0	0	0	0	0
Cactaceae	*Harrisia martinii**	Harrisia Cactus	100	0	50	0	0	11	0	0	20	0	100	0	0
Cactaceae	*Opuntia stricta**	Prickly Pear	0	0	0	0	0	0	0	0	0	0	0	0	0

Family	Scientific Name	Common Name	Percentage of secondary sites in each regional ecosystem containing the species												
			11.3.2	11.3.25	11.4.8	11.4.9	11.5.3	11.5.9	11.9.2	11.10.1	11.10.3	11.10.7	11.10.8	11.10.13	Non-remnant
Cactaceae	*Opuntia tomentosa* *	Velvet Pear; Wooly Pear	50	0	25	0	14	0	0	0	20	0	0	0	0
Caesalpiniaceae	*Bauhinia hookeri*	White Bauhinia	0	67	0	100	0	0	0	0	0	0	0	0	0
Caesalpiniaceae	*Cassia brewsteri*	Brewster's Cassia	50	0	25	0	14	0	0	0	0	0	0	0	50
Caesalpiniaceae	*Chamaecrista absus*	Pig's ear; Sensitive Pea	0	33	0	0	14	44	0	0	20	67	0	40	25
Caesalpiniaceae	*Chamaecrista nomame*		0	0	0	0	0	0	0	0	0	0	0	0	0
Caesalpiniaceae	*Chamaecrista rotundifolia**	Round-leaf Sensitive Pea	0	0	0	0	0	0	0	0	0	33	0	0	0
Caesalpiniaceae	*Petalostylis labicheoides*	Butterfly Bush	0	0	0	0	0	0	0	0	0	0	0	0	0
Caesalpiniaceae	*Senna coronilloides*	Brigalow Senna	0	0	0	100	0	0	0	0	0	0	0	0	0
Caesalpiniaceae	*Senna occidentalis**	Coffee Senna	0	100	0	0	0	0	0	0	0	0	0	0	0
Campanulaceae	*Lobelia purpurascens*	White Root	0	0	0	0	0	0	0	0	0	33	0	0	0
Campanulaceae	*Wahlenbergia gracilis*	Blue Bell	0	0	0	0	0	0	0	0	0	0	0	0	0
Capparaceae	*Apophyllum anomalum*	Warrior Bush; Broom Bush	0	0	25	100	0	0	0	0	0	0	0	0	0
Capparaceae	*Capparis canescens*	Bumble Bush; Wild Orange	50	0	0	0	14	11	0	67	20	0	0	0	0
Capparaceae	*Capparis lasiantha*	Wyjeelah; Nepine	100	0	75	0	29	0	0	0	0	0	100	0	50
Caryophyllaceae	*Polycarpaea corymbosa*		0	0	0	0	0	11	0	0	0	33	0	0	0
Casuarinaceae	*Allocasuarina luehmannii*	Bull Oak	0	0	0	0	0	11	0	0	0	0	0	0	0
Casuarinaceae	*Casuarina cristata*	Belah	0	0	50	0	0	0	0	0	0	0	0	0	0
Celastraceae	*Denhamia cunninghamii*	Yellow-berry Bush	0	0	0	0	0	0	33	0	0	0	0	0	0
Celastraceae	*Denhamia oleaster*		0	0	0	0	0	0	0	0	0	0	0	0	0
Chenopodiaceae	*Dysphania melanocarpa* forma *melanocarpa*	Black Crumbweed	0	33	0	0	14	22	0	0	0	0	0	0	25
Chenopodiaceae	*Einadia nutans* subsp. *nutans*	Climbing Saltbush	0	0	50	0	14	0	0	0	0	0	0	0	25
Chenopodiaceae	*Einadia nutans* subsp. *linifolia*	Narrow Climbing Saltbush	0	0	25	0	0	0	0	0	0	0	0	0	0

Family	Scientific Name	Common Name	Percentage of secondary sites in each regional ecosystem containing the species												
			11.3.2	11.3.25	11.4.8	11.4.9	11.5.3	11.5.9	11.9.2	11.10.1	11.10.3	11.10.7	11.10.8	11.10.13	Non-remnant
Chenopodiaceae	*Enchylaena tomentosa* var. *tomentosa*	Ruby Saltbush	0	0	50	0	0	0	0	0	0	0	0	0	0
Chenopodiaceae	*Maireana microphylla*	Small-leaf Bluebush	0	0	25	0	0	0	0	0	0	0	0	0	0
Chenopodiaceae	*Salsola australis*	Roly-Poly	0	0	25	100	14	0	0	0	0	0	0	0	25
Chenopodiaceae	*Sclerolaena birchii*	Galvanised Burr	0	0	0	0	0	0	0	0	0	0	0	0	0
Cleomaceae	*Cleome tetrandra* var. *tetrandra*		0	0	0	0	0	22	0	0	0	0	0	0	0
Cleomaceae	*Cleome viscosa*	Tick Weed	0	0	0	0	0	0	33	0	0	33	0	0	0
Combretaceae	*Terminalia oblongata*	Yellow-wood	0	0	50	0	0	0	0	0	0	0	0	0	0
Commelinaceae	*Commelina diffusa*	Climbing Dayflower	0	100	0	0	0	0	0	0	0	0	100	0	0
Commelinaceae	*Commelina lanceolata*		0	0	0	0	0	22	0	33	0	33	0	20	0
Commelinaceae	*Murdannia graminea*	Grass Lily	0	0	0	0	29	67	0	33	0	33	0	20	50
Convolvulaceae	*Bonamia media*		50	0	0	0	43	56	0	0	0	33	0	40	0
Convolvulaceae	*Evolvulus alsinoides*	Dwarf Morning Glory	100	0	100	0	86	67	33	67	40	100	0	80	25
Convolvulaceae	*Ipomoea brownii*		0	0	0	0	0	0	0	0	20	33	0	60	0
Convolvulaceae	*Ipomoea plebia*	Bell Vine	0	100	0	100	14	0	0	0	0	0	0	40	25
Convolvulaceae	*Ipomoea polymorpha*		0	0	0	0	57	78	0	0	0	0	0	20	50
Convolvulaceae	*Jacquemontia paniculata*		50	0	50	0	0	11	33	0	0	0	0	0	0
Convolvulaceae	*Polymeria pusilla*		0	0	0	0	0	0	33	0	0	0	0	0	25
Convolvulaceae	*Xenostegia tridentata*		0	0	0	0	0	0	0	0	20	33	0	60	0
Cyperaceae	*Abildgaardia ovata*		0	0	0	0	0	0	33	0	0	0	0	0	0
Cyperaceae	*Bulbostylis barbata*		0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	*Cyperus betchei*		0	0	0	0	0	0	0	33	20	33	0	20	0
Cyperaceae	*Cyperus concinnus*		0	0	0	100	0	0	0	0	0	0	0	0	0

Family	Scientific Name	Common Name	Percentage of secondary sites in each regional ecosystem containing the species												
			11.3.2	11.3.25	11.4.8	11.4.9	11.5.3	11.5.9	11.9.2	11.10.1	11.10.3	11.10.7	11.10.8	11.10.13	Non-remnant
Cyperaceae	*Cyperus conicus* var. *conicus*		0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	*Cyperus difformis*	Variable Flatsedge	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	*Cyperus fulvus*	Sticky Sedge	50	0	0	0	29	11	0	0	0	33	0	0	0
Cyperaceae	*Cyperus gracilis*	Slender Flat-sedge	50	67	50	100	43	0	0	0	0	0	0	0	0
Cyperaceae	*Cyperus leiocaulon*		0	33	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	*Cyperus perangustus*		0	0	0	100	0	0	0	0	0	0	0	0	0
Cyperaceae	*Cyperus rotundus**	Purple Nutsedge	0	0	0	0	0	0	33	0	0	0	0	0	0
Cyperaceae	*Eleocharis acuta*	Common Spikerush	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperaceae	*Fimbristylis dichotoma*	Common Fringe-sedge	100	0	0	0	71	100	33	33	0	67	0	20	75
Cyperaceae	*Gahnia aspera*	Rough Saw-sedge	0	0	0	0	0	0	0	33	0	0	100	0	0
Cyperaceae	*Scleria brownii*		0	0	25	0	0	0	67	0	0	0	100	20	0
Cyperaceae	*Scleria sphacelata*		0	0	0	0	0	0	0	100	60	0	100	0	0
Ebenaceae	*Diospyros humilis*	Small-leaved Ebony	0	0	0	0	14	0	0	0	0	0	100	0	0
Erythroxylaceae	*Erythroxylum australe*	Australian Cocaine Bush; Dogwood	0	0	50	0	43	33	0	67	80	67	0	80	0
Euphorbiaceae	*Acalypha eremorum*	Soft Acalypha	0	0	0	0	0	0	0	0	0	0	0	0	0
Euphorbiaceae	*Euphorbia bifida*		0	0	0	0	14	0	33	0	0	0	0	20	25
Euphorbiaceae	*Euphorbia drummondii*	Caustic Weed	0	0	0	0	29	0	33	33	20	33	0	60	0
Euphorbiaceae	*Euphorbia hirta**	Asthma Weed	0	33	0	0	0	0	0	0	0	0	0	0	0
Euphorbiaceae	*Euphorbia tannensis*	Desert Spurge	0	0	0	0	0	0	0	33	0	0	0	0	0
Euphorbiaceae	*Jatropha gossypiifolia**	Bellyache Bush	0	0	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	*Aeschynomene brevifolia*		0	0	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	*Aeschynomene indica*	Indian Jointvetch	0	0	0	0	0	0	0	0	0	0	0	0	0

Family	Scientific Name	Common Name	Percentage of secondary sites in each regional ecosystem containing the species												
			11.3.2	11.3.25	11.4.8	11.4.9	11.5.3	11.5.9	11.9.2	11.10.1	11.10.3	11.10.7	11.10.8	11.10.13	Non-remnant
Fabaceae	*Bossiaea carinalis*		0	0	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	*Crotalaria juncea**	Brown Hemp	0	0	0	0	14	0	0	0	0	0	0	0	25
Fabaceae	*Crotalaria medicaginea*	Trefoil Rattlepod	0	0	0	0	0	22	0	0	0	0	0	0	0
Fabaceae	*Crotalaria mitchellii*	Yellow Rattlepod	0	67	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	*Crotalaria montana*		0	0	0	0	0	0	0	33	0	0	0	0	0
Fabaceae	*Crotalaria pallida**	Smooth Rattlepod	0	33	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	*Daviesia filipes*		0	0	0	0	0	0	0	33	0	0	0	0	0
Fabaceae	*Desmodium filiforme*		0	33	0	0	43	11	0	0	0	0	0	0	0
Fabaceae	*Desmodium macrocarpum*	Large-podded Trefoil	50	0	0	0	0	0	0	33	0	0	0	20	0
Fabaceae	*Desmodium rhytidophyllum*	Hairy Trefoil	0	0	0	0	0	0	0	33	0	0	0	0	0
Fabaceae	*Desmodium varians*	Slender Tick-trefoil	0	0	75	0	0	11	33	0	0	0	0	0	0
Fabaceae	*Erythrina vespertilio*	Bat's Wing Coral Tree	0	33	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	*Galactia tenuiflora*		0	0	0	0	29	44	33	33	20	33	0	60	50
Fabaceae	*Glycine* sp. (Mackay S.B. Andrews+ 43)		0	0	25	0	29	0	33	0	0	33	0	0	0
Fabaceae	*Glycine tomentella*	Woolly Glycine	50	33	0	0	29	44	33	33	0	0	0	20	25
Fabaceae	*Hovea longipes*	Brush Hovea	0	0	0	0	0	0	0	0	0	0	100	0	0
Fabaceae	*Hovea tholiformis*		0	0	0	0	0	0	0	67	0	0	0	20	0
Fabaceae	*Indigofera australis*	Australian Indigo	0	0	0	0	0	0	0	33	0	0	0	0	0
Fabaceae	*Indigofera colutea*	Sticky Indigo	50	0	0	0	14	22	0	0	0	0	0	0	75
Fabaceae	*Indigofera hirsuta*	Hairy Indigo	0	0	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	*Indigofera linifolia*	Narrow-leafed Indigo	0	0	0	0	0	0	100	0	0	0	0	0	25
Fabaceae	*Indigofera linnaei*	Birdsville indigo	50	0	0	0	0	11	67	0	0	0	0	0	50

Family	Scientific Name	Common Name	Percentage of secondary sites in each regional ecosystem containing the species												
			11.3.2	11.3.25	11.4.8	11.4.9	11.5.3	11.5.9	11.9.2	11.10.1	11.10.3	11.10.7	11.10.8	11.10.13	Non-remnant
Fabaceae	*Indigofera* sp. A		0	0	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	*Macroptilium atropurpureum**	Siratro	0	33	0	0	0	0	0	0	0	0	0	0	25
Fabaceae	*Macroptilium lathryoides**	Phasey Bean	0	33	0	0	0	0	0	0	0	0	0	0	13
Fabaceae	*Pycnospora lutescens*	Pycnospora	0	0	0	0	0	0	0	33	0	0	0	0	0
Fabaceae	*Rhynchosia minima*	Least Snout-bean	0	0	25	0	29	0	67	0	0	0	0	0	50
Fabaceae	*Sesbania cannabina*	Sesbania Pea	0	0	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	*Stylosanthes hamata**	Caribbean Stylo	0	67	0	0	43	33	33	0	0	0	0	0	50
Fabaceae	*Stylosanthes humilis**	Townsville Stylo	50	33	0	0	14	0	0	0	0	0	0	0	25
Fabaceae	*Stylosanthes scabra**	Shrubby Stylo	100	0	0	0	71	89	100	33	20	100	0	80	100
Fabaceae	*Tephrosia dietrichiae*		0	0	0	0	0	11	0	0	0	0	0	0	0
Fabaceae	*Tephrosia filipes* subsp. *filipes*		0	0	0	0	0	0	33	0	0	33	0	40	0
Fabaceae	*Tephrosia juncea*		0	0	0	0	0	0	0	33	0	0	0	20	0
Fabaceae	*Tephrosia leptoclada*		0	0	0	0	29	33	0	0	0	0	0	0	0
Fabaceae	*Tephrosia* sp. A		0	0	0	0	0	0	0	33	0	0	0	0	0
Fabaceae	*Tephrosia* sp. B		0	0	0	0	0	0	33	0	0	0	0	0	0
Fabaceae	*Zornia areolata*		0	0	0	0	43	11	0	0	0	0	0	0	0
Fabaceae	*Zornia muelleriana subsp. muelleriana*		0	0	0	0	14	44	0	0	0	33	0	20	0
Fabaceae	*Zornia muriculata subsp. angustata*		50	33	0	0	0	11	0	0	0	0	0	0	25
Fabaceae	*Zornia* sp.		0	0	0	0	29	11	0	33	0	33	0	0	25
Goodeniaceae	*Goodenia glabra*	Smooth Goodenia	0	0	0	0	0	11	0	0	0	0	0	0	0
Goodeniaceae	*Goodenia grandiflora*	Large-flowered Goodenia	0	0	0	0	0	0	0	0	0	0	0	0	0

Family	Scientific Name	Common Name	Percentage of secondary sites in each regional ecosystem containing the species												
			11.3.2	11.3.25	11.4.8	11.4.9	11.5.3	11.5.9	11.9.2	11.10.1	11.10.3	11.10.7	11.10.8	11.10.13	Non-remnant
Goodeniaceae	*Goodenia* sp. (Mt Castletower M.D. Crisp 2753)		0	0	0	0	0	0	0	67	20	0	0	0	0
Hemerocallidaceae	*Dianella nervosa*	Flax Lily	0	0	0	0	0	11	0	0	20	0	0	0	0
Johnsoniaceae	*Tricoryne elatior*	Yellow Autumn-lily	0	0	0	0	0	11	0	0	0	0	0	0	0
Juncaceae	*Juncus polyanthemus*	Australian Grey Rush	0	0	0	0	0	0	0	0	0	0	0	0	0
Juncaceae	*Juncus usitatus*	Common Rush	0	33	0	0	0	0	0	0	0	0	0	0	0
Lamiaceae	*Ajuga australis*	Australian Bugle	0	33	0	0	0	0	0	0	0	0	0	0	0
Lamiaceae	*Anisomeles malabarica*	Catmint	0	0	0	0	0	0	0	0	0	0	0	0	0
Lamiaceae	*Clerodendrum floribundum*	Lolly Bush	0	67	0	0	0	11	0	0	0	0	0	0	25
Lamiaceae	*Clerodendrum tomentosum*	Hairy Lolly Bush	0	0	0	0	14	0	0	0	0	0	0	0	0
Lamiaceae	*Ocimum caryophyllinum*	Holy Basil	0	0	25	0	0	0	33	0	0	0	0	0	0
Lamiaceae	*Plectranthus parviflorus*	Little Spurflower	0	0	0	0	0	0	0	0	0	0	100	0	0
Lauraceae	*Cassytha filiformis*	Love Vine; Dodder Laurel	0	0	0	0	0	11	33	0	0	0	100	0	0
Laxmanniaceae	*Eustrephus latifolius*	Wombat Berry	0	0	0	0	0	0	33	33	0	0	0	0	25
Laxmanniaceae	*Lomandra longifolia*	Spiny-head Mat-rush	0	67	0	0	0	0	0	0	0	0	0	40	0
Laxmanniaceae	*Lomandra multiflora*	Many-flowered Mat-rush	0	0	0	0	0	0	67	33	0	0	0	0	0
Loranthaceae	*Amyema congener*	Variable Mistletoe	0	0	0	0	0	0	0	0	0	0	0	0	0
Loranthaceae	*Amyema conspicua*	Alphitonia Mistletoe	0	0	0	0	0	0	0	0	0	0	100	0	0
Malvaceae	*Abutilon guineense**	Chinese Lantern	0	33	0	0	0	0	0	0	0	0	0	0	25
Malvaceae	*Abutilon oxycarpum*	Lantern Bush	0	0	75	0	29	0	0	0	0	0	100	0	0
Malvaceae	*Abutilon oxycarpum* var. *incanum*	Lantern Bush	0	0	50	100	14	0	0	0	0	0	0	0	0
Malvaceae	*Gossypium australe*	Australian Cotton	0	0	0	0	0	0	0	0	0	0	0	0	0
Malvaceae	*Hibiscus brachysiphonius*	Low Hibiscus	0	0	25	0	0	0	0	0	0	0	0	0	0

Family	Scientific Name	Common Name	Percentage of secondary sites in each regional ecosystem containing the species												
			11.3.2	11.3.25	11.4.8	11.4.9	11.5.3	11.5.9	11.9.2	11.10.1	11.10.3	11.10.7	11.10.8	11.10.13	Non-remnant
Malvaceae	*Hibiscus meraukensis*	Merauke Hibiscus	0	0	0	0	0	11	0	0	20	0	0	60	0
Malvaceae	*Hibiscus sturtii*	Hill Hibiscus	50	0	50	0	0	0	0	0	0	0	0	0	0
Malvaceae	*Malvastrum americanum**	Spiked Malvastrum	0	0	0	100	29	0	33	0	0	0	0	0	0
Malvaceae	*Malvastrum coromandelianum**	Prickly Malvastrum	0	33	0	0	0	0	0	0	0	0	0	0	0
Malvaceae	*Sida aprica*		0	0	0	0	0	0	0	0	20	0	0	0	0
Malvaceae	*Sida atherophora*		0	0	0	0	0	0	0	0	20	0	0	0	0
Malvaceae	*Sida cordifolia**	Flannel Weed	50	100	0	0	29	33	0	0	20	33	0	0	25
Malvaceae	*Sida corrugata*	Variable Sida	0	0	25	0	0	0	0	0	0	0	0	0	0
Malvaceae	*Sida hackettiana*	Golden Rod; Spiked Sida	100	33	25	0	100	78	67	0	20	100	100	60	75
Malvaceae	*Sida pleiantha*		0	0	0	0	0	0	33	0	0	0	0	0	25
Malvaceae	*Sida rhombifolia**	Paddy's Lucerne	0	100	0	0	0	0	0	0	0	0	0	0	0
Malvaceae	*Sida rohlenae*	Shrub Sida	0	0	25	0	0	0	0	0	0	0	0	0	0
Malvaceae	*Sida* sp.		0	0	0	0	0	0	0	33	0	0	0	0	0
Malvaceae	*Sida* sp. (Aramac E.J. Thompson+ JER192)		0	0	0	0	0	11	0	0	0	0	0	0	0
Malvaceae	*Sida* sp. (Musselbrook M.B. Thomas+ MRS437)		0	0	0	0	0	11	0	33	60	33	0	40	0
Malvaceae	*Sida spinosa**	Spiny Sida	100	33	0	0	100	22	33	33	20	100	0	40	100
Marsileaceae	*Marsilea sp.*	Nardoo	0	0	0	0	0	0	0	0	0	0	0	0	0
Meliaceae	*Owenia acidula*	Emu Apple	0	0	25	100	14	0	0	0	0	0	0	0	25
Menispermaceae	*Stephania japonica*	Snake Vine	0	33	0	0	0	0	0	0	0	0	0	0	0
Menispermaceae	*Tinospora smilacina*	Heart Vine	0	33	0	0	0	0	0	0	20	0	0	40	0
Menyanthaceae	*Nymphoides* sp.	Water Snowflake	0	0	0	0	0	0	0	0	0	0	0	0	0

Family	Scientific Name	Common Name	Percentage of secondary sites in each regional ecosystem containing the species												
			11.3.2	11.3.25	11.4.8	11.4.9	11.5.3	11.5.9	11.9.2	11.10.1	11.10.3	11.10.7	11.10.8	11.10.13	Non-remnant
Mimosaceae	*Vachellia bidwillii*	Corkwood Wattle	0	0	25	0	14	0	33	0	0	0	0	0	0
Mimosaceae	*Acacia bancroftiorum*	Bancroft Wattle	0	0	0	0	0	0	0	0	0	0	0	60	0
Mimosaceae	*Acacia burdekensis*	Burdekin Wattle	0	0	0	0	14	33	0	33	0	33	100	40	0
Mimosaceae	*Acacia curvinervia*		0	0	0	0	0	0	0	0	0	0	0	20	0
Mimosaceae	*Acacia dietrichiana*	Dietrich Wattle	0	0	0	0	0	0	0	33	0	0	0	40	0
Mimosaceae	*Acacia excelsa*	Ironwood Wattle	0	0	0	0	14	11	33	0	0	0	0	0	0
Mimosaceae	*Acacia flavescens*	Red Wattle	0	0	0	0	0	0	0	33	0	33	0	20	0
Mimosaceae	*Acacia harpophylla*	Brigalow	0	0	75	0	0	0	0	0	0	0	0	0	0
Mimosaceae	*Acacia julifera* subsp. *julifera*		0	0	0	0	0	0	0	0	0	0	0	0	0
Mimosaceae	*Acacia macradenia*	Zig-Zag Wattle	0	33	0	0	0	0	0	33	0	0	0	0	0
Mimosaceae	*Acacia rhodoxylon*	Ringy Rosewood	0	0	0	0	0	0	0	0	0	0	0	20	0
Mimosaceae	*Acacia salicina*	Sally Wattle; Willow Wattle	50	33	0	0	14	0	33	0	0	0	0	0	25
Mimosaceae	*Acacia shirleyi*	Lancewood	0	0	0	0	0	0	0	0	80	0	100	60	0
Mimosaceae	*Albizia canescens*	Belmont Siris	0	33	0	0	0	0	0	0	0	0	0	0	0
Mimosaceae	*Archidendropsis basaltica*	Dead Finish	0	0	0	0	14	0	0	0	0	0	0	0	50
Mimosaceae	*Leucaena leucocephala**	Leucaena	0	0	0	0	0	0	0	0	0	0	0	0	0
Mimosaceae	*Neptunia gracilis*	Native Sensitive Plant	0	0	0	0	0	0	67	0	0	0	0	0	75
Molluginaceae	*Glinus lotoides*	Hairy Carpet-weed	0	0	0	0	0	0	0	0	0	0	0	0	0
Moraceae	*Ficus opposita*	Sandpaper Fig	0	100	0	0	0	0	0	0	0	0	0	0	0
Moraceae	*Ficus rubiginosa*	Rock Fig	0	0	0	0	0	0	0	0	0	0	100	0	0
Moraceae	*Trophis scandens*	Burny Vine	0	0	0	0	0	0	0	0	0	0	100	0	0
Myrsinaceae	*Myrsine variabilis*	Muttonwood	0	0	0	0	0	0	0	0	0	0	100	0	0

Family	Scientific Name	Common Name	Percentage of secondary sites in each regional ecosystem containing the species												
			11.3.2	11.3.25	11.4.8	11.4.9	11.5.3	11.5.9	11.9.2	11.10.1	11.10.3	11.10.7	11.10.8	11.10.13	Non-remnant
Myrtaceae	*Corymbia aureola*	Yellowjacket	0	0	0	0	0	0	0	0	0	0	0	80	0
Myrtaceae	*Corymbia citriodora* subsp. *citriodora*	Lemon-scented Gum	0	0	0	0	0	0	0	67	0	0	0	0	0
Myrtaceae	*Corymbia clarksoniana*	Clarkson's Bloodwood	0	0	0	0	0	0	0	0	0	0	0	0	0
Myrtaceae	*Corymbia dallachiana*	Ghost Gum	0	0	0	0	0	11	0	0	0	33	0	0	0
Myrtaceae	*Corymbia erythrophloia*	Variable-barked Bloodwood	0	0	0	0	0	0	33	0	0	0	0	0	0
Myrtaceae	*Corymbia tessellaris*	Carbeen; Blackbutt	0	0	0	0	0	0	0	0	0	0	0	0	0
Myrtaceae	*Corymbia trachyphloia*	Brown Bloodwood	0	0	0	0	0	0	0	67	0	0	0	0	0
Myrtaceae	*Eucalyptus camaldulensis*	River Red Gum	0	67	0	0	0	0	0	0	0	0	0	0	0
Myrtaceae	*Eucalyptus crebra*	Narrow-Leaved Ironbark	0	0	0	0	0	11	0	33	20	67	0	0	0
Myrtaceae	*Eucalyptus melanophloia*	Silver-leaved Ironbark	50	0	0	0	0	22	0	33	0	33	0	20	0
Myrtaceae	*Eucalyptus orgadophila*	Mountain Coolibah	0	0	0	0	0	0	33	0	0	0	0	0	0
Myrtaceae	*Eucalyptus populnea*	Poplar Box	100	0	0	0	71	0	0	0	0	0	0	0	25
Myrtaceae	*Gossia bidwillii*	Python Tree	0	0	0	0	0	0	0	0	0	0	100	0	0
Myrtaceae	*Leptospermum lamellatum*	Weeping Tea-tree	0	0	0	0	0	0	0	33	0	0	0	0	0
Myrtaceae	*Lophostemon grandiflorus*	Northern Swamp Mahogany	0	33	0	0	0	0	0	0	0	0	0	0	0
Myrtaceae	*Lophostemon suaveolens*	Swamp Mahogany	0	0	0	0	0	0	0	0	0	0	100	0	0
Myrtaceae	*Lysicarpus angustifolius*	Budgeroo	0	0	0	0	0	0	0	33	0	0	0	20	0
Myrtaceae	*Melaleuca fluviatilis*	Weeping Paperbark	0	33	0	0	0	0	0	0	0	0	0	0	0
Myrtaceae	*Melaleuca leucadendra*	Paperbark	0	0	0	0	0	0	0	0	0	0	0	0	0
Myrtaceae	*Melaleuca nervosa*	Broad-leaved Paperbark	0	0	0	0	14	78	0	0	0	0	0	0	0
Nyctaginaceae	*Boerhavia pubescens*		50	0	75	100	71	11	33	0	0	0	0	0	25
Olacaceae	*Ximenia americana**	Tallow Wood; Yellow Plum	0	0	0	0	0	0	0	0	0	0	0	0	0

Family	Scientific Name	Common Name	Percentage of secondary sites in each regional ecosystem containing the species												
			11.3.2	11.3.25	11.4.8	11.4.9	11.5.3	11.5.9	11.9.2	11.10.1	11.10.3	11.10.7	11.10.8	11.10.13	Non-remnant
Oleaceae	*Jasminum didymum* subsp. *lineare*	Desert Jasmine	0	0	50	0	0	0	0	0	20	0	0	0	0
Oleaceae	*Jasminum didymum* subsp. *racemosum*	Native Jasmine	0	0	0	0	0	0	0	0	0	0	100	0	0
Oleaceae	*Jasminum simplicifolium* subsp. *australiense*	Stiff Jasmine	0	0	0	0	0	0	0	0	0	0	100	0	0
Orchidaceae	*Cymbidium canaliculatum*	Black Orchid	50	0	25	0	0	0	0	0	0	0	0	0	0
Oxalidaceae	*Oxalis corniculata*	Creeping Woodsorrel	100	33	0	0	0	0	0	67	0	0	0	20	25
Passifloraceae	*Passiflora foetida**	Stinking Passionflower	0	33	0	0	0	0	0	0	0	0	0	0	0
Pentapetaceae	*Melhania oblongifolia*		100	0	50	0	29	33	67	33	0	0	0	0	0
Phyllanthaceae	*Breynia oblongifolia*	Coffee Bush	0	0	0	0	29	0	0	67	0	33	0	20	0
Phyllanthaceae	*Phyllanthus carpentariae*		0	0	0	0	0	22	0	33	20	67	0	40	0
Phyllanthaceae	*Phyllanthus collinus*		0	0	25	0	100	56	0	33	20	100	0	0	0
Phyllanthaceae	*Phyllanthus fuernrohrii*	Sand Spurge	0	0	0	0	0	0	33	0	0	0	0	0	0
Phyllanthaceae	*Phyllanthus maderaspatensis*		0	0	0	0	0	0	67	0	0	0	0	0	25
Phyllanthaceae	*Phyllanthus* sp. (Myra Vale J.J. Bruhl+ 181)		0	0	0	0	43	44	0	0	0	33	0	0	25
Phyllanthaceae	*Phyllanthus virgatus*	Creeping Phyllanthus	100	33	75	0	14	11	0	67	0	0	0	20	50
Picrodendraceae	*Petalostigma pubescens*	Quinine Tree	0	0	0	0	0	44	0	33	0	100	0	20	25
Pittosporaceae	*Bursaria incana*	Prickly Pine	0	0	25	0	0	0	33	33	0	0	100	0	0
Plantaginaceae	*Scoparia dulcis**	Licorice Weed	0	67	0	0	14	11	0	0	0	33	100	0	0
Plumbaginaceae	*Plumbago zeylanica*	Wild Plumbago	0	0	0	100	0	0	0	0	0	0	0	0	0
Poaceae	*Alloteropsis cimicina*	Summer Grass	0	67	0	0	43	67	0	0	60	33	0	80	25
Poaceae	*Alloteropsis semialata*	Cockatoo Grass	0	0	0	0	0	0	33	0	0	0	0	0	0
Poaceae	*Ancistrachne uncinata*	Hooky Grass	0	0	50	0	0	0	0	0	0	0	100	0	0

Family	Scientific Name	Common Name	Percentage of secondary sites in each regional ecosystem containing the species												
			11.3.2	11.3.25	11.4.8	11.4.9	11.5.3	11.5.9	11.9.2	11.10.1	11.10.3	11.10.7	11.10.8	11.10.13	Non-remnant
Poaceae	*Aristida benthamii*	Bentham's Wiregrass	0	0	0	0	0	11	0	67	40	33	0	40	0
Poaceae	*Aristida calycina var. calycina*	Dark Wiregrass	100	0	25	0	100	67	0	67	80	100	0	80	50
Poaceae	*Aristida gracilipes*		100	0	50	0	14	0	67	33	20	0	0	0	0
Poaceae	*Aristida holathera*	Tall Kerosene Grass	0	0	0	0	29	44	33	0	0	33	0	20	0
Poaceae	*Aristida inaequiglumis*	Unequal Wiregrass	0	0	0	0	0	11	0	0	0	0	0	0	0
Poaceae	*Aristida spuria*		0	0	0	0	0	0	0	33	0	0	0	0	0
Poaceae	*Arundinella nepalensis*	Reedgrass	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Bothriochloa decipiens var. cloncurrensis*	Pitted Bluegrass	0	0	0	0	0	11	0	0	0	0	0	0	0
Poaceae	*Bothriochloa ewartiana*	Desert Bluegrass	100	33	0	0	14	0	100	0	0	0	0	0	25
Poaceae	*Bothriochloa pertusa**	Indian Couch	100	100	75	0	71	44	100	0	0	33	0	0	100
Poaceae	*Capillipedium parviflorum*	Scented-top Grass	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Cenchrus ciliaris**	Buffel Grass	100	100	75	100	86	33	100	33	20	67	0	0	100
Poaceae	*Chloris barbata**	Purpletop Chloris	0	0	0	0	0	0	0	0	0	0	0	0	25
Poaceae	*Chloris divaricata*	Slender Chloris	0	0	100	0	29	11	0	0	0	0	0	0	0
Poaceae	*Chloris gayana**	Rhodes Grass	0	33	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Chloris virgata**	Feathertop Rhodes Grass	0	67	0	0	14	0	0	0	0	0	0	0	0
Poaceae	*Chrysopogon fallax*	Golden Beard Grass	100	0	25	0	86	78	33	33	20	67	0	20	75
Poaceae	*Cleistochloa subjuncea*		0	0	0	0	0	0	0	67	80	0	100	80	0
Poaceae	*Cymbopogon obtectus*	Silkyheads	0	0	0	0	0	0	0	67	0	0	0	0	0
Poaceae	*Cymbopogon refractus*	Barbed Wire Grass	0	0	50	0	0	0	0	67	0	0	0	0	0
Poaceae	*Cynodon dactylon**	Bermuda Grass; Green Couch	0	67	0	0	14	0	0	0	0	0	0	0	0
Poaceae	*Dactyloctenium radulans*	Button Grass	0	33	0	100	14	56	0	0	0	0	0	0	75

Family	Scientific Name	Common Name	Percentage of secondary sites in each regional ecosystem containing the species												
			11.3.2	11.3.25	11.4.8	11.4.9	11.5.3	11.5.9	11.9.2	11.10.1	11.10.3	11.10.7	11.10.8	11.10.13	Non-remnant
Poaceae	*Dichanthium sericeum*	Queensland Bluegrass	0	0	0	0	0	0	0	33	0	0	0	0	0
Poaceae	*Digitaria ammophila*	Silky Umbrella Grass	0	33	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Digitaria brownii*	Cotton Panic Grass	0	33	0	0	0	0	0	0	0	33	0	0	0
Poaceae	*Digitaria ciliaris*	Summer Grass	0	0	0	0	0	0	0	0	0	0	0	0	25
Poaceae	*Digitaria diminuta*		0	0	0	0	0	0	0	33	100	33	0	60	25
Poaceae	*Digitaria divaricatissima*	Umbrella Grass	0	0	0	0	14	33	0	0	0	33	0	0	0
Poaceae	*Digitaria eriantha**		0	100	0	0	14	11	33	0	0	33	0	0	50
Poaceae	*Digitaria longiflora*		0	0	0	0	14	22	0	0	0	0	0	20	0
Poaceae	*Digitaria minima*		0	0	0	0	14	0	0	0	0	0	0	0	0
Poaceae	*Digitaria ramularis*		0	0	0	0	0	0	0	0	0	33	0	0	0
Poaceae	*Digitaria* sp. A		0	0	0	0	0	22	0	0	0	33	0	0	0
Poaceae	*Dinebra decipiens* var. *decipiens*	Slender Cane Grass	0	0	0	0	0	0	0	0	0	33	100	0	0
Poaceae	*Dinebra ligulata*		0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Echinochloa colona**	Awnless Barnyard Grass	0	67	0	100	0	0	0	0	0	0	0	0	0
Poaceae	*Eleusine indica**	Indian Crowfoot Grass	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Enneapogon lindleyanus*	Conetop Nineawn	0	0	25	0	43	0	0	33	0	0	0	0	0
Poaceae	*Enneapogon* sp. A		0	0	25	0	0	0	67	0	0	0	0	0	0
Poaceae	*Enteropogon ramosus*	Curly Windmill Grass	0	0	0	0	43	0	0	0	0	0	0	0	50
Poaceae	*Eragrostis elongata*	Clustered Lovegrass	0	33	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Eragrostis lacunaria*	Purple Lovegrass	0	0	75	0	57	44	0	0	60	0	0	60	25
Poaceae	*Eragrostis leptostachya*	Paddock Lovegrass	0	0	0	0	14	0	0	0	0	33	0	0	0
Poaceae	*Eragrostis parviflora*	Weeping Lovegrass	0	0	0	0	0	0	0	0	0	0	0	0	0

Family	Scientific Name	Common Name	Percentage of secondary sites in each regional ecosystem containing the species												
			11.3.2	11.3.25	11.4.8	11.4.9	11.5.3	11.5.9	11.9.2	11.10.1	11.10.3	11.10.7	11.10.8	11.10.13	Non-remnant
Poaceae	*Eragrostis pilosa**	Soft Lovegrass	0	0	0	100	0	0	0	0	0	0	0	0	0
Poaceae	*Eragrostis sororia*		50	0	0	0	57	78	0	0	20	67	0	60	25
Poaceae	*Eragrostis spartinoides*		0	0	0	0	14	11	0	67	0	33	0	20	0
Poaceae	*Eragrostis speciosa*	Hansome Lovegrass	0	0	0	0	29	11	0	0	0	0	0	0	0
Poaceae	*Eremochloa bimaculata*	Poverty Grass	0	0	0	0	0	11	0	0	0	0	0	0	0
Poaceae	*Eriachne mucronata*	Mountain Wanderrie Grass	0	0	0	0	14	11	0	0	0	33	0	0	0
Poaceae	*Eriachne obtusa*	Northern Wanderrie Grass	0	0	0	0	0	22	0	33	40	0	0	20	0
Poaceae	*Eriochloa crebra*	Cup Grass	0	0	0	100	29	11	0	0	0	67	0	20	0
Poaceae	*Eriochloa pseudoacrotricha*	Early Spring Grass	0	0	0	0	0	0	0	33	0	0	0	20	0
Poaceae	*Eulalia aurea*	Silky Browntop	0	0	0	0	0	11	0	0	0	0	0	0	25
Poaceae	*Heteropogon contortus*	Black Speargrass	50	33	0	0	14	11	33	0	0	0	0	0	25
Poaceae	*Hymenachne amplexicaulis*	Olive Hymenachne	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Hyparrhenia rufa*	Thatch Grass	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Megathyrsus maximus* var. *maximus*	Guinea Grass	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Megathyrsus maximus* var. *pubiglumis*	Green Panic	0	100	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Melinis repens*	Red Natal Grass	0	33	0	0	29	11	33	67	40	67	0	80	0
Poaceae	*Panicum effusum*	Hairy Panic	50	0	0	0	14	11	0	100	20	67	0	40	25
Poaceae	*Paspalidium caespitosum*	Brigalow Grass	0	0	50	0	0	0	0	0	20	0	0	0	0
Poaceae	*Paspalidium constricutum*	Knottybutt Grass	0	0	25	0	0	0	0	0	0	0	0	0	0
Poaceae	*Paspalidium distans*		0	0	50	0	0	0	0	0	0	0	0	0	0
Poaceae	*Paspalidium gracile*	Slender Panic	0	0	0	0	0	0	0	0	60	33	0	20	0

Family	Scientific Name	Common Name	Percentage of secondary sites in each regional ecosystem containing the species												
			11.3.2	11.3.25	11.4.8	11.4.9	11.5.3	11.5.9	11.9.2	11.10.1	11.10.3	11.10.7	11.10.8	11.10.13	Non-remnant
Poaceae	*Paspalidium rarum*	Rare Paspalidium	0	0	0	0	0	33	0	0	0	0	0	0	0
Poaceae	*Perotis rara*	Comet Grass	0	33	0	0	29	56	0	0	20	33	0	0	25
Poaceae	*Schizachyrium fragile*	Firegrass	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Setaria surgens*		0	33	0	0	29	44	0	33	0	33	100	20	0
Poaceae	*Sorghum leiocladum*	Wild Sorghum	0	0	0	0	0	0	0	33	0	0	0	0	0
Poaceae	*Sporobolus caroli*	Fairy Grass	0	0	25	100	29	0	0	0	0	0	0	0	25
Poaceae	*Sporobolus scabridus*		0	0	25	100	0	0	0	0	0	0	0	0	0
Poaceae	*Thellungia advena*	Coolibah Grass	0	0	0	0	0	0	33	0	0	0	0	0	0
Poaceae	*Themeda avenacea*	Native Oatgrass	0	0	25	0	0	0	0	0	0	0	0	0	0
Poaceae	*Themeda triandra*	Kangaroo Grass	0	0	0	0	0	0	67	67	0	33	0	20	0
Poaceae	*Thyridolepis xerophila*		0	0	0	0	0	0	0	0	40	0	0	20	0
Poaceae	*Tragus australianus*	Small Burrgrass	0	0	0	0	0	0	0	0	0	0	0	0	25
Poaceae	*Tripogon loliiformis*	Five-minute Grass	0	0	0	0	0	0	0	0	0	0	0	0	0
Poaceae	*Urochloa foliosa*	Leafy Panic	0	33	0	100	0	0	33	0	0	0	0	0	0
Poaceae	*Urochloa mosambicensis**	Sabi Grass	50	100	25	0	71	33	33	0	40	67	0	0	100
Poaceae	*Urochloa piligera*	Hairy Armgrass	0	0	25	0	14	78	0	0	20	0	0	60	25
Polygalaceae	*Polygala triflora*		0	0	0	0	14	0	0	0	0	0	0	0	0
Polygonaceae	*Persicaria attenuata*	White Smartweed	0	0	0	0	0	0	0	0	0	0	0	0	0
Pontederiaceae	*Monochoria cyanea*	Native Water Hyacinth	0	0	0	0	0	0	0	0	0	0	0	0	0
Proteaceae	*Grevillea decora*		0	0	0	0	0	0	0	0	0	0	0	0	0
Proteaceae	*Grevillea parallela*	Silver Oak; Beefwood	0	0	0	0	0	0	0	0	0	0	0	0	0
Proteaceae	*Grevillea pteridifolia*	Golden Parrot Tree; Fern-leaved Grevillea	0	0	0	0	0	0	0	0	0	0	0	0	0

Family	Scientific Name	Common Name	Percentage of secondary sites in each regional ecosystem containing the species												
			11.3.2	11.3.25	11.4.8	11.4.9	11.5.3	11.5.9	11.9.2	11.10.1	11.10.3	11.10.7	11.10.8	11.10.13	Non-remnant
Proteaceae	*Grevillea sessilis*		0	0	0	0	0	0	0	0	0	0	0	0	0
Proteaceae	*Grevillea striata*	Beefwood	0	0	0	0	0	11	0	0	0	0	0	0	0
Proteaceae	*Hakea lorea*	Corkwood; Bootlace Oak	0	0	0	0	0	0	0	33	0	0	0	0	0
Proteaceae	*Persoonia amaliae*		0	0	0	0	0	0	0	33	0	0	0	0	0
Proteaceae	*Persoonia falcata*	Wild Pear; Geebung	0	0	0	0	0	0	0	100	20	0	0	0	0
Pteridaceae	*Cheilanthes sieberi*	Poison Rock Fern	50	33	75	100	43	33	0	100	100	67	0	80	25
Pteridaceae	*Cheilanthes nudiuscula*		0	0	0	0	0	0	0	0	0	0	100	0	0
Putranjivaceae	*Drypetes deplanchei*	Yellow Tulip; Grey Boxwood	0	0	0	0	0	0	0	0	0	0	100	0	0
Rhamnaceae	*Alphitonia excelsa*	Red Ash; Soap Tree	50	0	0	0	71	67	0	67	100	100	100	100	25
Rhamnaceae	*Ventilago viminalis*	Vine Tree	0	0	25	100	29	11	33	0	0	0	0	20	0
Rubiaceae	*Coelospermum reticulatum*	Medicine Bush	0	0	0	0	0	0	0	67	0	0	0	0	0
Rubiaceae	*Cyclophyllum coprosmoides*	Coast Canthium; Sweet Susie	0	0	0	0	0	0	0	33	0	0	0	0	0
Rubiaceae	*Larsenaikia ochreata*	Native Gardenia	0	0	0	0	0	0	0	100	20	33	100	80	0
Rubiaceae	*Oldenlandia mitrasacmoides* subsp. *trachymenoides*		0	0	0	0	0	11	0	0	0	0	0	0	0
Rubiaceae	*Pavetta granitica*		0	0	0	0	0	0	0	0	0	33	100	0	0
Rubiaceae	*Pomax umbellata*	Pomax	0	0	0	0	0	0	0	33	0	0	0	0	0
Rubiaceae	*Psydrax odorata* subsp. *buxifolia*	Shiny-leaved Canthium	0	0	0	0	0	0	0	0	0	0	100	0	0
Rubiaceae	*Psydrax oleifolia*	Wild Lemon; Myrtle	0	0	0	0	0	11	33	0	0	0	0	0	25
Rubiaceae	*Richardia brasiliensis**	White Eye; Mexican Clover	0	33	0	0	0	33	0	0	0	0	100	0	0
Rubiaceae	*Spermacoce brachystema*	Stiff-leafed Spermacoce	0	0	0	0	14	44	0	0	20	0	0	40	0
Rutaceae	*Acronychia laevis*	Hard Aspen	0	0	0	0	0	0	0	0	0	0	100	0	0
Rutaceae	*Flindersia australis*	Crow's Ash	0	0	0	0	0	0	0	0	0	0	0	0	0

Family	Scientific Name	Common Name	Percentage of secondary sites in each regional ecosystem containing the species												
			11.3.2	11.3.25	11.4.8	11.4.9	11.5.3	11.5.9	11.9.2	11.10.1	11.10.3	11.10.7	11.10.8	11.10.13	Non-remnant
Rutaceae	*Flindersia dissosperma*	Scrub Leopardwood	0	0	25	0	0	11	0	0	0	0	0	0	0
Rutaceae	*Geijera parviflora*	Wilga	0	0	25	100	0	0	0	0	0	0	0	0	0
Rutaceae	*Geijera salicifolia*	Scrub Wilga; Green Satinheart	0	0	0	0	0	0	0	0	0	0	100	0	0
Santalaceae	*Exocarpos latifolius*	Broad-leaved Ballart; Scrub Cherry	0	0	0	0	0	0	0	0	0	0	100	0	0
Santalaceae	*Santalum lanceolatum*	Northern Sandalwood	0	0	0	0	0	0	0	0	0	0	0	0	0
Sapindaceae	*Alectryon connatus*	Grey Bird's-eye	0	0	0	0	0	0	0	0	0	0	100	0	0
Sapindaceae	*Alectryon diversifolius*	Scrub Boonaree	0	0	25	100	0	0	0	0	0	0	0	0	0
Sapindaceae	*Atalaya hemiglauca*	Whitewood	50	0	25	0	14	0	100	0	0	0	0	0	25
Sapindaceae	*Dodonaea lanceolata*	Hop Bush	0	0	0	0	0	0	0	33	0	0	0	0	0
Sapindaceae	*Dodonaea stenophylla*		0	0	0	0	0	0	0	0	0	0	0	0	0
Sapotaceae	*Planchonella pohlmanniana*	Yellow Boxwood	0	0	0	0	0	0	0	0	0	33	0	0	0
Sapotaceae	*Planchonella pubescens*		0	0	0	0	0	0	0	0	0	0	100	0	0
Scrophulariaceae	*Eremophila debilis*	Winter Apple	0	0	0	0	29	0	0	0	0	0	0	0	0
Scrophulariaceae	*Eremophila mitchellii*	False Sandalwood	50	0	75	0	14	0	0	0	0	0	0	0	0
Scrophulariaceae	*Myoporum montanum*	Western Boobialla	0	0	0	0	0	0	0	0	0	0	0	0	0
Solanaceae	*Datura leichhardtii**	Thornapple	0	33	0	0	0	0	33	0	0	0	0	0	0
Solanaceae	*Pimelea sericostachya*		0	33	0	0	0	0	0	0	0	0	0	0	0
Solanaceae	*Solanum ellipticum*	Potato Bush	0	33	25	0	14	0	0	67	0	0	100	20	0
Solanaceae	*Solanum esuriale*	Quena	0	0	25	0	0	0	0	0	0	0	0	0	0
Solanaceae	*Solanum parvifolium*		0	0	25	0	0	0	0	0	40	0	0	0	0
Sparrmanniaceae	*Corchorus trilocularis*	Wild Jute	0	0	0	0	0	0	0	0	0	0	0	0	0
Sparrmanniaceae	*Grewia latifolia*	Dysentery Plant; Dog's Balls	0	0	50	0	29	11	33	33	0	0	0	0	0

Family	Scientific Name	Common Name	Percentage of secondary sites in each regional ecosystem containing the species												
			11.3.2	11.3.25	11.4.8	11.4.9	11.5.3	11.5.9	11.9.2	11.10.1	11.10.3	11.10.7	11.10.8	11.10.13	Non-remnant
Sparrmanniaceae	*Grewia retusifolia*	Dysentery Bush; Emu Berry	100	33	25	0	57	11	0	0	0	33	0	0	50
Stylidiaceae	*Stylidium eglandulosum*	Woolly-stemmed Triggerplant	0	0	0	0	0	0	0	0	0	0	0	0	0
Typhaceae	*Typha* sp.	Bulrush	0	0	0	0	0	0	0	0	0	0	0	0	0
Ulmaceae	*Trema tomentosa*	Poison Peach	0	0	0	0	0	0	0	0	0	0	100	20	0
Verbenaceae	*Stachytarpheta jamaicensis**	Snake weed	0	33	0	0	0	0	0	0	0	0	0	0	0
Violaceae	*Pigea enneasperma*	Purple Spade Flower	100	33	0	0	57	11	67	0	0	33	0	0	0
Violaceae	*Pigea stellarioides*	Orange Spade Flower	0	33	0	0	29	56	0	100	40	100	0	80	0
Vitaceae	*Cissus oblonga*	Smooth Water Vine	0	0	0	0	0	0	0	0	0	0	100	0	0
Vitaceae	*Clematicissus opaca*	Pepper Vine	0	33	0	0	0	0	0	0	0	0	0	0	0
Vitaceae	*Tetrastigma nitens*	Native Grape; Three-leaf Water Vine	0	0	0	0	0	0	0	0	0	0	100	0	0
Xanthorrhoeaceae	*Xanthorrhoea johnsonii*	Johnson's Grass Tree	0	0	0	0	0	0	0	33	0	0	0	20	0
Zygophyllaceae	*Tribulopis angustifolia*		0	0	0	0	14	33	0	0	0	0	0	20	0
Zygophyllaceae	*Tribulus terrestris**	Goat's Head; Bullhead; Small Caltrop	0	0	0	100	14	0	33	0	0	0	0	0	0

Appendix C2 Fauna recorded during field surveys

Common Name	Scientific Name	Abundance per Broad Vegetation Group*										
		7a	10a	12a	16a/9e	17a	17b	18b	24a	25a	34d	NR†
MAMMALS												
Short-beaked Echidna	*Tachyglossus aculeatus*	++		+	+				++	+		+
Eastern Grey Kangaroo	*Macropus giganteus*				++		+	++	+		+	++
Common Wallaroo	*Macropus robustus*		++	++					+++			
Unadorned/Herbert's Rock-wallaby	*Petrogale inornata/herberti*	+++										
Swamp Wallaby	*Wallabia bicolor*		++	+	+				+++	+		
Rufous Bettong	*Aepyprymnus rufescens*			+		+		++				++
Narrow-nosed Planigale	*Planigale tenuirostris*						+			++		+
Common Planigale	*Planigale maculata*							+				+
Koala	*Phascolarctos cinereus*		+	+	+++	+			+			
Common Brush-tailed Possum	*Trichosurus vulpecula*	+		++	+++	+++	+	++				
Krefft's Glider	*Petaurus notatus*						+			+		
Squirrel Glider	*Petaurus norfolcensis*				++			+				
Central Greater Glider	*Petauroides armillatus*	+	++		+++	++					++	
House Mouse	*Mus musculus*		+	+				+	++			
Delicate Mouse	*Pseudomys delicatulus*		+					++				+
Eastern Pebble Mouse	*Pseudomys patrius*			++				++				
Lakeland Downs Mouse	*Leggadina lakedownensis*		++	++				+				
Water Rat	*Hydromys chrysogaster*											+
European Rabbit	*Oryctolagus cuniculus*		+		++	++	+++	+	+	++		+
Little Red Flying-fox	*Pteropus scapulatus*				++							++

Common Name	Scientific Name	Abundance per Broad Vegetation Group*									
		7a	10a	12a	16a/9e	17a	17b	18b	24a	25a	34d	NR†
Feral Pig	*Sus scrofa*				+							+
Feral Cat	*Felis catus*			+	+		+	+	+	+		++
Dingo	*Canis lupus dingo*			++	++			++				
Red Fox	*Vulpes vulpes*							+				
Bats												
Gould's Wattle Bat	*Chalinolobus gouldii*		+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
Chocolate Wattle Bat	*Chalinolobus morio*		++	++		+	+	++	+++			+++
Hoary Wattle Bat	*Chalinolobus nigrogriseus*				++	+				+		
Little Pied Bat	*Chalinolobus picatus*		+++	++	+	-	+	+++	+++	-	+++	+++
Long-eared Bat	*Nyctophilus* sp.			+++	+	++	+	+	+	++		+
Western Broad-nosed Bat	*Scotorepens balstoni*		-	+	++	+++	-	+++	+++	+++	-	+++
Little Broad-nosed bat	*Scotorepens greyii*		+++	+++	+++	+++	+	+++	+++	+++	+++	+++
Inland Forest Bat	*Vespadelus baverstocki*		+	+++	-	-	-	+	++	-		+++
Eastern Cave Bat	*Vespadelus troughtoni*		+	+++		+++	+	+++	+++			+
Eastern Bentwing Bat	*Miniopterus orianae oceanensis*		+++	++	++	+	+	+++	+++		-	
White-striped Freetail-bat	*Austronomus australis*			+								
Greater Northern Freetail-bat	*Chaerephon jobensis*		+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
Northern Freetail Bat	*Ozimops lumsdenae*		+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
Eastern Freetail Bat	*Ozimops ridei*		++	+++	+++	+++	+++	+++	+++	+++	-	+++
Bristle-faced Freetail Bat	*Setriostris eleryi*		-	-					-			++
Yellow-bellied Sheathtail-bat	*Saccolaimus flaviventris*		-	+++	+++	+++	+	+++	+++	+++	+++	+++
Troughton's Sheathtail-bat	*Taphozous troughtoni*		-	-	-		-	-	-	-		-

Common Name	Scientific Name	Abundance per Broad Vegetation Group*										
		7a	10a	12a	16a/9e	17a	17b	18b	24a	25a	34d	NR†
BIRDS												
Emu	*Dromaius novaehollandiae*			+					+		+	
Magpie Goose	*Anseranas semipalmata*											++
Plumed Whistling-duck	*Dendrocygna eytoni*				+							++
Australian Wood Duck	*Chenonetta jubata*											++
Pacific Black Duck	*Anas superciliosa*										++	++
Grey Teal	*Anas gracilis*										++	
Hardhead	*Aythya australis*											+
Brown Quail	*Synoicus ypsilophorus*			++							+	++
Stubble Quail	*Coturnix pectoralis*											+
Australasian Grebe	*Tachybaptus novaehollandiae*											+
Common Bronzewing	*Phaps chalcoptera*					++			+			
Crested Pigeon	*Ocyphaps lophotes*			+		++	+++	++				++
Squatter Pigeon	*Geophaps scripta*			++		++		+				++
Bar-shouldered Dove	*Geopelia humeralis*				+			++	+			
Diamond Dove	*Geopelia cuneata*			+				+				
Peaceful Dove	*Geopelia placida*			+++	+++	++		+++	+++	++		+++
Australian Bustard	*Ardeotis australis*							++				+
Pheasant Coucal	*Centropus phasianinus*		+	++	++	++	+	++		++		
Channel-billed Cuckoo	*Scythrops novaehollandiae*			+	++		++	++	+	+		+
Horsfield's Bronze-cuckoo	*Chrysococcyx basalis*					+						
Shining Bronze-cuckoo	*Chrysococcyx lucidus*		++						++			
Little Bronze-cuckoo	*Chrysococcyx minutillus*				+							+

Common Name	Scientific Name	Abundance per Broad Vegetation Group*									
		7a	10a	12a	16a/9e	17a	17b	18b	24a	25a	34d	NR†
Pallid Cuckoo	*Cacomantis pallidus*					+			+			++
Fan-tailed Cuckoo	*Cacomantis flabelliformis*								+			
Pacific Koel	*Eudynamys orientalis*				++	++	+					
Tawny Frogmouth	*Podargus strigoides*	+		+	++			++	+			
Australian Owlet-nightjar	*Aegotheles cristatus*		++	+				+				
White-throated Nightjar	*Eurostopodus mystacalis*	+		+						++		+
White-throated Needletail	*Hirundapus caudacutus*											++
Eurasian Coot	*Fulica atra*											+
Brolga	*Antigone rubicunda*											++
Bush Stone-curlew	*Burhinus grallarius*				+				+			
Pied Stilt	*Himantopus himantopus*									+		+
Masked Lapwing	*Vanellus miles*					++						++
Black-fronted Dotterel	*Elseyornis melanops*											++
Painted Buttonquail	*Turnix varius*		++	++				++				++
Little Black Cormorant	*Phalacrocorax sulcirostris*											++
Australasian Darter	*Anhinga novaehollandiae*											+
Australian Pelican	*Pelecanus conspicillatus*											+
Eastern Great Egret	*Ardea alba modesta*				+							+
Intermediate Egret	*Ardea intermedia*											+
White-necked Heron	*Ardea pacifica*											+
Cattle Egret	*Bubulcus ibis*											+
White-faced heron	*Egretta novaehollandiae*											++
Nankeen Night-heron	*Nycticorax caledonicus*											++

Common Name	Scientific Name	Abundance per Broad Vegetation Group*										
		7a	10a	12a	16a/9e	17a	17b	18b	24a	25a	34d	NR†
Straw-necked Ibis	*Threskiornis spinicollis*											++
Royal Spoonbill	*Platalea regia*											+
Black-shouldered Kite	*Elanus axillaris*									+		
Wedge-tailed Eagle	*Aquila audax*		++	++	+							++
Pacific Baza	*Aviceda subcristata*		+							+		
Brown Goshawk	*Accipiter fasciatus*			+				+				
Black Kite	*Milvus migrans*							++		+		++
Whistling Kite	*Haliastur sphenurus*			+++	+++	+++	+	+++	++	++	+	+++
Southern Boobook	*Ninox novaeseelandiae*	+	+	++	++	+++	+	++	+	++		++
Laughing Kookaburra	*Dacelo novaeguineae*		++	+++	+++	+++	+++	+++	+++	+++		+++
Blue-winged Kookaburra	*Dacelo leachii*				++	+	+	++		+++		
Red-backed Kingfisher	*Todiramphus pryrrhopygius*											+
Forest Kingfisher	*Todiramphus macleayii*				+	++			+	+++		
Sacred Kingfisher	*Todiramphus sanctus*		+							+++		
Rainbow Bee-eater	*Merops ornatus*		+	+++	++	++		++	+++	++		++
Dollarbird	*Eurystomus orientalis*				+++	+++				+++		
Nankeen Kestrel	*Falco cenchroides*				+	++						++
Peregrine Falcon	*Falco peregrinus*			+			+					
Brown Falcon	*Falco berigora*		+									
Sulphur-crested Cockatoo	*Cacatua galerita*	+++	+++	+++	+++	+++	++	+++	+++	+++	++	++
Glossy Black-cockatoo	*Calyptorhynchus lathami*									+		
Galah	*Eolophus roseicapilla*			++	++	++	+	++				++
Cockatiel	*Nymphicus hollandicus*						++					+

Common Name	Scientific Name	Abundance per Broad Vegetation Group*									
		7a	10a	12a	16a/9e	17a	17b	18b	24a	25a	34d	NR†
Red-winged Parrot	*Aprosmictus erythropterus*		++	+++	+++	+++	+++	+++	++	+++		+++
Pale-headed Rosella	*Platycercus adscitus*		++	+++	+++	+++	+++	+++	+++	++	++	++
Budgerigar	*Melopsittacus undulatus*		++	++				+				++
Little Lorikeet	*Glossopsitta pusilla*					+						
Rainbow Lorikeet	*Trichoglossus haematodus*	++	+++	+++	+++	+++	++	+++	+++	+++		++
Scaly-breasted Lorikeet	*Trichoglossus chlorolepidotus*			++								
Spotted Bowerbird	*Chlamydera maculata*			+	++	+++	++	+	+			
Red-backed Fairywren	*Malurus melanocephalus*		++	++	++	+++	+++	++	++	+++	+	+++
Purple-backed Fairywren	*Malurus assimilis*				+			++		++		
Noisy Miner	*Manorina melanocephala*		+++	++	+++	+++	++	++	++	+++	++	++
Yellow-throated Miner	*Manorina flavigula*			++		++	+++	++	++			++
Singing Honeyeater	*Gavicalis virescens*			+			+			+		
Scarlet Honeyeater	*Myzomela sanguinolenta*									+		
Brown Honeyeater	*Lichmera indistincta*	+		++	++			+++	+			++
Blue-faced Honeyeater	*Entomyzon cyanotis*		++	+++	+++	+++		+++	++		++	++
White-throated Honeyeater	*Melithreptus albogularis*	+	+++	+++	+++	++	+	+++	++	+	+	
Striped Honeyeater	*Plectorhyncha lanceolata*			++	+			++	+++			
Little Friarbird	*Philemon citreogularis*		+++	+++	+++	++	+++	++	+++	+++	+	++
Noisy Friarbird	*Philemon corniculatus*		+++	+++	+++	+++	++	+++	+++	+++	+	+++
Striated Pardalote	*Pardalotus striatus*		+++	+++	+++	+++	+++	+++	+++	+++	++	+++
Yellow Thornbill	*Acanthiza nana*		++						+++			
Buff-rumped Thornbill	*Acanthiza reguloides*		+++					++	+++	++		
Speckled Warbler	*Pyrrholaemus sagittatus*			+				+				

Common Name	Scientific Name	Abundance per Broad Vegetation Group*										
		7a	10a	12a	16a/9e	17a	17b	18b	24a	25a	34d	NR†
Weebill	*Smicrornis brevirostris*		+++	+++	+++	+++	+	+++	+++	+++	++	++
White-throated Gerygone	*Gerygone olivacea*	+		+++	++	++		+++	+++	+++		+
Grey-crowned Babbler	*Pomatostomus temporalis*		+++	+++	++	++		+++	+++	+++		
Golden-headed Cisticola	*Cisticola exilis*											+
Silvereye	*Zosterops lateralis*	++								++		
Masked Woodswallow	*Artamus personatus*											++
White-browed Woodswallow	*Artamus superciliosus*				++				++			++
Black-faced Woodswallow	*Artamus cinereus*							+				
White-breasted Woodswallow	*Artamus leucorynchus*				++							
Grey Butcherbird	*Cracticus torquatus*		+++	++	+++	++		++	+++	+	+	
Pied Butcherbird	*Cracticus nigrogularis*		++	+++	+++	+++	+++	+++	+++	+++	+	+++
Australian Magpie	*Gymnorhina tibicen*		+++	+++	+++	+++	+++	+++	+++	+++		+++
Pied Currawong	*Strepera graculina*	+++	+++	+++	++	++		+++	+++	+		+
Black-faced Cuckooshrike	*Coracina novaehollandiae*		+++	+++	++	++	+++	+++	+++	+++		+++
White-bellied Cuckooshrike	*Coracina papuensis*			++	+	+	++					
White-winged Triller	*Lalage tricolor*					+		++				
Common Cicadabird	*Edolisoma tenuirostre*								+			
Varied Sitella	*Daphoenositta chrysoptera*		+++		++				++			
Grey Shrikethrush	*Colluricincla harmonica*		+++		++			++	+++			+
Golden Whistler	*Pachycephala pectoralis*	+										
Rufous Whistler	*Pachycephala rufiventris*		++	+++	++	+++	+	+++	+++	+++	+	++
Olive-backed Oriole	*Oriolus sagittatus*		+++	++	++	+	+	+++	++			
Australasian Figbird	*Sphecotheres vieilloti*			++	++	++						

Common Name	Scientific Name	Abundance per Broad Vegetation Group*										
		7a	10a	12a	16a/9e	17a	17b	18b	24a	25a	34d	NR†
Spangled Drongo	*Dicrurus bracteatus*				+					++		
Grey Fantail	*Rhipidura albiscapa*	+	++	++	++			+++	+++			++
Rufous Fantail	*Rhipidura rufifrons*	+						+				
Willie Wagtail	*Rhipidura leucophrys*		+	+	++	+	+	++	+	++	+	++
Magpie-lark	*Grallina cyanoleuca*			+		+++		++				+++
Leaden Flycatcher	*Myiagra rubecula*	+	+++	+	++		++	++	++	++		
Australian Raven	*Corvus coronoides*			++	+	+						
Torresian Crow	*Corvus orru*		+++	+++	+++	+++	+++	+++	+++	+++		+++
White-winged Chough	*Corcorax melanorhamphos*			++	++	+			+			
Apostlebird	*Struthidea cinerea*	+	++	+++	++	+++		++	++		++	++
Jacky Winter	*Microeca fascinans*			+								
Eastern Yellow Robin	*Eopsaltria australis*								+			
Australasian Reed Warbler	*Acrocephalus australis*											+
Brown Songlark	*Megalurus cruralis*											+
Rufous Songlark	*Megalurus mathewsi*						+++		+	+		++
Common Myna	*Acridotheres tristis*											++
Mistletoebird	*Dicaeum hirundinaceum*	+	+	+	+			+	+++		+	
Australasian Pipit	*Anthus novaeseelandiae*											++
Chestnut-breasted Mannikin	*Lonchura castaneothorax*			++								++
Plum-headed Finch	*Neochmia modesta*			++								
Double-barred Finch	*Taeniopygia bichenovii*	+	++	+++	+			+++	++		+	
REPTILES												
Robust Blind Snake	*Anilios ligatus*				+							

Common Name	Scientific Name	Abundance per Broad Vegetation Group*									
		7a	10a	12a	16a/9e	17a	17b	18b	24a	25a	34d	NR†
Small-headed Blind Snake	*Anilios affinis*					+		+	+			
Spotted Python	*Antaresia maculosa*			+								
Black-headed Python	*Aspidites melanocephalus*									+		
Brown Tree Snake	*Boiga irregularis*				+							
Green Tree Snake	*Dendrelaphis punctulatus*											+
Eastern Brown Snake	*Pseudonaja textilis*											+
Coral Snake	*Brachyurophis australis*			+								
Yellow-faced Whipsnake	*Demansia psammophis*						+			+		
Curl Snake	*Suta suta*			+								
Burton's Legless Lizard	*Lialis burtonis*		+		+				+			
Eastern Striped Skink	*Ctenotus robustus/spaldingi*		+++	++		+	+	+	++			++
Eastern Barred Wedgesnout Ctenotus	*Ctenotus strauchii*							++		++		
Eastern Mulch-slider	*Lerista fragilis*		+++	++		+		+	+++	+		+
Common Dwarf Skink	*Menetia greyii*			++								
Dwarf Litter-skink	*Pygmaeascincus timlowi*			+	++	++						++
Iridescent Litter-skink	*Lygisaurus foliorum*		+++		++				+++			
Shaded-litter Rainbow-skink	*Carlia munda*			++	++	++		++		+		++
Open-litter Rainbow-skink	*Carlia pectoralis*	+++		++	+++	+++		++	+++			
Robust Rainbow-skink	*Carlia schmeltzii*			+	+		+		+			
Tussock Rainbow-skink	*Carlia vivax*				++					++		
Elegant Snake-eyed Skink	*Cryptoblepharus pulcher*		++	++	++	+	+	++				
Fire-tailed Skink	*Morethia taeniopleura*		+++	+++	++	++	+	+	+++			+
Bearded Dragon	*Pogona barbata*			+				+				

Common Name	Scientific Name	Abundance per Broad Vegetation Group*										
		7a	10a	12a	16a/9e	17a	17b	18b	24a	25a	34d	NR†
Tommy Roundhead	*Diporiphora australis*		++	+++				++	++			
Black-headed Monitor	*Varanus tristis*					+		++				+
Dubious Dtella	*Gehyra dubia*	+		+++	++		+++	++	+++	++		+
Chain-backed Dtella	*Gehyra catenata*				++		+		++	+++		
Bynoe's Gecko	*Heteronotia binoei*	+++	+++	+++	+++	+++	++	+++	+++	+++		+++
Spiny Knob-tail Gecko	*Nephrurus asper*								+			
Box-patterned Gecko	*Lucasium steindachneri*		++	+++		++	++	+++		++		
Eastern Fat-tailed Gecko	*Diplodactylus platyurus*			++		+++			+			
Wood Gecko	*Diplodactylus vittatus*		+						+++			
Ocellated Velvet Gecko	*Oedura monilis*							+	+	+++		
Ornate Velvet Gecko	*Oedura picta*			++								
Eastern Spiny-tailed Gecko	*Strophurus williamsi*			++			+			+		+
AMPHIBIANS												
Cane Toad	*Rhinella marina*	+		+++	+++	+++	++	+++	+++	++	+++	+++
Spotted Grass Frog	*Limnodynastes tasmaniensis*			+		++	++	+		+		++
Scarlet sided Pobblebonk	*Limnodynastes terraereginae*				++	++					++	
Green Tree-Frog	*Litoria caerulea*			+					++	+	++	
Desert Tree-Frog	*Litoria rubella*							+		++	+++	++
Roth's Tree Frog	*Litoria rothii*										++	
Bumpy Rocket Frog	*Litoria inerma*					++					++	+++
Broad-palmed Frog	*Litoria latopalmata*											+
Ornate Burrowing Frog	*Platyplectrum ornatum*		+	++	+++	+++	++	+++	++	+++	+++	+++
Short-footed Frog	*Cyclorana brevipes*					++	+	++	+	+		

Common Name	Scientific Name	Abundance per Broad Vegetation Group*										
		7a	10a	12a	16a/9e	17a	17b	18b	24a	25a	34d	NR†
New Holland Frog	*Cyclorana novaehollandiae*					++					+++	++
Green-stripe Frog	*Cyclorana albogutata*										+	++
Wrinkled Toadlet	*Uperoleia rugosa*							+				+
Major Toadlet	*Pseudophryne major*										++	

*Abundance: + = only one individual recorded; ++ = more than one individual but present in fewer than half the sites surveyed; +++ = present in the majority of sites surveyed.
†NR = non-remnant pasture.

APPENDIX D

ANABAT RESULTS

Microbat Call Interpretation Report

Prepared for ("Client"):	METSERVE
Survey location/project name:	Saraji West
Survey dates:	25 October – 3 November 2018
Client project reference:	
Job no.:	MET-1802
Report date:	14 December 2018

DISCLAIMER:

© Copyright – Balance! Environmental, ABN 75 795 804 356. This document and its content are copyright and may not be copied, reproduced or distributed (in whole or part) without the prior written permission of Balance! Environmental other than by the Client for the purposes authorised by Balance! Environmental ("Intended Purpose"). To the extent that the Intended Purpose requires the disclosure of this document and/or its content to a third party, the Client must procure such agreements, acknowledgements and undertakings as may be necessary to ensure that the third party does not copy, reproduce, or distribute this document and its content other than for the Intended Purpose. This disclaimer does not limit any rights Balance! Environmental may have under the Copyright Act 1968 (Cth).

The Client acknowledges that the Final Report is intended for the sole use of the Client, and only to be used for the Intended Purpose. Any representation or recommendation contained in the Final Report is made only to the Client. Balance! Environmental will not be liable for any loss or damage whatsoever arising from the use and/or reliance on the Final Report by any third party.

Methods

Data received & post-processing

Balance! Environmental received 14 ZCA data files and associated log files, recorded using two Anabat Express detectors (Titley Scientific, Brisbane) over seven consecutive nights (25th October – 2nd November 2018).

The ZCA files were processed with *AnalookW* (Corben 2018) to extract individual Anabat ZC call-sequence files for analysis. This process yielded some 33,000 ZC files; however, when a generic noise filter was applied in *AnalookW*, fewer than 3000 ZC files were found to contain identifiable bat-calls. Most of the noise files were generated from Anabat B (Meserve).

Call analysis and identification

All ZC files that passed the noise filter were analysed in *AnalookW*, with species identification achieved manually by comparing call spectrograms and derived metrics with those of reference calls from central and northern Queensland and/or with published call descriptions (e.g. Reinhold et al. 2001). Consideration was also given to the probability of species' occurrence based on published distribution information (e.g. Churchill 2008; van Dyck *et al.* 2013) and on-line database records (e.g. http://www.ala.org.au).

Reporting standard

The format and content of this report follows Australasian Bat Society standards for the interpretation and reporting of bat call data (Reardon 2003), available on-line at http://www.ausbats.org.au/.

Species nomenclature follows Jackson & Groves (2015), which elevates the sub-genus names proposed by Reardon *et al.* (2014) for the *Mormopterus* free-tailed bats to genus level; hence *Ozimops lumsdenae* (syn. *M.* beccarii) and *O. ridei* (syn. *M. ridei* and *M.* 'species 2') are used herein.

Results & Discussion

A total of 2469 individual bat calls were identified in this data set, with 82% (2031) of those recorded by Anabat B (Metserve) and the remainder (438 calls) recorded by Anabat ECO1019.

Reliable identification was achieved on 2191 calls (89% of total), which were attributed to seven unique species and two species pairs, the members of which cannot be differentiated based on call characteristics. The positively-identified species included the following:

- *Chalinolobus gouldii;*
- *Nyctophilus geoffroyi / N. gouldi;*
- *Scotorepens balstoni;*
- *Scotorepens greyii / S. sanborni;*
- *Vespadelus troughtoni;*
- *Chaerephon jobensis;*
- *Ozimops lumsdenae;*
- *Ozimops ridei;* and
- *Saccolaimus flaviventris.*

Eighteen percent (278) of the calls could not be reliably identified due to similarities in call characteristics shared by several species that are likely to occur in the study area. These unresolved calls were allocated to one of the following species groups:

- *Chalinolobus gouldii / Ozimops ridei;*
- *C. gouldii / Scotorepens balstoni;*
- *Scotorepens greyii / Chalinolobus nigrogriseus;*
- *Saccolaimus flaviventris / Chaerephon jobensis;* and
- *S. flaviventris / Ozimops lumsdenae.*

Of these unresolved groups, only one potentially represents an additional species (*i.e. Chalinolobus nigrogriseus*), with the others all containing species that were otherwise positively identified form more typical calls.

Table 1 provides a summary of species' presence on each detector-night throughout the survey. Where unresolved calls were identified, all members of the relevant group are listed as "possible" unless positive identification was achieved on other calls.

Sample spectrograms of each recorded call type are shown at Appendix 1.

References

Churchill, S. (2008). *Australian Bats*. Jacana Books, Allen & Unwin; Sydney.

Corben, C. (2018). AnalookW for bat call analysis using ZCA. Version 4.3x, 19 July 2018.

Jackson, S. and Groves, C. (2015). *Taxonomy of Australian Mammals*. CSIRO Publishing, Melbourne.

Reardon, T. (2003). Standards in bat detector based surveys. *Australasian Bat Society Newsletter* **20**, 41-43.

Reardon, T. B., McKenzie, N. L., Cooper, S. J. B., Appleton, B., Carthew, S. and Adams, M. (2014). A molecular and morphological investigation of species boundaries and phylogenetic relationships in Australian free-tailed bats *Mormopterus* (Chiroptera : Molossidae). *Australian Journal of Zoology* **62**, 109–136.

Reinhold, L., Law, B., Ford, G. and Pennay, M. (2001). *Key to the bat calls of south-east Queensland and north-east New South Wales*. Department of Natural Resources and Mines, Brisbane.

van Dyck, S., Gynther, I. and Baker, A. (ed.) (2013). *Field Companion to the Mammals of Australia*. New Holland; Sydney.

Table 1. Microbat species recorded during the Saraji West survey, 25 October – 2 November 2018.

♦ = 'definite' - at least one call was attributed unequivocally to the species

□ = 'possible' - calls similar to those of the species were recorded, but were not reliably identified

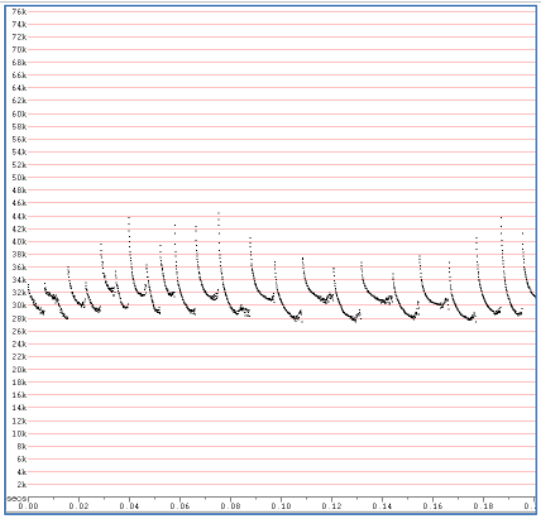
Detector:	Anabat B Metserve							Anabat ECO1019				
Date:	25-Oct	26-Oct	27-Oct	28-Oct	29-Oct	30-Oct	1-Nov	26-Oct	27-Oct	28-Oct	29-Oct	30-Oct
Chalinolobus gouldii	♦	♦	♦	♦	♦	♦	♦	♦		♦	♦	♦
Chalinolobus nigrogriseus	□	□	□			□	□			□		
Nyctophilus species						♦						
Scotorepens balstoni	♦	♦	♦	□	□	♦	♦					♦
Scotorepens greyii / S. sanborni		♦	♦	♦	♦	♦	♦				♦	♦
Vespadelus troughtoni							♦					♦
Chaerephon jobensis	□	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	
Ozimops lumsdenae		♦	♦	♦	♦	♦	♦	♦		♦	♦	♦
Ozimops ridei	□	♦	♦	□	□	♦	♦	♦		♦	□	□
Saccolaimus flaviventris	♦	♦	♦		♦	♦	♦		♦	♦	♦	♦

Glossary

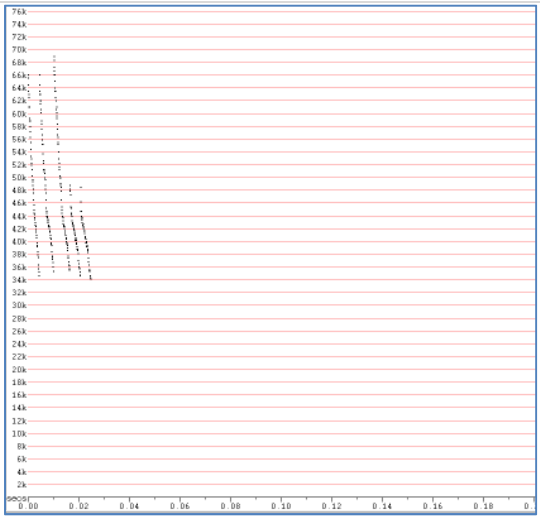
Technical terms used in this report are described in the following table.

Approach phase	The part of a bat *call* emitted as the bat starts to home in on a detected prey item; a transitional series of *pulses* between the *search phase* and *feeding buzz*, that become progressively steeper and shorter in duration.
Call	Refers to a single bat call, made up of a series of individual sound *pulses* in one or more *phases* (*search, approach, feeding buzz*).
CF (=Constant Frequency)	A type of *pulse* in which the dominant component consists of a more-or-less 'pure tone' of sound at a Constant Frequency; with *shape* appearing flat on the sonogram. Often also contains a brief *FM* component at the beginning and/or end of the CF component (*viz.* FM-CF-FM).
Characteristic frequency (Fc)	The frequency of the flattest part of a *pulse*; usually the lowest frequency reached in the *qCF* component of a pulse. This is often the primary diagnostic feature for species identification.
Duration	The time period from the beginning of a *pulse* to the end of the pulse.
Feeding buzz	The terminal part of a *call*, following the *approach phase*, emitted as the bat catches a prey item; a distinctive, rapid series of very steep, very short-duration pulses.
FM (=Frequency Modulated)	A type of *pulse* in which there is substantial change in frequency from beginning to end; *shape* ranges from almost vertical and linear through varying degrees of curvature.
FC range	Refers to the range of frequencies occupied by the *characteristic frequency* section of *pulses* within a call or set of calls.
Frequency sweep or "band-width"	The range of frequencies through which a *pulse* sweeps from beginning to end; Maximum frequency (Fmax) – minimum frequency (Fmin).
Knee	The transitional part of a *pulse* between the initial (usually steeper) frequency sweep and the *characteristic frequency* section (usually flatter); time to knee (Tk) and frequency of knee (Fk) can be diagnostic for some species.
Pulse	An individual pulse of sound within a bat *call*; the *shape*, *duration* and *characteristic frequency* of a pulse are the key diagnostic features used to differentiate species.
Pulse body	The part of the *pulse* between the *knee* and *tail* and containing the *characteristic frequency* section.
Pulse shape	The general appearance of a *pulse* on the sonogram, described using relative terms related to features such as slope and degree of curvature. See also *CF, qCF* and *FM*.
qCF (=quasi Constant Frequency)	A type of *pulse* in which there is very little change in frequency from beginning to end; *shape* appears to be almost flat. Some pulses also contain an *FM* component at the beginning and/or end of the qCF component (*viz.* FM-qCF).
Search phase	The part of a bat *call* generally required for reliable species diagnosis. A consistent series of *pulses* emitted by a bat that is searching for prey or and/or navigating through its habitat. Search phase pulses generally have longer duration, flatter slope and more consistent shape than *approach phase* and *feeding buzz* pulses.
Sequence	Literally, a sequence of *pulses* that may be from one or more bats; but generally refers to a *call* or part (e.g. *phase*) of a call.
Tail	The final component of a *pulse*, following the *characteristic frequency* section; may consist of a short or long sweep of frequencies either upward or downward from the Fc; or may be absent.

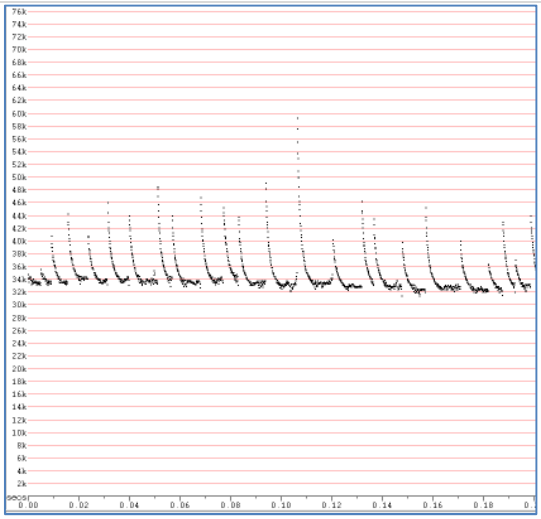
Appendix 1 Representative call sequences from the Saraji West survey, October 2018.
AnalookW spectrograms with time between pulses removed pulses



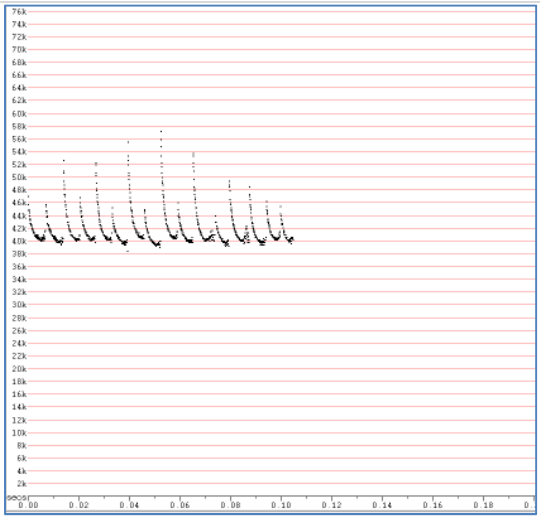
Chalinolobus gouldii



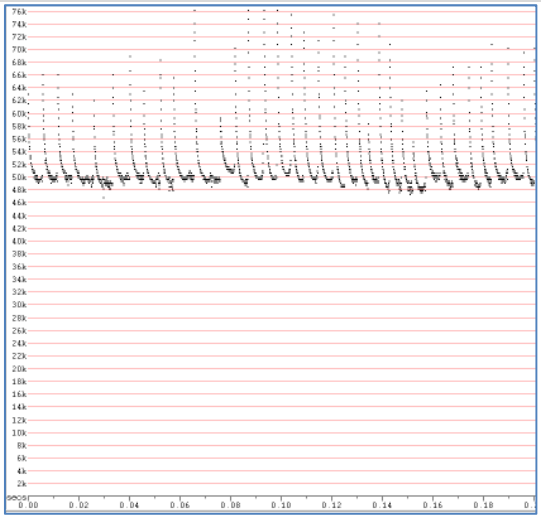
Nyctophilus species



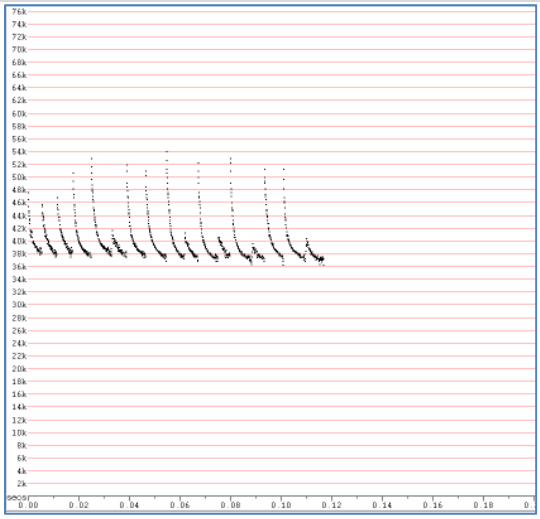
Scotorepens balstoni



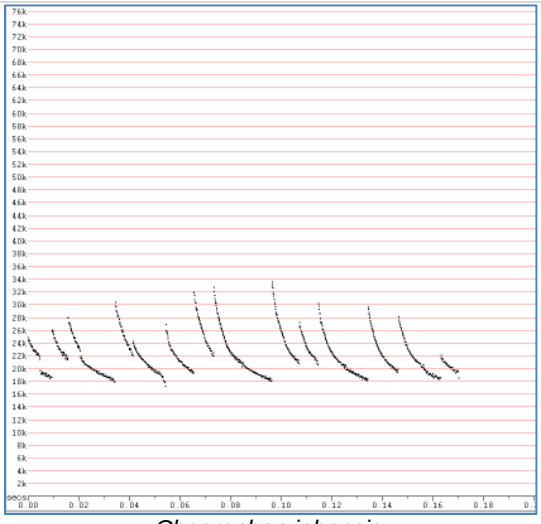
Scotorepens greyii / S. sanborni



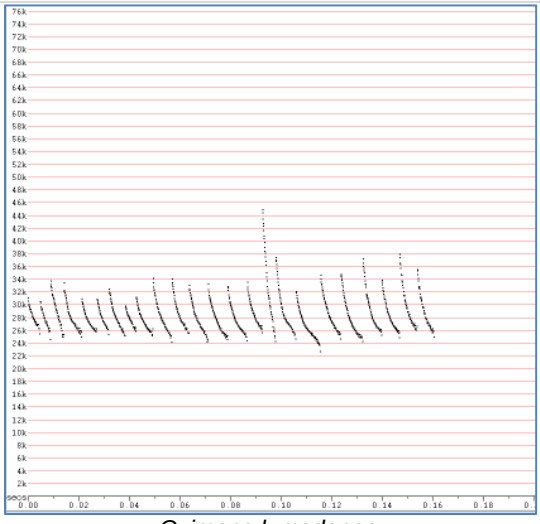
Vespadelus troughtoni



Scotorepens spp. or *Chalinolobus nigrogriseus*



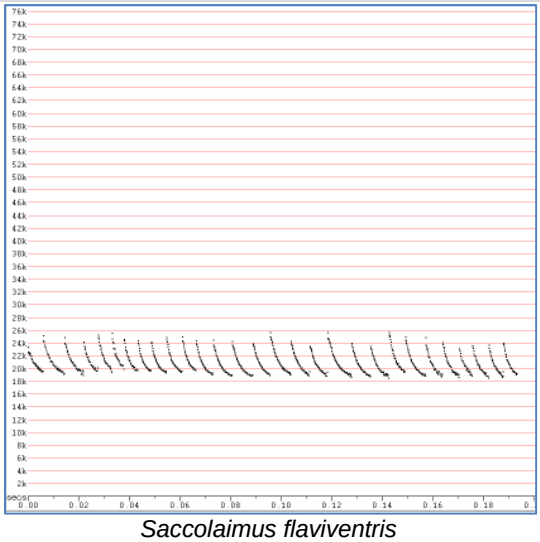
Chaerephon jobensis



Ozimops lumsdenae



Ozimops ridei



Saccolaimus flaviventris

Microbat Call Interpretation Report

Prepared for ("Client"):	METSERVE
Survey location/project name:	Saraji West
Survey dates:	26 March – 7 May 2019
Client project reference:	
Job no.:	MET-1901
Report date:	19 August 2019

DISCLAIMER:

© Copyright – Balance! Environmental, ABN 75 795 804 356. This document and its content are copyright and may not be copied, reproduced or distributed (in whole or part) without the prior written permission of Balance! Environmental other than by the Client for the purposes authorised by Balance! Environmental ("Intended Purpose"). To the extent that the Intended Purpose requires the disclosure of this document and/or its content to a third party, the Client must procure such agreements, acknowledgements and undertakings as may be necessary to ensure that the third party does not copy, reproduce, or distribute this document and its content other than for the Intended Purpose. This disclaimer does not limit any rights Balance! Environmental may have under the Copyright Act 1968 (Cth).

The Client acknowledges that the Final Report is intended for the sole use of the Client, and only to be used for the Intended Purpose. Any representation or recommendation contained in the Final Report is made only to the Client. Balance! Environmental will not be liable for any loss or damage whatsoever arising from the use and/or reliance on the Final Report by any third party.

Methods

Data received & post-processing

Balance! Environmental received 30 ZCA data files and associated log files, recorded using two Anabat Express detectors (Titley Scientific, Brisbane) over three survey periods: 26-28 March; 8-15 April; and 30 April – 7 May 2019.

Deployment locations for the two detectors were extracted from the included LOG files. These are plotted on the map at **Figure 1**, with the GPS data extract for each detector listed in **Appendix 1**.

The ZCA files were processed with *Anabat Insight* (version 1.8.9; Titley Scientific) to extract individual Anabat ZC call-sequence files for analysis. This process yielded 37,660 ZC files; however, 33,931 of those files were discarded by the application of a noise filter to remove those files containing only non-bat sounds (e.g. from insects, wind, etc.).

Call analysis and identification

All ZC files that passed the noise filter were analysed in *Anabat Insight*. First-pass call identification was achieved using a Decision Tree analysis to group and label similar calls based primarily on frequency characteristics. Species identities within each group were then verified and/or altered manually by reviewing call spectrograms and derived metrics and comparing them with those of reference calls from central and northern Queensland and/or with published call descriptions (e.g. Reinhold et al. 2001). Consideration was also given to the probability of species' occurrence based on published distribution information (e.g. Churchill 2008; van Dyck *et al.* 2013) and on-line database records (e.g. http://www.ala.org.au).

Reporting standard

The format and content of this report follows Australasian Bat Society standards for the interpretation and reporting of bat call data (Reardon 2003), available on-line at http://www.ausbats.org.au/.

Species nomenclature follows Jackson & Groves (2015).



Figure 1 Bat detector deployment locations – Saraji West surveys, March, April and May 2019.

Results & Discussion

Detector A recorded no bat-call data on the nights of 28th March and 10th April; and Detector B failed to record any bat calls on the nights of 27th March and 10th April. A total of 3737 individual bat calls were identified across the remaining detector-nights.

Reliable identification was achieved on 1636 calls (44% of total detected calls), which were attributed to the following 11 unique species and two indistinguishable species pairs:

- *Chalinolobus gouldii;*
- *Chalinolobus morio;*
- *Chalinolobus picatus;*
- *Nyctophilus geoffroyi / N. gouldi;*
- *Scotorepens balstoni;*
- *Scotorepens greyii / S. sanborni;*
- *Vespadelus troughtoni;*
- *Miniopterus orianae oceanensis;*
- *Austronomus australis;*
- *Chaerephon jobensis;*
- *Ozimops lumsdenae;*
- *Ozimops ridei;* and
- *Saccolaimus flaviventris.*

Fifty-six percent (2101) of the calls could not be reliably identified due to similarities in call characteristics shared by several species that are likely to occur in the study area. These unresolved calls were allocated to one of several multi-species groups, including:

- *C. gouldii / O. ridei;*
- *C. gouldii / S. balstoni;*
- *C. morio / V. troughtoni;*
- *C. picatus / M. o. oceanensis;*
- *C. picatus / S. greyii / S. sanborni;*
- *C. picatus / Vespadelus baverstocki;*
- *S. flaviventris / C. jobensis;*
- *S. flaviventris / O. lumsdenae;* and
- *O. lumsdenae / Taphozous troughtoni.*

Two of these unresolved groups represent potential additional species (*i.e. C. picatus* / ***V. baverstocki*** and *O. lumsdenae* / ***T. troughtoni***); however, it is considered unlikely that *V. baverstocki* would occur in the study area. The latter species, *T. troughtoni*, may be present if suitable subterranean roost sites exist in the broader study area.

Table 1 provides a summary of species' presence on each detector-night throughout the survey. Where unresolved calls were identified, all members of the relevant group are listed as "possible" unless positive identification was achieved on other calls.

Sample spectrograms of each recorded call type are shown at **Appendix 2**.

References

Churchill, S. (2008). *Australian Bats*. Jacana Books, Allen & Unwin; Sydney.

Corben, C. (2018). AnalookW for bat call analysis using ZCA. Version 4.3x, 19 July 2018.

Jackson, S. and Groves, C. (2015). *Taxonomy of Australian Mammals*. CSIRO Publishing, Melbourne.

Reardon, T. (2003). Standards in bat detector based surveys. *Australasian Bat Society Newsletter* **20**, 41-43.

Reardon, T. B., McKenzie, N. L., Cooper, S. J. B., Appleton, B., Carthew, S. and Adams, M. (2014). A molecular and morphological investigation of species boundaries and phylogenetic relationships in Australian free-tailed bats *Mormopterus* (Chiroptera : Molossidae). *Australian Journal of Zoology* **62**, 109–136.

Reinhold, L., Law, B., Ford, G. and Pennay, M. (2001). *Key to the bat calls of south-east Queensland and north-east New South Wales*. Department of Natural Resources and Mines, Brisbane.

van Dyck, S., Gynther, I. and Baker, A. (ed.) (2013). *Field Companion to the Mammals of Australia*. New Holland; Sydney.

Table 1-A. Microbat species recorded during the Saraji West survey, March-May 2019 – **Detector A**.

♦ = 'definite' - at least one call was attributed unequivocally to the species

□ = 'possible' - calls similar to those of the species were recorded, but were not reliably identified

Detector - serial number:	**A - SN318011**														
Detector-night:	26/3	27/3	28/3	08/4	09/4	10/4	11/4	12/4	13/4	15/4	30/4	01/5	03/5	06/5	07/5
Chalinolobus gouldii	♦	♦		♦	♦		♦		♦	♦	♦	♦	□	♦	□
Chalinolobus morio	♦				□					□	□	♦			
Chalinolobus picatus	□				□		♦		□	□	♦	♦	♦		♦
Nyctophilus sp.	♦				♦				♦				♦		
Scotorepens balstoni	♦			♦	□		□				□	♦			♦
Scotorepens greyii	♦				♦		♦		♦	♦	□	♦	♦		□
Vespadelus baverstocki	□				□				□	□	□		□		
Vespadelus troughtoni	♦				♦				♦	□	□	♦		♦	♦
Miniopterus orianae oceanensis	♦						□			♦		♦	♦		♦
Austronomus australis								♦							
Chaerephon jobensis	♦	♦		♦	♦		♦	♦	♦	♦	♦	♦	♦	♦	♦
Ozimops lumsdenae	♦	□		♦	♦		♦	♦	♦	♦	♦	♦		♦	
Ozimops ridei	♦	□		□	□		□		□	♦	♦	□	□	♦	□
Saccolaimus flaviventris	♦	□		♦	♦		♦	□	□		□	□	□	♦	
Taphozous troughtoni												□	□		

Table 1-B. Microbat species recorded during the Saraji West survey, March-May 2019 – **Detector B**.

♦ = 'definite' - at least one call was attributed unequivocally to the species

□ = 'possible' - calls similar to those of the species were recorded, but were not reliably identified

Detector - serial number:	**B - SN324680**														
Detector-night:	26/3	27/3	28/3	08/4	09/4	10/4	11/4	12/4	13/4	15/4	30/4	01/5	03/5	06/5	07/5
Chalinolobus gouldii	♦		♦	♦	♦		♦	♦	♦	♦	□	♦	♦	♦	♦
Chalinolobus morio								□	□	♦	□	♦	♦	□	
Chalinolobus picatus	□			□			□	□	□	□	□	♦	♦	♦	□
Nyctophilus sp.			♦	♦					♦			♦		♦	
Scotorepens balstoni	□		□	□	□							♦	□		
Scotorepens greyii	□			♦			□	♦	♦	♦	□	♦	♦	♦	□
Vespadelus baverstocki				□				□	□			□	□		
Vespadelus troughtoni								♦	♦	♦	□		♦	♦	
Miniopterus orianae oceanensis			♦					♦	♦	♦	♦	♦	♦	♦	♦
Austronomus australis															
Chaerephon jobensis	♦		♦	♦	♦		♦	♦	♦	♦	♦	♦	♦	♦	♦
Ozimops lumsdenae	♦		♦	♦	♦		♦		♦	♦	♦	♦	♦		♦
Ozimops ridei	♦		♦	♦	♦		♦	♦	♦	♦	♦	♦	♦	□	□
Saccolaimus flaviventris			♦	♦			♦	♦	♦	♦	□	♦	♦	□	□
Taphozous troughtoni				□						□			□		□

Glossary

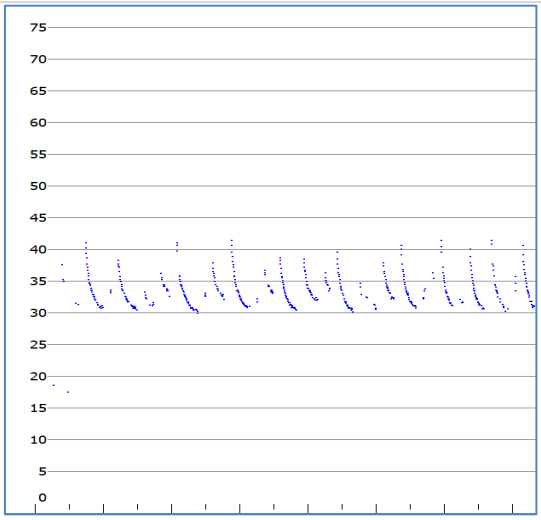
Technical terms used in this report are described in the following table.

Approach phase	The part of a bat *call* emitted as the bat starts to home in on a detected prey item; a transitional series of *pulses* between the *search phase* and *feeding buzz*, that become progressively steeper and shorter in duration.
Call	Refers to a single bat call, made up of a series of individual sound *pulses* in one or more *phases* (*search, approach, feeding buzz*).
CF (=Constant Frequency)	A type of *pulse* in which the dominant component consists of a more-or-less 'pure tone' of sound at a Constant Frequency; with *shape* appearing flat on the sonogram. Often also contains a brief *FM* component at the beginning and/or end of the CF component (*viz.* FM-CF-FM).
Characteristic frequency (Fc)	The frequency of the flattest part of a *pulse*; usually the lowest frequency reached in the *qCF* component of a pulse. This is often the primary diagnostic feature for species identification.
Duration	The time period from the beginning of a *pulse* to the end of the pulse.
Feeding buzz	The terminal part of a *call*, following the *approach phase*, emitted as the bat catches a prey item; a distinctive, rapid series of very steep, very short-duration pulses.
FM (=Frequency Modulated)	A type of *pulse* in which there is substantial change in frequency from beginning to end; *shape* ranges from almost vertical and linear through varying degrees of curvature.
FC range	Refers to the range of frequencies occupied by the *characteristic frequency* section of *pulses* within a call or set of calls.
Frequency sweep or "band-width"	The range of frequencies through which a *pulse* sweeps from beginning to end; Maximum frequency (Fmax) – minimum frequency (Fmin).
Knee	The transitional part of a *pulse* between the initial (usually steeper) frequency sweep and the *characteristic frequency* section (usually flatter); time to knee (Tk) and frequency of knee (Fk) can be diagnostic for some species.
Pulse	An individual pulse of sound within a bat *call*; the *shape*, *duration* and *characteristic frequency* of a pulse are the key diagnostic features used to differentiate species.
Pulse body	The part of the *pulse* between the *knee* and *tail* and containing the *characteristic frequency* section.
Pulse shape	The general appearance of a *pulse* on the sonogram, described using relative terms related to features such as slope and degree of curvature. See also *CF, qCF* and *FM*.
qCF (=quasi Constant Frequency)	A type of *pulse* in which there is very little change in frequency from beginning to end; *shape* appears to be almost flat. Some pulses also contain an *FM* component at the beginning and/or end of the qCF component (*viz.* FM-qCF).
Search phase	The part of a bat *call* generally required for reliable species diagnosis. A consistent series of *pulses* emitted by a bat that is searching for prey or and/or navigating through its habitat. Search phase pulses generally have longer duration, flatter slope and more consistent shape than *approach phase* and *feeding buzz* pulses.
Sequence	Literally, a sequence of *pulses* that may be from one or more bats; but generally refers to a *call* or part (e.g. *phase*) of a call.
Tail	The final component of a *pulse*, following the *characteristic frequency* section; may consist of a short or long sweep of frequencies either upward or downward from the Fc; or may be absent.

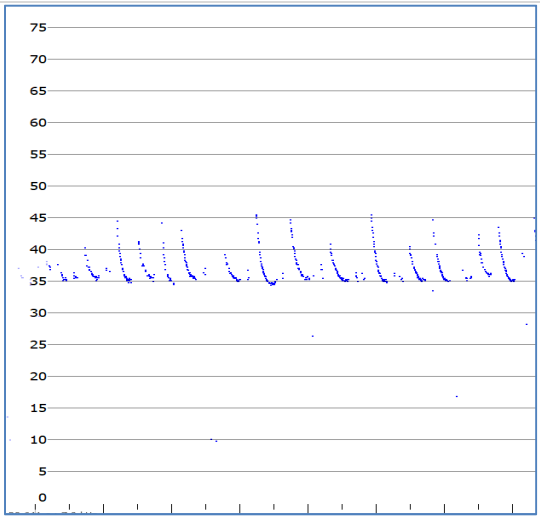
Appendix 1 GPS coordinates derived from detector LOG files.

Detector name	Serial Number	Date	Latitude	Longitude
A	SN318011	26/03/2019	-22.37716	148.21459
		27/03/2019	-22.37623	148.23676
		28/03/2019	-22.37618	148.23673
		8/04/2019	-22.39008	148.22679
		9/04/2019	-22.3665	148.20516
		10/04/2019	-22.39518	148.23804
		11/04/2019	-22.37769	148.22077
		12/04/2019	-22.35665	148.19285
		13/04/2019	-22.37584	148.25864
		15/04/2019	-22.35043	148.19961
		30/04/2019	-22.35911	148.2297
		1/05/2019	-22.34987	148.20114
		3/05/2019	-22.35026	148.19531
		6/05/2019	-22.28541	148.15191
		7/05/2019	-22.30574	148.19387
B	SN324680	26/03/2019	-22.3904	148.22627
		27/03/2019	-22.37693	148.20079
		28/03/2019	-22.37695	148.20086
		8/04/2019	-22.37699	148.20077
		9/04/2019	-22.37691	148.20069
		10/04/2019	-22.37602	148.2143
		11/04/2019	-22.37597	148.21452
		12/04/2019	-22.35903	148.1982
		13/04/2019	-22.35358	148.23393
		15/04/2019	-22.3537	148.23395
		30/04/2019	-22.35166	148.21131
		1/05/2019	-22.34241	148.21047
		3/05/2019	-22.34033	148.21277
		6/05/2019	-22.29084	148.16613
		7/05/2019	-22.33003	148.21279

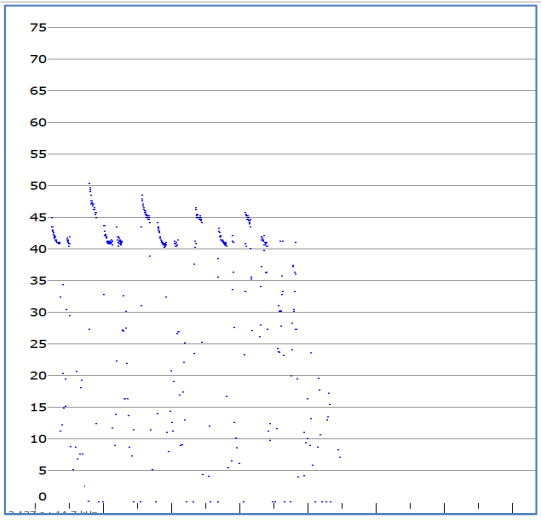
Appendix 2 Representative call sequences from the Saraji West surveys, March-May 2019.
AnalookW spectrograms with time between pulses removed pulses



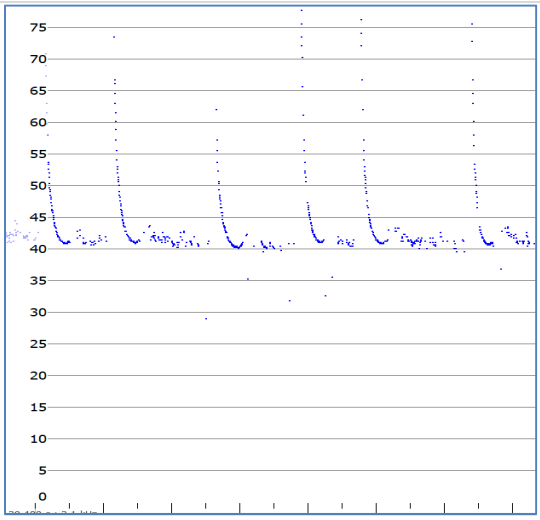
Chalinolobus gouldii



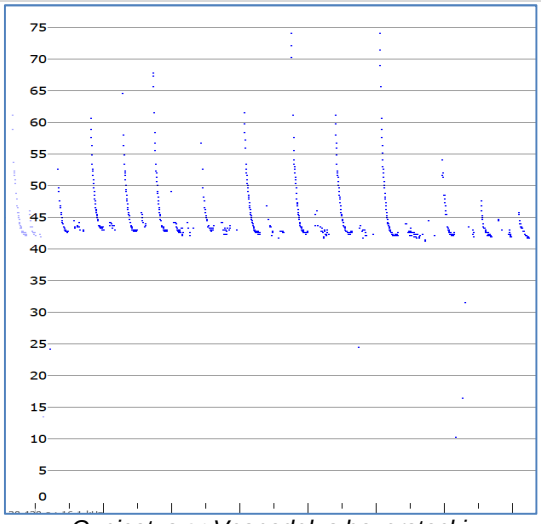
Scotorepens balstoni



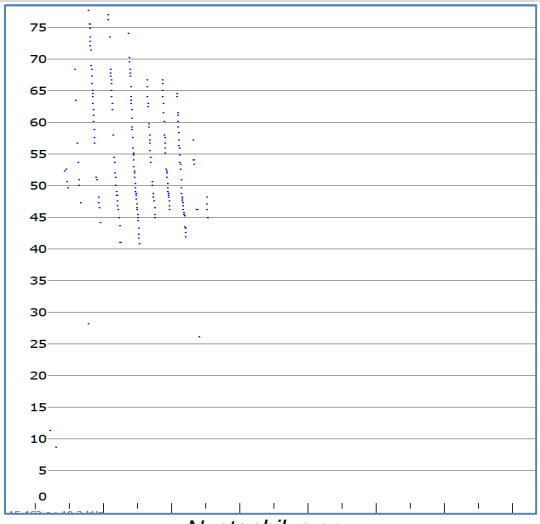
Chalinolobus picatus



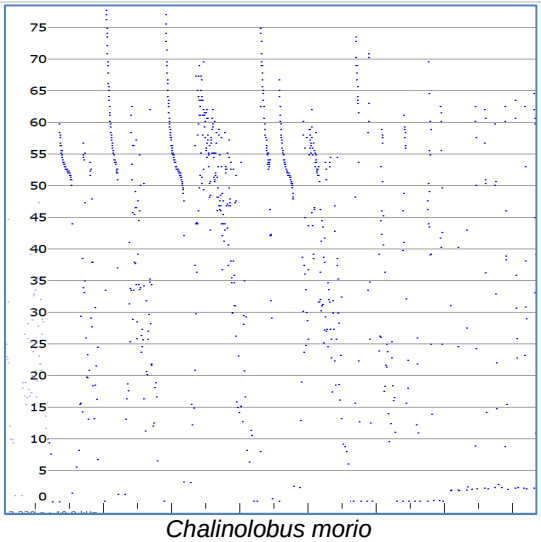
Scotorepens greyii / S. sanborni



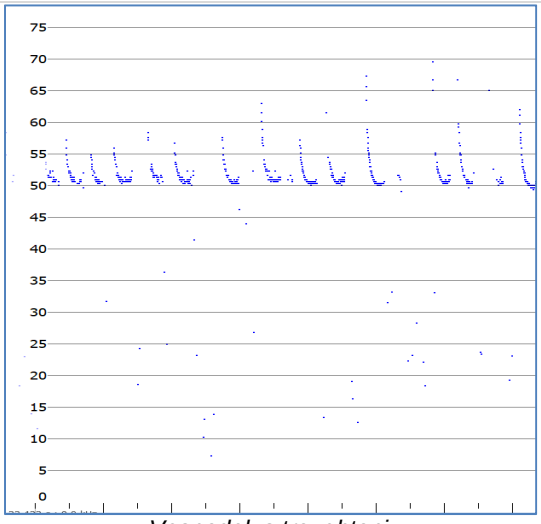
C. picatus or *Vespadelus baverstocki*



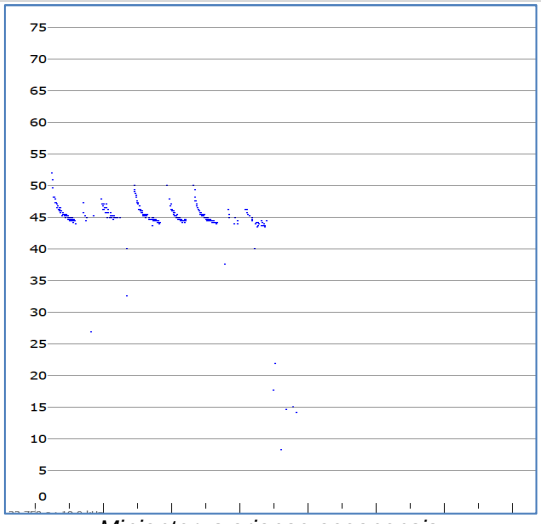
Nyctophilus sp.



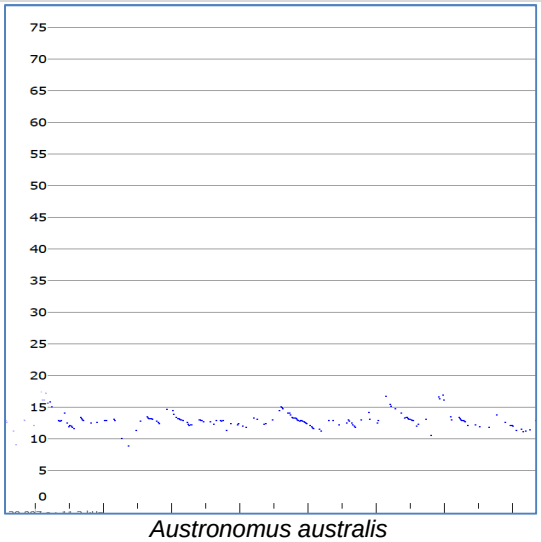
Chalinolobus morio



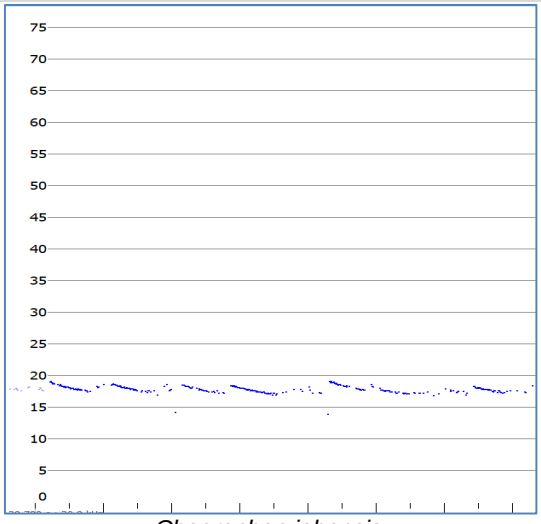
Vespadelus troughtoni



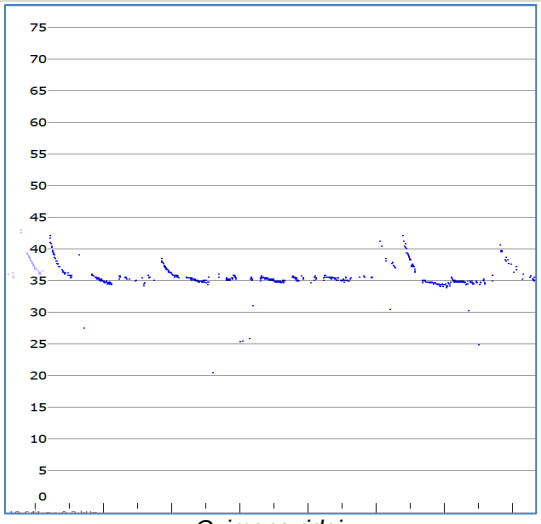
Miniopterus orianae oceanensis



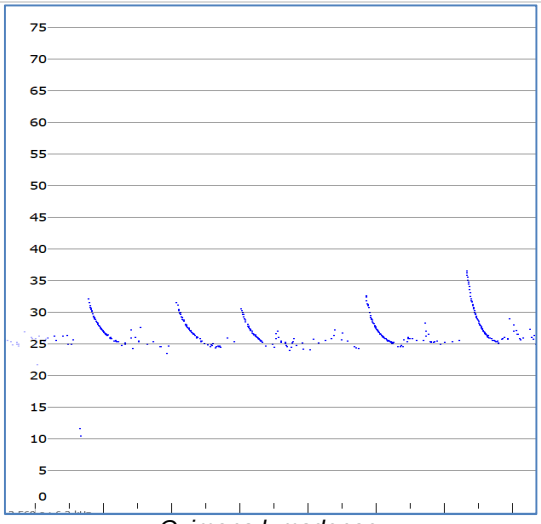
Austronomus australis



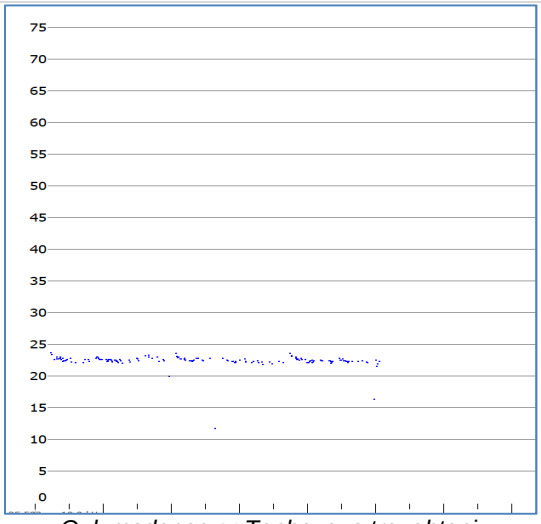
Chaerephon jobensis



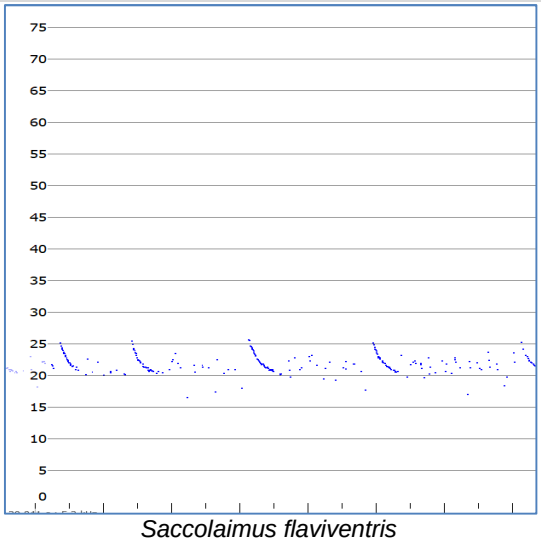
Ozimops ridei



Ozimops lumsdenae



O. lumsdenae or *Taphozous troughtoni*



Saccolaimus flaviventris

Microbat Call Interpretation Report

Prepared for ("Client"):	METSERVE
Survey location/project name:	Dysart area
Survey dates:	23-30 September 2019
Client project reference:	
Job no.:	MET-1902
Report date:	4 December 2019

DISCLAIMER:

© Copyright – Balance! Environmental, ABN 75 795 804 356. This document and its content are copyright and may not be copied, reproduced or distributed (in whole or part) without the prior written permission of Balance! Environmental other than by the Client for the purposes authorised by Balance! Environmental ("Intended Purpose"). To the extent that the Intended Purpose requires the disclosure of this document and/or its content to a third party, the Client must procure such agreements, acknowledgements and undertakings as may be necessary to ensure that the third party does not copy, reproduce, or distribute this document and its content other than for the Intended Purpose. This disclaimer does not limit any rights Balance! Environmental may have under the Copyright Act 1968 (Cth).

The Client acknowledges that the Final Report is intended for the sole use of the Client, and only to be used for the Intended Purpose. Any representation or recommendation contained in the Final Report is made only to the Client. Balance! Environmental will not be liable for any loss or damage whatsoever arising from the use and/or reliance on the Final Report by any third party.

Methods

Data received & post-processing

Balance! Environmental received 13 ZCA data files and associated log files, recorded using two Anabat Express detectors (Titley Scientific, Brisbane) deployed over eight consecutive nights (23-30 September 2019). The raw data files were named according to the site numbers at which each detector was deployed. These deployment details are summarised in **Table 1**.

The ZCA files were processed with *Anabat Insight* (version 1.9.1; Titley Scientific) to extract individual Anabat ZC call-sequence files for analysis. This process yielded 23,231 ZC files; however, 19,620 of those files were discarded by the application of a noise filter to remove files containing only non-bat sounds (e.g. from insects, wind, etc.).

Call analysis and identification

All ZC files that passed the noise filter were analysed in *Anabat Insight*. First-pass call identification was achieved using a Decision Tree analysis to group and label similar calls based primarily on frequency characteristics. Species identities within each group were then verified and/or altered manually by reviewing call spectrograms and derived metrics and comparing them with those of reference calls from central and northern Queensland and/or with published call descriptions (e.g. Reinhold et al. 2001). Consideration was also given to the probability of species' occurrence based on published distribution information (e.g. Churchill 2008; van Dyck *et al.* 2013) and on-line database records (e.g. http://www.ala.org.au).

Reporting standard

The format and content of this report follows Australasian Bat Society standards for the interpretation and reporting of bat call data (Reardon 2003), available on-line at http://www.ausbats.org.au/.

Species nomenclature follows Jackson & Groves (2015).

Table 1 Bat detector deployment details extracted from the data files.

Detector:	Anabat A - SN318011						Anabat B - SN324680						
Date:	24/9	25/9	26/9	27/9	28/9	29/9	23/9	24/9	25/9	27/9	28/9	29/9	30/9
Site:	S27	A7	A8	A9	S32	S34	S26	S28	S29	S31	S30	S33	A10

Results & Discussion

Of the 3,611 ZC files passed the noise filter, 913 were found to contain only brief and/or weak and/or highly-fragmented bat calls that were of no use for species identification. From the 2,698 files that remained a total of 2881 bat calls were identified.

Reliable identification was achieved on 2184 calls (76% of total), which were attributed to 12 unique species and two indistinguishable species pairs. These positively identified species included:

- *Chalinolobus gouldii;*
- *Chalinolobus morio;*
- *Chalinolobus picatus;*
- *Nyctophilus geoffroyi / N. gouldi;*
- *Scotorepens balstoni;*
- *Scotorepens greyii / S. sanborni;*
- *Vespadelus baverstocki;*
- *Vespadelus troughtoni;*
- *Miniopterus orianae oceanensis;*
- *Chaerephon jobensis;*
- *Ozimops lumsdenae;*
- *Ozimops ridei;*
- *Setirostris eleryi;* and
- *Saccolaimus flaviventris*.

The other 697 calls could not be reliably identified due to similarities in call characteristics shared by several species. These unresolved calls were allocated to one of the following multi-species groups:

- *C. gouldii / O. ridei / S. balstoni;*
- *C. morio / V. troughtoni;*
- *C. picatus / S. greyii / S. sanborni;*
- *S. greyii / S. eleryi;*
- *S. flaviventris / C. jobensis;*
- *S. flaviventris / O. lumsdenae;* and
- *O. lumsdenae / Taphozous troughtoni.*

The above groups mostly represent species that were also identified positively from more typical calls. The last group potentially represents an additional species for this survey. *Taphozous troughtoni* is likely present in the study area, but it's calls can be difficult to distinguish from those of *O. lumsdenae*. Calls allocated to the group had shorter duration, more uniform pulses than those allocated positively to *O. lumsdenae*, but it was still not possible to reliably attribute them to *T. troughtoni*.

Table 2 provides a summary of species' presence per site. Where unresolved calls were identified, all members of the relevant group are listed as "possible" unless positive identification was achieved on other calls. Sample spectrograms of each recorded call type are shown at **Appendix 1**.

References

Churchill, S. (2008). *Australian Bats*. Jacana Books, Allen & Unwin; Sydney.

Jackson, S. and Groves, C. (2015). *Taxonomy of Australian Mammals*. CSIRO Publishing, Melbourne.

Reardon, T. (2003). Standards in bat detector based surveys. *Australasian Bat Society Newsletter* **20**, 41-43.

van Dyck, S., Gynther, I. and Baker, A. (ed.) (2013). *Field Companion to the Mammals of Australia*. New Holland; Sydney.

Table 2. Microbat species recorded during the Dysart surveys, 23-30 September 2019.

♦ = 'definite' - at least one call was attributed unequivocally to the species

□ = 'possible' - calls similar to those of the species were recorded, but were not reliably identified

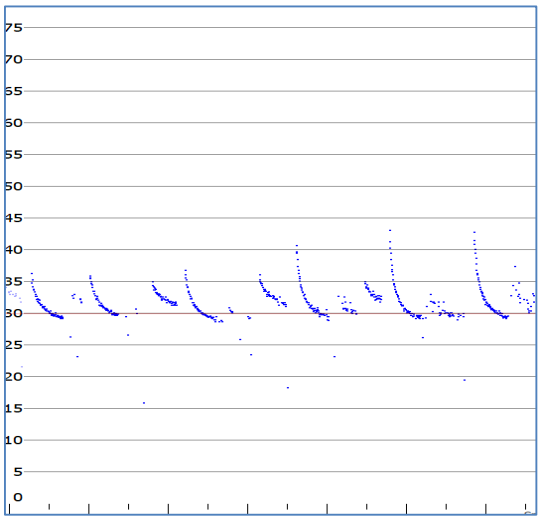
Site:	A7	A8	A9	A10	S26	S27	S28	S29	S30	S31	S32	S33	S34
Chalinolobus gouldii	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	□
Chalinolobus morio		♦	♦	♦	♦	□	♦		□	♦	♦	♦	□
Chalinolobus picatus	♦	♦	♦	♦	□	□	□	□	♦	♦	□	♦	□
Nyctophilus sp.			♦			♦				♦	♦	♦	
Scotorepens balstoni	□	♦	♦	♦		□	□	♦			♦	♦	♦
Scotorepens greyii	♦	♦	♦	♦	□	♦	♦	♦	♦	♦	♦	♦	♦
Vespadelus baverstocki		♦		♦	♦	♦		♦	♦	♦	♦	♦	
Vespadelus troughtoni			♦	□		□			□	♦	♦	♦	♦
Miniopterus orianae oceanensis	♦								♦	□			□
Chaerephon jobensis	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦
Ozimops lumsdenae	♦		♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦
Ozimops ridei	□	♦	♦	♦	♦	□	♦	♦	♦	□	□	♦	♦
Setirostris eleryi		□	♦	□	□	□		□	□	□	□		□
Saccolaimus flaviventris		♦	♦	♦	♦	□		♦	♦	♦	♦	♦	♦
Taphozous troughtoni	□		□			□	□		□	□	□	□	□

Glossary

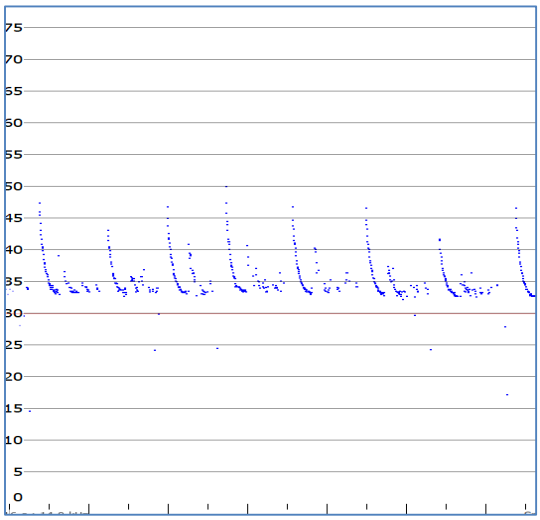
Technical terms used in this report are described in the following table.

Approach phase	The part of a bat *call* emitted as the bat starts to home in on a detected prey item; a transitional series of *pulses* between the *search phase* and *feeding buzz*, that become progressively steeper and shorter in duration.
Call	Refers to a single bat call, made up of a series of individual sound *pulses* in one or more *phases* (*search, approach, feeding buzz*).
CF (=Constant Frequency)	A type of *pulse* in which the dominant component consists of a more-or-less 'pure tone' of sound at a Constant Frequency; with *shape* appearing flat on the sonogram. Often also contains a brief *FM* component at the beginning and/or end of the CF component (*viz.* FM-CF-FM).
Characteristic frequency (Fc)	The frequency of the flattest part of a *pulse*; usually the lowest frequency reached in the *qCF* component of a pulse. This is often the primary diagnostic feature for species identification.
Duration	The time period from the beginning of a *pulse* to the end of the pulse.
Feeding buzz	The terminal part of a *call*, following the *approach phase*, emitted as the bat catches a prey item; a distinctive, rapid series of very steep, very short-duration pulses.
FM (=Frequency Modulated)	A type of *pulse* in which there is substantial change in frequency from beginning to end; *shape* ranges from almost vertical and linear through varying degrees of curvature.
FC range	Refers to the range of frequencies occupied by the *characteristic frequency* section of *pulses* within a call or set of calls.
Frequency sweep or "band-width"	The range of frequencies through which a *pulse* sweeps from beginning to end; Maximum frequency (Fmax) – minimum frequency (Fmin).
Knee	The transitional part of a *pulse* between the initial (usually steeper) frequency sweep and the *characteristic frequency* section (usually flatter); time to knee (Tk) and frequency of knee (Fk) can be diagnostic for some species.
Pulse	An individual pulse of sound within a bat *call*; the *shape*, *duration* and *characteristic frequency* of a pulse are the key diagnostic features used to differentiate species.
Pulse body	The part of the *pulse* between the *knee* and *tail* and containing the *characteristic frequency* section.
Pulse shape	The general appearance of a *pulse* on the sonogram, described using relative terms related to features such as slope and degree of curvature. See also *CF, qCF* and *FM*.
qCF (=quasi Constant Frequency)	A type of *pulse* in which there is very little change in frequency from beginning to end; *shape* appears to be almost flat. Some pulses also contain an *FM* component at the beginning and/or end of the qCF component (*viz.* FM-qCF).
Search phase	The part of a bat *call* generally required for reliable species diagnosis. A consistent series of *pulses* emitted by a bat that is searching for prey or and/or navigating through its habitat. Search phase pulses generally have longer duration, flatter slope and more consistent shape than *approach phase* and *feeding buzz* pulses.
Sequence	Literally, a sequence of *pulses* that may be from one or more bats; but generally refers to a *call* or part (e.g. *phase*) of a call.
Tail	The final component of a *pulse*, following the *characteristic frequency* section; may consist of a short or long sweep of frequencies either upward or downward from the Fc; or may be absent.

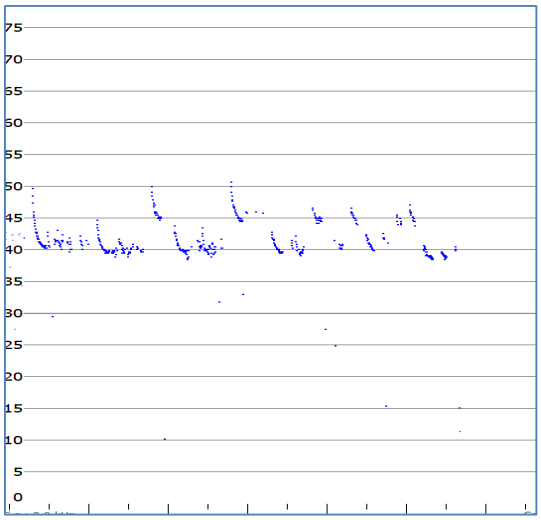
Appendix 1 Representative call sequences from the Dysart survey, 23-30 September 2019.
Time scale (*x*-axis) = 10ms per tick; time between pulses removed



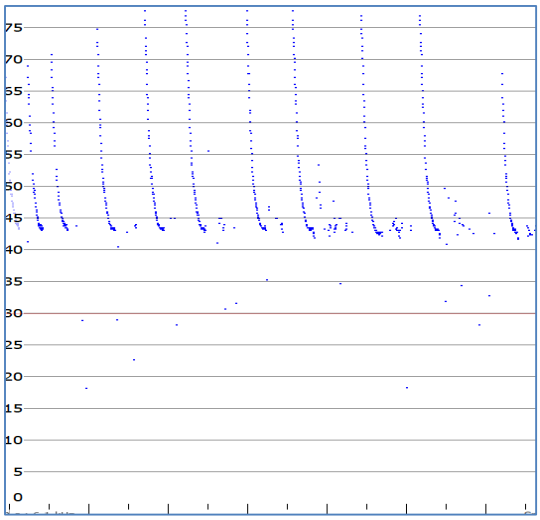
Chalinolobus gouldii



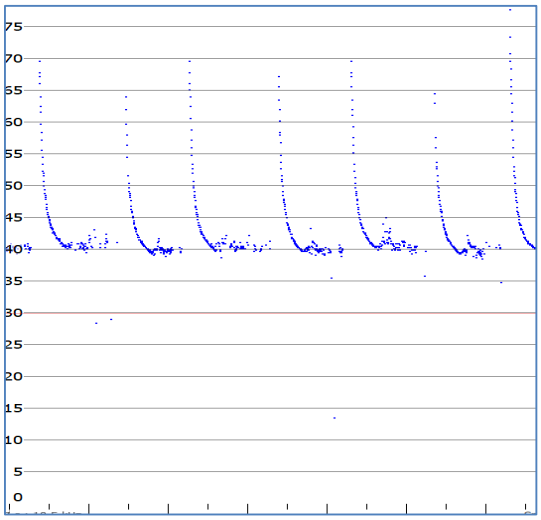
Scotorepens balstoni



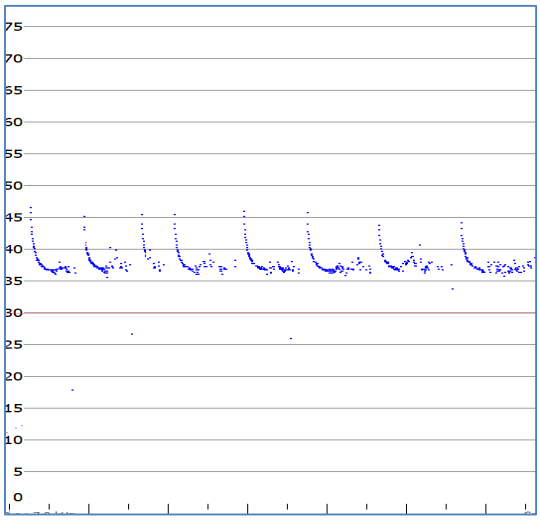
Chalinolobus picatus



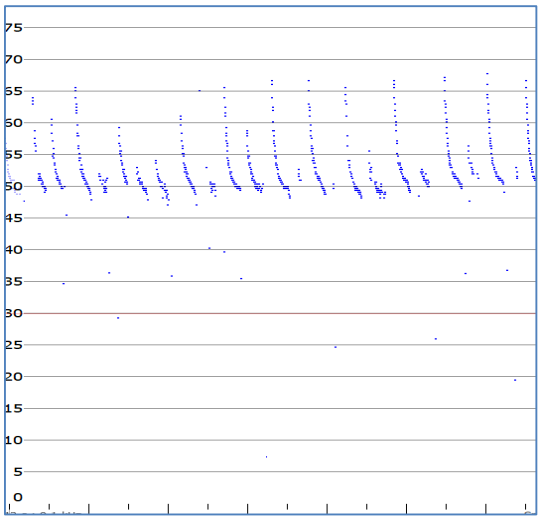
Vespadelus baverstocki



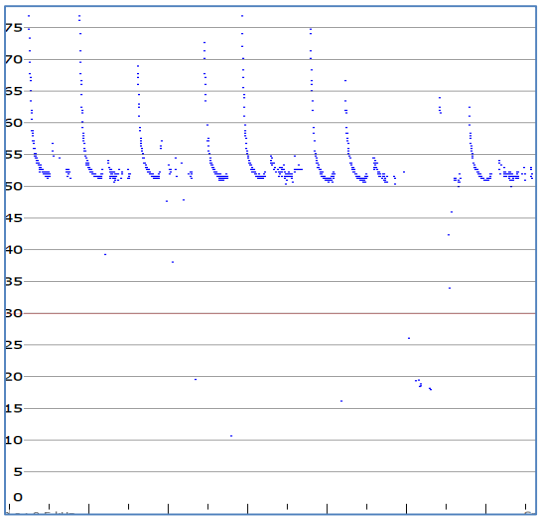
Scotorepens greyii / S. sanborni



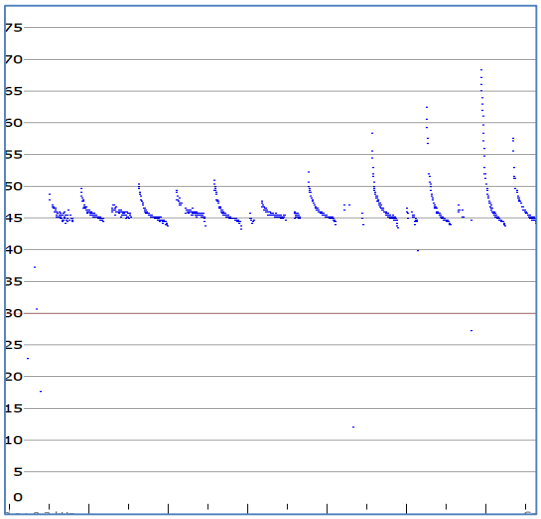
Setirostris eleryi



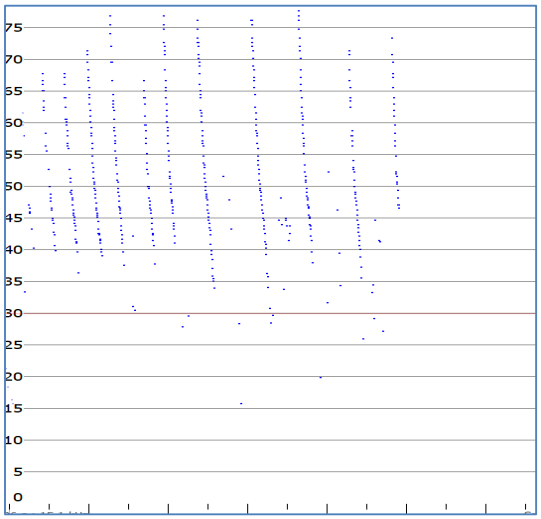
Chalinolobus morio



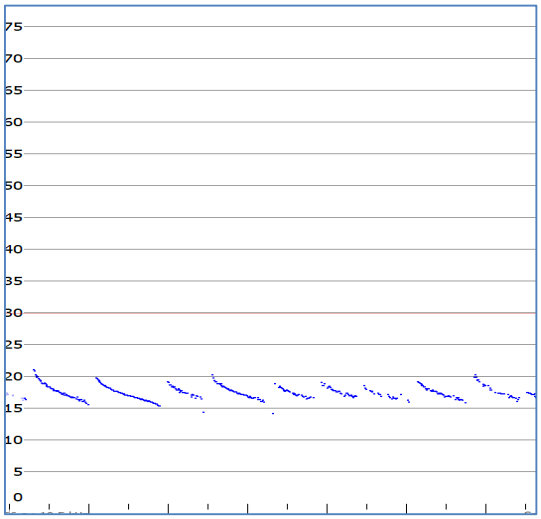
Vespadelus troughtoni



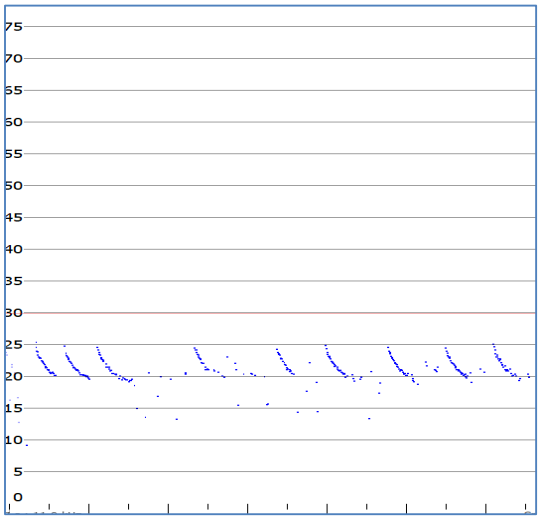
Miniopterus orianae oceanensis



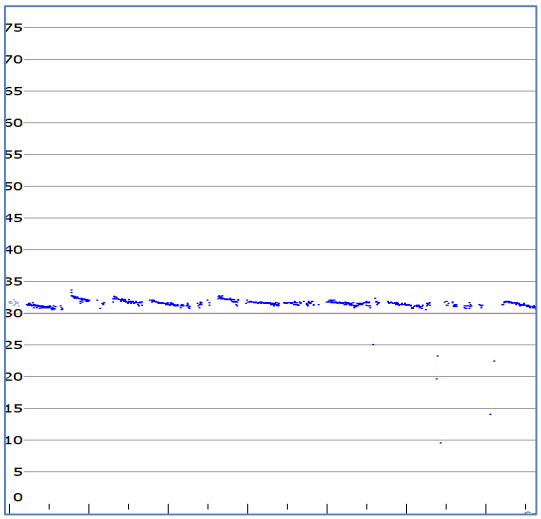
Nyctophilus sp.



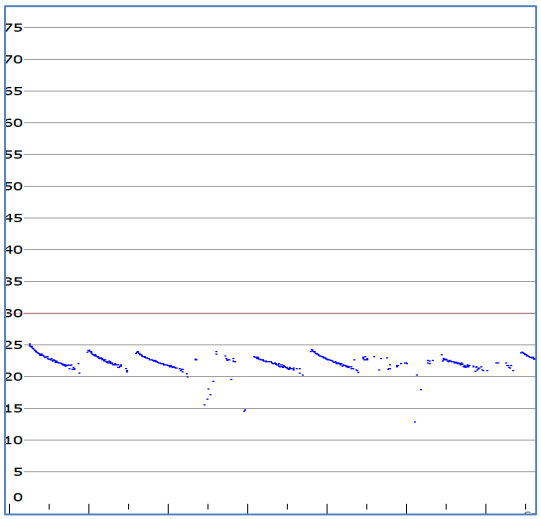
Chaerephon jobensis



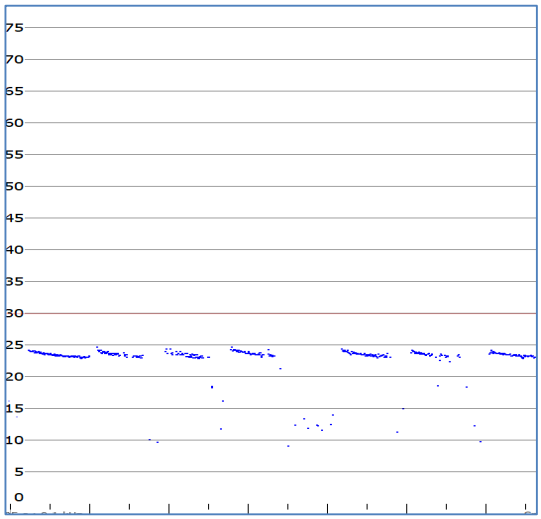
Saccolaimus flaviventris



Ozimops ridei



Ozimops lumsdenae



O. lumsdenae / Taphozous troughtoni

Appendix E- Stakeholder Engagement Plan

VITRINITE
BRIGHTER COAL

Stakeholder Engagement Plan

Vulcan Complex Project

April 2020



METSERVE
Mining & Energy Technical Services Pty Ltd

This report has been prepared solely for the benefit of Vitrinite Pty Ltd. Mining and Energy Technical Services Pty Ltd (METServe) accepts no liability for the use or interpretation of any information contained in this report for any other purpose other than intended, or for its use by any party other than the above named Client.

Document History and Status

Issue	Revision	Issued to	Qty	Date	Reviewed by
1	1 (Draft)	METServe		07/01/2020	Dave Moss
2	2 (Draft)	METServe		18/02/2020	Dave Moss
3	3 (Final Draft)	Vitrinite		26/03/2020	Dave Moss
4	4 (Final)	Vitrinite		31/03/2020	Dave Moss

Printed:	1 April 2020
Last saved:	1 April 2020
File ID:	00279945
Project Manager:	Dave Moss
Name of Organisation:	Vitrinite Pty Ltd
Name of Project:	Vulcan Complex Project
Name of Document:	Stakeholder Engagement Plan
Document Version:	004
Project Number:	VI010

PO Box 306
Fortitude Valley Post Office
Fortitude Valley
QLD 4006

ABN 94 143 463 316

TABLE OF CONTENTS

1 INTRODUCTION 1
1.1 PROJECT OVERVIEW 1
1.2 EXISTING LAND USE AND TENURE 2
1.3 PURPOSE AND SCOPE OF THE STAKEHOLDER ENGAGEMENT PLAN 4
1.4 OBJECTIVES 4
2 STAKEHOLDER ENGAGEMENT PLANNING 5
2.1 IDENTIFICATION AND ASSESSMENT 5
2.2 STAKEHOLDER IDENTIFICATION 5
2.2.1 Landholders 7
2.2.2 Traditional Owners 8
2.2.3 Local Councils 8
2.2.4 Organisations with Infrastructure on the MLA 8
2.2.5 Nearby Businesses 8
2.2.6 State and Federal Regulators 8
2.2.7 Neighbouring Mining Operations 8
3 STAKEHOLDER ENGAGEMENT ACTIVITIES 9
3.1.1 Landholders 9
3.1.2 Traditional Owners 10
3.1.3 Local Council 10
3.1.4 Organisations with Infrastructure on the MLA 10
3.1.5 Nearby Businesses 10
3.1.6 State and Federal Regulators 10
3.1.7 Neighbouring Operations 10
3.1.8 Statutory Public Notification 10
3.2 COMMUNICATION CHANNELS 11
4 ONGOING ENGAGEMENT 12
5 RECORD KEEPING, REPORTING AND REVIEW 13
5.1 RECORD KEEPING 13
5.2 REPORTING 13
5.3 ANNUAL REVIEW 13
6 ROLES AND RESPONSIBILITIES 14
7 REHABILITATION AND CLOSURE 15
7.1 ENGAGEMENT AND CLOSURE PLANNING 15
7.2 ONGOING PRCP ENGAGEMENT 15

APPENDICES

Appendix A Stakeholder register ..... A
Appendix B Landholder Record of Consultation ....B

FIGURES

Figure 1 Project Location..... 3

1 INTRODUCTION

Mining and Energy Technical Services Pty Ltd (METServe) has been engaged by Vitrinite Pty. Ltd., owner of Qld Coal Aust No.1 Pty. Ltd. and Queensland Coking Coal Pty. Ltd. (Vitrinite) to manage the environmental approvals process for the Vulcan Complex Project (VCP or the Project). As part of the Project, Vitrinite will require a Stakeholder Engagement Plan (SEP) to be developed to ensure that relevant stakeholders are consulted about the Project, and stakeholder feedback is appropriately recorded, documented and considered throughout the Project planning process.

1.1 PROJECT OVERVIEW

The proposed Project comprises a new small scale coking coal mine located approximately 30 kilometres (km) north-west of Dysart and 35 km south-east of Moranbah in Queensland's Bowen Basin **(Figure 1**). The Project lies immediately west of BHP Billiton Mitsubishi Alliance's (BMA) Peak Downs Mine. BMA is the underlying land owner of the Project.

The Jupiter hard coking coal target has been defined and selected for open cut development via a single pit. The project will operate for approximately 4 years and will extract approximately 6 Million tonne (Mt) of Run of Mine (ROM) hard coking coal at a rate of up to 1.95 Million tonne per annum (Mtpa). The Project will target the Alex and multiple Dysart Lower coal seams. Truck and shovel mining operations will be employed to develop the pit. ROM coal will be trucked off site for toll washing at a nearby facility between Moranbah and Coppabella on the Peak Downs Highway.

A small out-of-pit waste rock dump will be established prior to commencing in-pit dumping activities that will continue for the life of the operation. Ancillary infrastructure, including a ROM pad, Mine Infrastructure Area (MIA), offices, roads and surface water management infrastructure will be established to the west and south of the open cut.

A realignment of the existing Saraji Road and services infrastructure to the eastern boundary of the proposed Mining Lease Application (MLA) area, adjacent to the existing rail easement, is also proposed. The re-alignment will occur on lease however the connection back to the existing alignment of Saraji Road to the north will extend off lease and will be subject to a separate approvals process.

In-pit dumping will fill the majority of the pit during operations with the remaining final void to be backfilled upon cessation of mining, resulting in the establishment of a low waste rock dump landform over the former pit area. The initial out-of-pit waste rock dump will be rehabilitated in-situ.

Vitrinite has been granted an Environmental Authority (EA0002054) and a Mineral Development Licence (MDL3039) to permit extraction of a bulk sample of coal from the Jupiter target. Prior to commencement of the VCP, Vitrinite will extract up to 600 kilotonnes (kt) of high-quality ROM coking coal from the bulk sample pit for testing by a number of international coal consumers. To access the coking coal within the bulk sample area, up to an additional 150 kt of weathered thermal coal lying above the coking coal, will also be extracted, incidentally. The bulk sample does not form part of the VCP however its features are assumed to form part of baseline conditions for the purposes of environmental assessment of the VCP.

The predominant pre-mining land use within the Project area is low intensity cattle grazing. A number of small scale commercial operations are located on the site. Rehabilitated coal exploration sites are also located across the Project area. Following mining activities, the land is proposed to be rehabilitated and returned to a post-mine land use which will be safe, stable, self-sustaining and capable of supporting the pre-mining land use of low intensity cattle grazing.

The Project is anticipated to require a workforce of 116 personnel (both permanent employees and contractors). As such, it is classified as a "large resource project" under the *Strong and Sustainable Resource Communities Act 2017 (*SSRC Act*)*. It is anticipated that less than approximately one quarter of this workforce would be present on site at any one time due to shift and roster arrangements and the inclusion of off-site haulage positions in this total. The Project's workforce will be primarily sourced from the regional area (i.e. Isaac and Mackay regions) and make use of the existing accommodation camp facilities and private housing at Moranbah and Dysart. Whilst sourcing

of local people will be prioritised, it is anticipated that a combination of regional workforce solutions (Drive-in / Drive-out (DIDO) from Mackay and Fly-in / Fly-out (FIFO) from Moranbah Airport) will be required.

For the purposes of this plan, it is assumed the workforce will reside in a mixture of accommodation facilities from camp (80%) to private residences (20%). It is assumed there will be a 50% / 50% split between Dysart and Moranbah. Travel to site from Dysart and Moranbah will be 80% bus (22 seat) and 20% private vehicle (approx.). There would be two 12 hour shifts per day, with crews operating on a 7 days on / 7 days off roster.

The following indicative workforce breakdown is proposed:

- Staff – 23;
- Mining contractor - 53; and
- Road Haulage – 40.

The Project will require a mining lease (ML) as well as environmental approvals under Queensland and Commonwealth legislation. A site specific Environmental Authority (EA) application will need to be submitted for approval in accordance with the Queensland Environmental Protection Act 1994 (EP Act). It is anticipated that this will not trigger the requirement for a supporting Environmental Impact Statement (EIS).

The Project will also be referred to the Commonwealth Department of the Environment and Energy (DoEE) for approval under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act).

1.2 Existing Land Use and Tenure

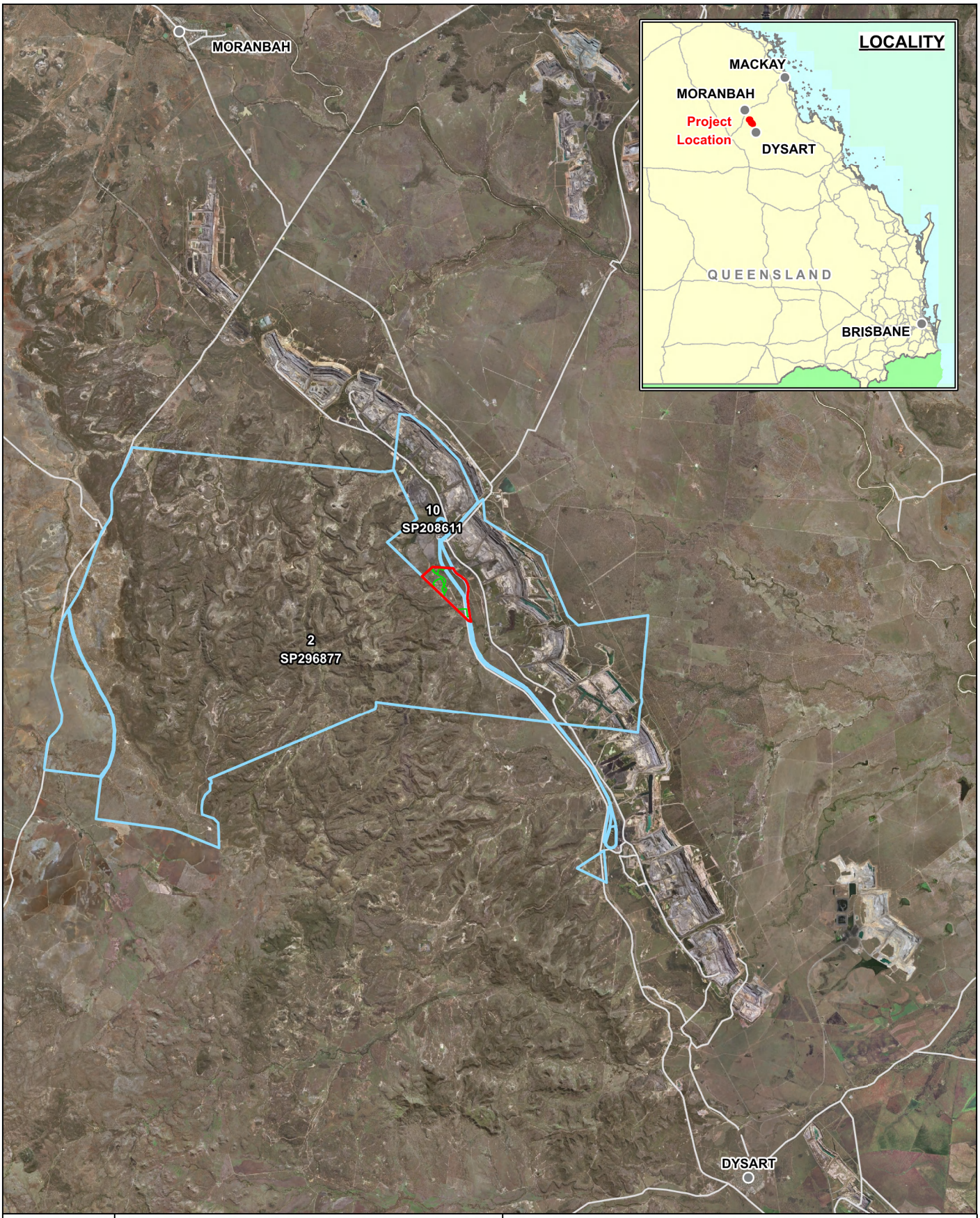
The Project MLA covers an area of approximately 408 hectares (ha) and is situated over multiple underlying tenures (MDL 3039, EPC 1732 and 1234). The MLA area overlies adjacent portions of existing Exploration Permit Coal (EPC) 1732 and 1234 tenements (held by Qld Coal Aust No.1 Pty Ltd and Queensland Coking Coal Pty Ltd, respectively). Both companies hold an equal 50% share of the Mineral Development Licence (MDL).

A list of the properties', tenure, usage and owners/managers within the proposed ML boundary are outlined in Table 1.

Table 1: Land Tenure and Real Property Descriptions for the Project

Lot/Plan	Tenure	Usage	Owner
10/SP208611	Lands Lease	Extractive	BHP Coal Pty Ltd
Saraji Road	Road Licence	Road for public use	Isaac Regional Council
26/CNS125	Lands Lease	Norwich Park Branch Railway	Aurizon

The Project falls within the Isaac Regional Council local government area. The region has a distinct mining influence with multiple significant coal mining operations in the immediate vicinity of the Project. A majority of the land within the MLA has been previously disturbed by agriculture and mining related activities. There are no rural or residential dwellings located within 10km of the Proposed VCP.



METSERVE
Mining & Energy Technical Services Pty Ltd

LEGEND

- Town
- Road
- Disturbance Area
- Mining Lease Application Area
- Property Boundary

Data Source: Town, Road - Geoscience Australia (2016); Survey Boundary - Vitrinite (2019); Property Boundary - QLD Government (2019); Imagery - ESRI, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

Vitrinite

Vulcan Complex Project
Regional Location Plan

5 0 5 10
Kilometers

Scale: 1:300,000 (A4)

26/03/2020

Datum: GDA94
Projection: MGA55

FIGURE 1

S:\Projects\V1005 Vulcan Project_MapInfo\Workspaces\Social_Impact_Assessment\V1005_SIA_Fig1_ProjectLocation_RevB.WOR

1.3 Purpose and Scope of the Stakeholder Engagement Plan

The purpose of the Project SEP is to assist in the planning, management and review of stakeholder engagement activities. Through the SEP, the Vitrinite aims to:

- Build and maintain effective relationships with its stakeholders; and
- Maintain its social license to operate.

The Project SEP is a live and iterative document that:

- Identifies relevant stakeholders across the life of the Project; initially during the approvals phase but also during post approval operations and rehabilitation and closure phases;
- Identifies appropriate engagement approaches, activities and timeframes for these activities, both during the approvals phase and post approval phases; and
- Details the requirements for recording, tracking and analysing consultation activities for reporting in the approval application, and for managing stakeholder concerns.

1.4 Objectives

The SEP aims to provide Vitrinite with a practical and ongoing management tool for effective stakeholder engagement and to assist in building and maintaining relationships, trust and credibility with the relevant groups.

The objectives of the SEP include:

- Identify and record key stakeholders;
- Identify challenges and opportunities;
- Establish and implement communication and consultation practices that promote an ongoing relationship with stakeholders;
- Provide timely and accurate information to stakeholders;
- Provide convenient and identifiable avenues for feedback from stakeholders;
- Record and respond to any complaints in a timely manner; and
- Facilitate consultation feedback and input into mine rehabilitation and closure plans.

2 STAKEHOLDER ENGAGEMENT PLANNING

This SEP outlines how stakeholder engagement will be planned, managed and reviewed. It has been developed based on the identification and assessment of stakeholders, issues, opportunities, risks, concerns and interests within the Project's area of influence and impact.

2.1 IDENTIFICATION AND ASSESSMENT

Identification of stakeholders that have an interest and influence in the Project's approval, construction, operation and eventual rehabilitation and closure is based on their proximity, dependency, representation, responsibility and strategic intent and includes relevant Government and non-Government development organisations. The process includes:

- Identify and assess issues, opportunities and associated risks, including access to resources;
- Identify stakeholder concerns and interest gathered through a variety of mechanisms including direct consultation; and
- Assess the impact of the Project's activities within the area of influence, including the social aspect of site closure.

2.2 STAKEHOLDER IDENTIFICATION

The identification of stakeholders is significant to the Project's longevity and sustainability. It is also practical to be able to identify and analyse the role and involvement that particular stakeholders will have throughout the life of the Project. As such, stakeholders have been classified into two categories (as defined under section 38 and section 41 of the EP Act) depending on the predicted level of Project impact, perceived level of stakeholder involvement on site activities, and the perceived level of interest in site activities or the outcomes of decisions. These two categories (and corresponding EP Act definitions) include:

1. Affected Stakeholder: Under section 38 of the EP Act this includes:
   - A person mentioned in subsection (2) for the operational land or any land joining it. This includes (amongst others) the registered proprietor/s of any freehold land, the registered holder/s of any land that is held from the State, any holder/s or applicant/s of mining tenures or other resource related tenures, trustees of any land under the Nature Conservation Act 1992 or Land Act 1994, and holders of any unallocated State land, State forests or Conservation parks or State Controlled Roads;
   - Registered native title body corporates, claimants or representative Aboriginal/Torres Strait Islander body; or
   - A relevant local government.
2. Interested Stakeholder: Under section 41(3)(b) of the EP Act this includes an unincorporated community or environmental body with a financial or non-financial interest in the local government area that the operational land is in.

Categorising stakeholders as above allows for targeted planning, assessment and reviewing of stakeholder consultation practices, feedback, schedules and timing.

Table 2 below lists relevant stakeholders according to the definitions under section 38 and section 41 of the EP Act, as well as a summary of perceived potential interests in the Project. Appendix A presents a register of completed engagement activities.

Table 2: Stakeholder list by category and potential concerns

Stakeholder Group	Potential Interests
Affected Stakeholders	
Underlying Landholders	) Lawful management of the land) Lawful operation of the project) Management of offsite impacts (particularly surface waters and groundwater)) Management of and interaction with BMA infrastructure) Land rehabilitation and post-mine land uses) Weed control) Site access) Unauthorised access controls
Adjacent Landholders	) Noise and dust emissions) Blasting overpressure and vibration) Management of offsite impacts (particularly surface waters and groundwater)) Quality of mine rehabilitation) Offsite impacts on land capability) Lighting emissions) Work opportunities) Land acquisition process) Transport and road impacts) Fences and gates
Traditional Owners	) Disturbance of cultural heritage sites and artefacts) Management of cultural heritage sites and artefacts) Access to land for cultural purposes) Employment opportunities
Local Council	) Compliance with development and planning conditions) Re-alignment of IRC road infrastructure and associated approval processes) Support for community and local business) Engagement with stakeholders) Impact of mine closure) Information on significant variations to Project) Worker and contractor accommodation impacts) Social infrastructure impacts
Stakeholders with infrastructure within the Proposed MLA	) Interaction with and effects on infrastructure) Possible relocation requirements) Continuity of service
Stakeholders with commercial operations within the proposed MLA	) Interaction with and effects on infrastructure and operations) Possible relocation requirements) Continuity of operations
Interested Stakeholders	
Queensland Department of Environment and Science (DES)	) EA application and PRCP) Environmental assessments and mitigation measures) Environmental management plans) Mine rehabilitation
Queensland Department of Natural Resources, Mines and Energy (DNRME)	) Mining Lease application) Water supply and water infrastructure

Stakeholder Group	Potential Interests
	) Compliance with operational plans and safety) Mine closure
Queensland Department of Transport and Main Roads (DTMR)	) Transport and road impacts) Transport Impact Assessment (TIA)) Pavement Impact Assessment (PIA)) Associated contributions) Road Use Management Plan
Commonwealth Department of the Environment and Energy (DoEE)	) EPBC Act referral) Assessment of MNES, values, impacts and mitigation measures
Downstream water users (BMA)	) Impacts on local and regional surface and groundwater) Potential flooding impacts and impacts on critical infrastructure

The VCP is a small scale, short term coal project located within a well-established coal mining region of Queensland. It is proposed on disturbed land immediately adjacent to a number of well-established large scale coal mining Projects. Based on this and limited social impacts determined to be associated with the Project, the need for broad community engagement has been determined not to be required. Representative bodies for the community (IRC, government agencies) will and have been consulted and the general public will have the opportunity to comment on the EA application and PRCP as part of the EA application assessment process. Vitrinite consider this to be an appropriate level of engagement.

2.2.1 Landholders

Underlying and adjacent landholders are described in Table 3.

Table 3: Landholders / Reserves by Lot / Plan and Property Name

Lot / Plan	Landholder / Reserve	Property Name
Underlying Landholders/ Reserves		
) 10 SP208611	BHP Coal Pty Ltd	Peak Downs Mine
) 26 CNS125	Aurizon Holdings Limited	Norwich Park Branch Railway
	Isaac Regional Council	Saraji Road Reserve
Adjacent Landholders		
) 2 SP296877	Robert A & Raye M O'Sullivan	Saraji Station

2.2.2 Traditional Owners

The Barada Barna People (QUD380/08), represented by the Barada Barna Aboriginal Corporation RNTBC ICN 8343 (BBAC), are the native title holders for the broader project area, and the 'Aboriginal party' for the Project under the Aboriginal Cultural Heritage Act 2003 (Qld).

2.2.3 Local Councils

The relevant local council is the Isaac Regional Council.

2.2.4 Organisations with Infrastructure on the MLA

The following organisations own and / or operate infrastructure on the proposed MLA:

- Aurizon;
- IRC;
- Telstra;
- Dyno Nobel Asia Pacific Ltd;
- Kalari Pty Ltd;
- Saraji Station; and
- BHP Billiton Mitsubishi Alliance (BMA) Pty Ltd.

2.2.5 Nearby Businesses

Businesses in close proximity to the proposed Vulcan Complex Project include:

- Dyno Nobel Asia Pacific Ltd;
- Kalari Pty Ltd;
- BHP Billiton Mitsubishi Alliance (BMA) Pty Ltd; and
- Saraji Station.

2.2.6 State and Federal Regulators

Relevant State and Federal regulatory agencies include:

- Queensland Department of Environment and Science (DES);
- Queensland Department of Natural Resources, Mines and Energy (DNRME);
- Queensland Department of Transport and Main Roads (DTMR); and
- Commonwealth Department of the Environment and Energy (DoEE).

2.2.7 Neighbouring Mining Operations

BMA own the neighbouring Peak Downs and Saraji coal mines.

3 STAKEHOLDER ENGAGEMENT ACTIVITIES

Stakeholder engagement activities (including frequency of engagement) have been identified for the various stakeholders discussed above, and once executed, are included in the Project's Stakeholder Register (refer Appendix A).

The level of stakeholder engagement will:

- Be based on the goals / objectives of the engagement program and effectiveness of the technique in reaching the target audience; and
- May vary considerably depending on the level of interest and impact the stakeholder has.

The methods of stakeholder engagement that have been considered include:

- Face to face meetings;
- Scheduled and routine conferences (monthly, quarterly, annual, etc.);
- Telephone meetings;
- Workshops; and / or
- Newsletters and email correspondence.

Regardless of the stakeholder group or method of engagement, all engagement should apply the following principles:

- Transparent - Open and honest in engagement activities, setting expectations;
- Realistic - Set clear objectives and understanding of what is to be achieved out of the engagement;
- Inclusive - Identify stakeholders and provide meaningful opportunities for them to engage;
- Respectful - Listen and acknowledge the needs of stakeholders, different opinions and perspectives; and
- Responsive - Consider and respond to issues and concerns, providing feedback to stakeholders.

3.1.1 Landholders

Underlying and adjacent landholders have been identified as Affected Project stakeholders.

Project Engagement activities will involve the following:

- Initial telephone contact between the Project Manager and the landholder;
- Round 1 - individual face-to-face meetings to discuss:
  - Draft Project description;
  - Environmental approvals and tenure processes and scheduling;
  - Environmental baseline surveys and monitoring undertaken to date and baseline results;
  - Approach to impact assessment and management of noise, dust, weed management, property disturbance etc.;
  - Approach to progressive rehabilitation and closure planning; and
  - Future communications protocol.
- Round 2 - individual face-to-face meetings to discuss:
  - Final Project description proposed for approval;
  - Results of impact assessment - particularly management of noise, dust and weeds, and closure impacts;
  - Proposed project rehabilitation and final landform / land use; and

- Further information on the environmental approvals process and opportunities to comment during the public notification process.

3.1.2 Traditional Owners

The Proponent and the BBAC have entered into an indigenous land use agreement (body corporate agreement) (ILUA) in respect of the Vulcan Project, which is in the process of being registered with the National Native Title Tribunal. The ILUA also contemplates the management of Aboriginal cultural heritage under the Aboriginal Cultural Heritage Act 2003 (Qld). Engagement will continue in accordance with the ILUA.

3.1.3 Local Council

The Project is located within the Isaac Regional Council and engagement will focus on the Project's potential impacts to the surrounding region (including infrastructure and transport impacts). IRC data has been interrogated as part of the social impact assessment, and impacts to local businesses, community groups, worker accommodation in Dysart and Moranbah, social infrastructure (health, education and emergency services) are considered to be limited.

Isaac Regional Council will be consulted directly in relation to the proposed realignment of IRC's Saraji Road and provided with regular Project updates. This will include approval applications requirements for the off-lease component of the road realignment to the north of the proposed MLA.

3.1.4 Organisations with Infrastructure on the MLA

Direct consultation will occur with each organisation that operates infrastructure on the proposed MLA. Each party will be engaged separately via e-mail, phone and face-to-face meetings to discuss current infrastructure operations, interactions with the project, realignment requirements and ongoing management requirements.

3.1.5 Nearby Businesses

Direct consultation will occur with each organisation that operates businesses on or adjacent to the proposed MLA. Each party will be engaged separately via e-mail, phone and face-to-face meetings to discuss current business operations, interactions with the project, potential relocation requirements and ongoing management requirements.

3.1.6 State and Federal Regulators

Engagement with State and Federal regulators will occur throughout the Project planning assessment and execution phases. Engagement will be via e-mail, phone and face-to-face meetings (including presentations of Project information). Engagement will typically be focussed around a number of approval process stages including:

- Introduction of proponent and project concept (including clarification of approval processes and assessment / application requirements);
- Discussion of baseline assessment findings;
- Discussion of impact assessment findings and management and mitigation proposals;
- Application pre-lodgement;
- Application assessment consultation, information requests, notification processes; and
- Compliance and reporting.

3.1.7 Neighbouring Operations

BMA operates the Peak Downs mine immediately to the east of the Project MLA. BMA will be engaged via e-mail, phone and face-to-face meetings.

3.1.8 Statutory Public Notification

Prescribed statutory public notification periods form part of the ML, EA and EPBC referral application and approvals process. During these periods, approval application material will be advertised in

various newspapers, made available on the Vitrinite website and on the DES and DoEE websites for the public to respond to by way of written submissions to the regulators.

3.2 COMMUNICATION CHANNELS

A Vitrinite channel of communication will be established linking Project staff / management to external stakeholders who wish to comment on (or ask questions about) the Projects various components and / or impacts. Information will also be included on the Vitrinite website and updated as necessary along with instructions on how external stakeholders can make a submission to DoEE, DNMRE, DES and / or Vitrinite during the public notification process.

Vitrinite will distribute information to stakeholders as required and in consideration of confidentiality requirements as well as releasing information as required in accordance with its public notification obligations.

Two-way communication is fundamental to engagement with stakeholders. Engagement and feedback opportunities should be actively sought to ensure that stakeholders are comfortable with the level of Project knowledge and so that any management of enquiries, complaints or issues can be handled efficiently. Feedback from Project consultation activities will be met within appropriate timeframes as follows:

- Telephone or face-to-face enquiries about current Project activities will aim to be responded to by the next business day;
- Telephone or face-to-face enquiries about non-current (ie. proposed) Project activities will aim to be responded to within three business days; and
- Email and letter enquires within five business days from date of receipt of correspondence.

4 ONGOING ENGAGEMENT

Stakeholders will continue to be engaged during the project construction, operations and closure phases. Specific consultation in relation to the Progressive Rehabilitation and Closure Plan (PRCP) is discussed in Section 7.

Affected stakeholders will be advised of any relevant Project changes that are proposed to occur throughout the Project execution. Relevant Project changes are considered to be those that significantly change the information, decisions and agreements that had been discussed in prior engagement or approval notification activities.

5 RECORD KEEPING, REPORTING AND REVIEW

A record of all stakeholder engagement (past, ongoing or prospective) should be maintained in order to verify stakeholder engagement conducted, address stakeholder concerns in a timely manner and manage the Project approval process to acknowledge and (where feasible) incorporate stakeholder feedback.

Appendix A provides relevant engagement records documented to date (at time of publication).

5.1 RECORD KEEPING

The Vitrinite Project Manager and / or personnel responsible for stakeholder engagement, as well as any staff responsible for holding a Project email and / or telephone number, will be accountable for implementing Vitrinite's record keeping process, including:

- Direct data entry into records; and
- Advising any other supporting staff responsible for inputting stakeholder engagement data into formal records.

5.2 REPORTING

For each stakeholder engagement record generated, the following should be reported:

- Consultation date(s);
- The stakeholders consulted;
- Consultation type (face-to-face meeting, community forum, workshop, quarterly meetings, etc.);
- Information provided;
- Topics of discussion; and
- Outcomes and ongoing commitments.

5.3 ANNUAL REVIEW

This SEP (including the Stakeholder Register) will be reviewed annually (post Project approval) and updated accordingly to ensure that:

- Any updated legislation, standards and other reference information is incorporated into the SEP and any supporting Vitrinite management systems; and
- Vitrinite's engagement process throughout the Project's operations and rehabilitation and closure phases remains efficient, informative and fit for purpose in accordance with accepted industry standards and legislative requirements.

6 ROLES AND RESPONSIBILITIES

The Vitrinite Project Manager is primarily responsible for the planning and implementation of stakeholder engagement activities for the Project. Where applicable, engagement will build on existing engagement between stakeholders and Vitrinite personnel. Accordingly, those involved with existing engagement tasks will play an ongoing role in the implementation of the SEP. Other Vitrinite personnel involved in stakeholder engagement are identified in the Stakeholder Register (Appendix A).

7 REHABILITATION AND CLOSURE

7.1 ENGAGEMENT AND CLOSURE PLANNING

A PRCP is required to be developed for the Project in accordance with the Queensland Government's Mined Land Rehabilitation Policy. The PRCP must be submitted as part of the site-specific EA application for a new mining activity and is required to comply with requirements as set out in DES' Progressive Rehabilitation and Closure Plans Guideline (PRCP Guideline) (effective as at 1 November 2019).

As part of the PRCP planning process, and in accordance with section 126C(1)(c)(iii) and (iv) of the EP Act as well as DES' PRCP Guideline, Vitrinite must demonstrate that sufficient effort has been made in engaging stakeholders in the preparation of the PRCP. The following three components should be considered:

- The identification of relevant stakeholders;
- Identification of a Stakeholder Engagement Register identifying the engagement carried out in developing the PRCP (it may refer to the Stakeholder Engagement Register appended to this document); and
- A description of ongoing (rehabilitation related) engagement proposed during Project operations and closure activities (note discussion of this in Section 7.2 below).

The above PRCP planning requirements have been considered in the development of this SEP, with rehabilitation and closure planning forming a component of the Project's stakeholder engagement process. Appendix A provides relevant engagement records documented to date (at time of publication). Appendix B provides a specific record of consultation with BMA, which is the primary stakeholder for the purposes of the PRCP, as the underlying landholder and downstream neighbour of the Project.

7.2 ONGOING PRCP ENGAGEMENT

The Progressive Rehabilitation and Closure Plans Guideline (PRCP Guideline), requires ongoing engagement with relevant stakeholders to determine any changes in stakeholder perspectives and to communicate any relevant closure related changes proposed by Vitrinite. Given the short duration of the proposed Project (four years of activity), it is considered unlikely that significant changes to the proposed rehabilitation activities will occur. Similarly, it is considered that stakeholder perspectives on rehabilitation are unlikely to change, particularly if the proposed rehabilitation activities are implemented successfully.

Nonetheless, Vitrinite commits to providing relevant stakeholders with copies of annual rehabilitation progress reporting and will utilise this mechanism for communication of any proposed changes to the PRCP and to obtain feedback from stakeholders for consideration in ongoing planning and activities. Should significant amendment of the PRCP be proposed, stakeholders will be engaged as part of the amendment process.

APPENDIX A

STAKEHOLDER REGISTER

Consultation date	Consultation type	Stakeholder	Location	Attendees	Information Provided	topics of discussion	outcomes/ ongoing commitments
20-Mar-2019	Meeting	O'Sullivans (Saraji and Cherwell)	Cherwell Station	Mike Cavanaugh, O'sullivan family	Planned location of water bores	Groundwater bores	Ongoing discussions around borehole conversion if suitable
30-April-2019	Meeting	DES	DES Office Emerald	Allison Sinclair, Mick Callan, Dave Moss, Heath Carney,	Vulcan Bulk Sample Project and Vitrinite introduction, VCP introduction	Bulk Sample Project Description, VCP introduction	BSP EA application planning to continue. Prelodgement meeting to be held in a few months prior to EA application submission
16-May-2019	Meeting	Barada Barna People	Vitrinite Office, Brisbane	Nick William Ryan Welker, Directors and members of Barada Barna Aboriginal Corporation, legal representatives	Project update presentation	Project update and preliminary ILUA discussions	Ongoing dialogue towards ILUA execution
21-May-2019	Meeting	DNRME (Coal Hub)	Rockhampton	Mick Callan, Nick Williams, DNMRE representatives	Project overview presentation	Project update	Ongoing consultation regarding project development
18-June-2019	Meeting	Barada Barna People	McCullough Robertson Lawyers	Nick William Ryan Welker, Directors and members of Barada Barna Aboriginal Corporation, legal representatives	Project update presentation	ILUA meetings, Info sessions, execution meeting	Ongoing dialogue towards ILUA execution
10-July-2019	Meeting	DES	DES Office Emerald	Allison Sinclair, Jessica Edgar, Mick Callan, Dave Moss. (joined later by Brenton Josie and Priti Mahajan)	Bulk Sample Project prelodgement, VCP assessment update, exploration activities update	Bulk Sample Project Description, environmental values, proposed mitigation and submission timing	BSP EA application submission to proceed as planned, Further updates on VCP to be provided.

Consultation date	Consultation type	Stakeholder	Location	Attendees	Information Provided	topics of discussion	outcomes/ ongoing commitments
20-Mar-2019	Meeting	O'Sullivans (Saraji and Cherwell)	Cherwell Station	Mike Cavanaugh, O'sullivan family	Planned location of water bores	Groundwater bores	Ongoing discussions around borehole conversion if suitable
30-April-2019	Meeting	DES	DES Office Emerald	Allison Sinclair, Mick Callan, Dave Moss, Heath Carney,	Vulcan Bulk Sample Project and Vitrinite introduction, VCM introduction	Bulk Sample Project Description, VCM introduction	BSP EA application planning to continue. Prelodgement meeting to be held in a few months prior to EA application submission
16-May-2019	Meeting	Barada Barna People	Vitrinite Office, Brisbane	Nick William Ryan Welker, Directors and members of Barada Barna Aboriginal Corporation, legal representatives	Project update presentation	Project update and preliminary ILUA discussions	Ongoing dialogue towards ILUA execution
21-May-2019	Meeting	DNRME (Coal Hub)	Rockhampton	Mick Callan, Nick Williams, DNMRE representatives	Project overview presentation	Project update	Ongoing consultation regarding project development
18-June-2019	Meeting	Barada Barna People	McCullough Robertson Lawyers	Nick William Ryan Welker, Directors and members of Barada Barna Aboriginal Corporation, legal representatives	Project update presentation	ILUA meetings, Info sessions, execution meeting	Ongoing dialogue towards ILUA execution
10-July-2019	Meeting	DES	DES Office Emerald	Allison Sinclair, Jessica Edgar, Mick Callan, Dave Moss. (joined later by Brenton Josie and Priti Mahajan)	Bulk Sample Project prelodgement, VCM assessment update, exploration activities update	Bulk Sample Project Description, environmental values, proposed mitigation and submission timing	BSP EA application submission to proceed as planned, Further updates on VCM to be provided.

Consultation date	Consultation type	Stakeholder	Location	Attendees	Information Provided	topics of discussion	outcomes/ ongoing commitments
10-July-2019	Meeting	IRC	IRC Office Moranbah	Pat Moore, Alexis Aylward, Mick Callan, Dave Moss	Overview of Bulk Sample Project and proposed haul routes and estimate volumes	Project overview provided, IRC approvals and notifications discussed, TIA and PIA requirement discussed, suitability of a Road Use Management Plan discussed	Vitrinite agreed to provide TIA/PIA and to ongoing consultation
10-July-2019	Meeting	Dyno Nobel	Dyno compound Office on site	Carlin, Dyno team x4, Mick Callan, Mike Cavanagh, Dave Moss	Overview of Bulk Sample Project, introduction to VCM	Interaction with Dyno operations discussed, potential Dyno relocation discussed,	Agreed to ongoing consultation and discussions with Dyno management
11-July-2019	Meeting	DTMR	DTMR Offices Mackay	Vickie Wood, Ross Young, Mick Callan, Dave Moss	Overview of Bulk Sample Project and proposed haul routes and estimate volumes	Project overview provided, DTMR approvals and notifications discussed, TIA and PIA requirement discussed, Notifiable road Use correspondence discussed.	Vitrinite agreed to provide TIA/PIA and to ongoing consultation
11-July-2019	Meeting	DNRME	DNRME Offices Rockhampton	Alex Grundy, Deb Toon, Mick Callan, Dave Moss	Overview of Bulk Sample Project, introduction to VCM	MDL Application requirements discussed and agreed. VCM and future opportunities broadly discussed	BSP EA and MDL application submissions to proceed as planned, Further updates on VCM to be provided.
31-July-2019	Meeting	Dyno Nobel	Vitrinite Office, Brisbane	John Stevens and Simon Masters (Dyno) Mick Callan, Nick Williams, Ryan Welker	Detailed project update	project interactions, update on project development	ongoing consultation

Consultation date	Consultation type	Stakeholder	Location	Attendees	Information Provided	topics of discussion	outcomes/ ongoing commitments
27-August-2019	Meeting	Dyno Nobel	Dyno Facility, Murrarie	John Stevens and simon masters (Dyno) Mick Callan, Ryan Welker	Project Update, interactions and relocation discussion	project interactions, update on preoject development	ongoing consultation
10-September-2019	Meeting	Barada Barna People	McCullough Robertson Lawyers	Nick William Ryan Welker, Directors and members of Barada Barna Aboriginal Corporation, legal representatives	Project update presentation	ILUA meetings, Info sessions, execution meeting	Ongoing dialogue towards Ilua execution
11-September-2019	Meeting	DES	DES Office - Gladstone	Chris Loveday, Nicholas Williams, Mick Callan, Dave Moss	VCM overview, values and impacts, approach to PRCP	VCM approval strategy, discussed likelihood of EIS and proposal to submit well informed EA application, identified environmental values and impacts. Approach to PRCP	Ongoing consultation around submission
11-September-2019	Meeting	RG Tanner	RG Tanner Gladstone	RG Tanner, Nicholas Williams, Mick Callan, Dave Moss	VCM overview	Port operations and allocations	Ongoing consultation
13-September-2019	Meeting	BMA/BHP	BHP Office, Brisbane			Water Supply	Ongoing consultation
24-October-2019	Meeting	O'Sullivans (Saraji and Cherwell)	Saraji Station			Land purchase options / Project Update	Ongoing consultation
30-October-2019	Teleconference	DES	Teleconference Brisbane-Emerald	Allison Sinclair, Gillian Naylor, Jessica Edgar, Dave Moss	PRCP approach	PRCP approach, confirmation of submission requirements, query guideline availability - timing, scope of supporting assessments	Ongoing consultation once guideline available and understood.

Consultation date	Consultation type	Stakeholder	Location	Attendees	Information Provided	topics of discussion	outcomes/ ongoing commitments
04-November-2019	Meeting	BMA/BHP	BHP Office, Brisbane	Mick Callan, Dave Moss, Alan Hocking	Provided surface water modelling and flood assessment	Water supply, data sharing, project update, flood modelling	BHP to review and provide comment
07-November-2019	Meeting	O'Sullivans (Saraji and Cherwell)	Cherwell Station	Mick Callan, Nick Williams, O'Sullivan Family	Project update, discuss land owner plans for property	Land purchase options / Project update	Ongoing negotiation
07-November-2019	Meeting	Isaac Regional Council	Moranbah	Mick Callan, Nick Williams, Sean Robinson		Project update, road haulage. Road relocation, compensation agreement for ML	Ongoing Consultation
20-November-2019	Meeting	Isaac Regional Council	Moranbah	Mick Callan, Rob Machill, Sean Robinson	Project update and draft road relocation plans	Road relocation discussions and approval process	IRC to provide draft compensation agreement for road relocation
17-December-2019	Meeting	BMA	BMA offices Brisbane	Alan Hocking, James Zhan, Julian Orth, Mick Callan, Dave Moss	VCM Overview, water supply options	Discussed water supply options, VCM flood mapping and potential for use of mine affected water	Ongoing consultation and water supply discussion, provision of VCM project flood mapping for BMA incorporation and consideration against critical infrastructure.
13-January-2020	Meeting	Barada Barna	McCullough Robertson Lawyers	Nick William Ryan Welker, Directors and members of Barada Barna Aboriginal Corporation, legal representatives	Project update presentation	ILUA meetings, Info sessions, execution meeting	Ongoing dialogue towards ILUA execution

Consultation date	Consultation type	Stakeholder	Location	Attendees	Information Provided	topics of discussion	outcomes/ ongoing commitments
28-January-2020	Meeting	Barada Barna	Chermside Bowls Club, 468 Rode Road, Chermside	Nick William Ryan Welker, Directors and members of Barada Barna Aboriginal Corporation, legal representatives	Project update presentation	ILUA meetings, Info sessions, execution meeting	Ongoing dialogue towards ILUA execution
29-January-2020	Meeting	Barada Barna	Ipswich Best Western Hotel, 51/55 Warwick Street, Ipswich	Nick William Ryan Welker, Directors and members of Barada Barna Aboriginal Corporation, legal representatives	Project update presentation	ILUA meetings, Info sessions, execution meeting	Ongoing dialogue towards ILUA execution
17-February-2020	Meeting	BMA	BMA offices Brisbane	Alan Hocking, James Zhan, Mick Callan, Dave Moss	VCM Overview, water supply options	Discussed water supply options, confirmation of no BMA concern on impacts of VCM flood modelling on critical infrastructure at BMA operations	Ongoing consultation and water supply discussion
04-February-2020	Meeting	Mines Inspectorate	Dysart	Nick Williams, Ryan Welker, Mick Callan, Mike Cavanaugh, James Richardson, large contingent of QLD mines inspectors	Powerpoint presentation outlining the Vulcan project, our development plans and our SHMS development plans	Project update, initial consultation on SMS development	Presentation well received by inspectors, Vitrinite committed to maintaining open dialogue as the project develops
13-February-2020	Meeting	Aurizon	Vitrinite office, Brisbane	Mick Callan, James Richardson, Nick Remmelt, Tiffany Bruce	Project presentation, draft rail protection plan	Project update and discuss rail interactions	Aurizon to provide feedback on management plan and arrange follow up meetings

Consultation date	Consultation type	Stakeholder	Location	Attendees	Information Provided	topics of discussion	outcomes/ ongoing commitments
20-February-2020	Meeting	Dyno Nobel	Dysart site	Mick Callan, Dave Moss, James Richardson, Site Manager of Dyno facility		Project update, inspect facilities	Ongoing consultation
20-February-2020	Meeting	DNRME	DNRME Offices Rockhampton	DNRME Reps, Mick Callan, James Richardson, Dave Moss	VCM Update and prelodgement MLA discussions	VCM Project information provided	Ongoing consultation around submission
20-February-2020	Meeting	Kalari Transport	Kalari yard at site followed by Kalari Depot in Moranbah	Kalari Personnel, Mick Callan, James Richardson, Dave Moss	Overview of Bulk Sample Project, VCM update	Discussion of haulage operations, use of site based yard	Ongoing consultation
20-February-2020	Meeting	IRC	IRC Office Moranbah	Steve Voke, IRC personnel, Mick Callan, James Richardson, Dave Moss	VCM update, Saraji Road alignment	compensation agreements, Road Use Management Plan, approval mechanisms under the Land Act. Opportunities to present to Council	Ongoing consultation
21-February-2020	Meeting / teleconference	DES	DES Office Emerald	Chris Loveday, Chris Wakes, Gillian Naylor, Louisa Nicholson, Barbara Van der pol, Jessica Edgar, Mick Callan, James Richardson, Dave Moss	VCM prelodgement meeting and PRCP approach and information requirements	Final VCM overview, impacts and mitigation presented and discussed, discussion of off lease road alignment being approved under Land act, Presented PRCP approach and raised a number of unsuitable guideline information requirements, (landform modelling and rehab trials), BMA levee and road reserve as PMLU's	Vitrinite to supply additional info on PRCP approach to landform stability and trials (supplied), DES to provide written response confirming information requirements.

Consultation date	Consultation type	Stakeholder	Location	Attendees	Information Provided	topics of discussion	outcomes/ ongoing commitments
25-February-2020	Meeting	IRC	Dysart	Mike Cavanaugh, IRC representatives		Discussions regarding Vitrinite use of recycled water for dust suppression	Ongoing consultation
30-March-2020	Teleconference	DES	Teleconference Brisbane- DES Emerald	Emma Burgess, Tenille Neilsen, Mick Callan, Dave Moss	VCM pre-lodgement meeting and PRCP approach and information requirements	Final VCM overview, impacts and mitigation presented and discussed, discussion of off lease road alignment being approved under Land act, Presented PRCP approach, PMLU's, rehab areas proposed timing	Vitrinite to submit application in near future
14-May-2021	MS Teams	DES	Video Conference Brisbane- DES Emerald	Keeley Hartzer, Dave Moss	Pre-lodgement discussion and information requirements	VCM PRCP	Ongoing consultation
24-May-2021	MS Teams	DES	Teleconference Brisbane- DES Emerald	Emma Burgess, Keeley Hartzer, Juliana McCosker Mick Callan, Dave Moss	VCM Draft EA condition review	VCM Conditions	Ongoing consultation

Consultation date	Consultation type	Stakeholder	Location	Attendees	Information Provided	topics of discussion	outcomes/ ongoing commitments
25-October-2021	Teleconference	DES	Teleconference Brisbane- DES Emerald	Marijke Schuurs, Christine Jones	EA Amendment Application	Pre-lodgement discussion	Ongoing consultation
24-March-2022	Meeting	DES	Vulcan Coal Mine- Moranbah	DES personnel, Dave Moss, Mick Callan	Planned CHPP + Rail amendment, site tour, Vulcan South Mine presentation	VCM site overview, Pre-lodgement discussion	Ongoing consultation
12-December-2022	Meeting	DES	Vulcan Coal Mine- Moranbah	Rebecca Freese, Joshua Radloff, Andrea Wyatt, Andrew Baillie, Jamey Mitchelson.	Evidence to demonstrate compliance with milestone criteria of RM3 for RA1.	Assessment of compliance with the PRCP Schedule, sequencing of rehabilitation	Ongoing consultation

APPENDIX B

LANDHOLDER RECORD OF CONSULTATION

Record of Consultation

Attendees:	Brett Garner (BMA) Trudy Mazucco (BMA) Nicholas Williams (Vitrinite) Mick Callan (Vitrinite) Dave Moss (METServe)	**Date/ Time:**	20 March 2020 (3:00pm)
		Consultation method:	Teleconference and e-mailed supporting material
		File Ref:	VI010 (00280789-001)
SUBJECT:	Vulcan Complex Project PRCP Consultation - BMA		

Introduction

This record of consultation has been prepared to document the discussion and outcomes of consultation between representatives of Vitrinite and BMA in relation to the Vulcan Complex Project (VCP) Progressive Rehabilitation and Closure Plan (PRCP). This record of consultation is intended to support Vitrinite's PRCP Stakeholder Consultation Register, required under Section 126C(1)(c)(iii) of the *Environmental Protection Act 1994*.

Information provided to stakeholders

VCP Project stage plans and PRCP Post Mine Land Use (PMLU) and rehabilitation area Plans were provided via e-mail in advance of the meeting. Dave Moss, on behalf of Vitrinite provided a summary of the following information:

- Brief overview of the VCP
- Brief overview of the PRCP requirements
- Vitrinite's approach to preparing the VCP PRCP
- Overview of the proposed:
    - PMLU's and rehabilitation areas;
    - the distribution of the PMLU's;
    - areas not affected by the Project;
    - progressive rehabilitation activities, schedule, milestones and criteria (physical and administrative).

Points raised by stakeholders

Brett Garner provided the following comments:

- BMA expects Vitrinite to adhere to the relevant requirements of the PRCP guideline
- As Project neighbours, BMA expects its interests to be protected from offsite impacts
- As landholders, BMA expects Vitrinite to successfully rehabilitate the land disturbed by proposed mining activities.
- BMA supports in principle the proposed Post Mine Land Uses, but reserves it rights for raising issues as the process advances

Brett Garner asked the following questions in relation to the PRCP:

- Will the Mining Lease (ML), Environmental Authority (EA) and PRCP notification processes occur simultaneously?

Vitrinite response: yes they will.

- What is the proposed Project submission and approval timing?

Vitrinite response: the intention is to submit the EA application before the end of March 2020, which will hopefully facilitate finalisation and issue of the EA by September 2020.

Trudy Mazucco asked the following questions in relation to the PRCP:

- Are there likely to be any engineered structures and will they attract a residual risk payment?

Vitrinite response: we will take the question on notice and provide you with a response

- What are the likely impacts on groundwater?

Vitrinite response: a full suite of environmental assessments, to an EIS standard, have been completed to support the EA application. This includes a full groundwater model and assessment. The VCP is modelled to cause minor localised drawdown to the east and is expected to generate limited (negligible) pit in-flows. Groundwater driven pit dewatering is not anticipated.

Brett Garner and Trudy Mazucco both advised they were looking forward to seeing the full PRCP document. Vitrinite confirmed BMA would be provided with a copy of the document along with the EA application and supporting information at the time of submission.

Consultation Outcomes

The following consultation outcomes were agreed:

- BMA expects Vitrinite to adhere to the relevant requirements of the PRCP guideline;
- As Project neighbours, BMA expects its interests to be protected from offsite impacts;
- As landholders, BMA expects Vitrinite to successfully rehabilitate the land disturbed by proposed mining activities;
- BMA supports the proposed Post Mine Land Uses;
- Vitrinite will confirm whether any engineered structures will remain and whether they will likely attract a residual risk payment; and
- Vitrinite will provide a 'Record of Consultation' (this document) to BMA for review and confirmation.

Both BMA and Vitrinite confirm this is an accurate record of consultation.





…… ……

on behalf of BMA on behalf of Vitrinite

Brett Garner (0417 712009)

……26/3/20……. ….26/03/2020…….

Date Date

Appendix F- Landform Evolution Modelling

Vulcan Coal Mine

Landform Evolution Modelling Study

Vitrinite Pty Ltd
1571-21-B2, 2 December 2022

Report Title	Vulcan Coal Mine, Landform Evolution Modelling Study
Client	Vitrinite Pty Ltd
Report Number	1571-21-B2

Revision Number	Report Date	Report Author	Reviewer
0 [DRAFT]	17 November 2022	RN	JO/GR
1	30 November 2022	RN	JO/GR
2	2 December 2022	RN	JO/GR

For and on behalf of WRM Water & Environment Pty Ltd
Level 9, 135 Wickham Tce, Spring Hill
PO Box 10703 Brisbane Adelaide St Qld 4000
Tel 07 3225 0200

Greg Roads

Senior Principal Engineer

NOTE: This report has been prepared on the assumption that all information, data and reports provided to us by our client, on behalf of our client, or by third parties (e.g. government agencies) is complete and accurate and on the basis that such other assumptions we have identified (whether or not those assumptions have been identified in this advice) are correct. You must inform us if any of the assumptions are not complete or accurate. We retain ownership of all copyright in this report. Except where you obtain our prior written consent, this report may only be used by our client for the purpose for which it has been provided by us.

Contents

1 Introduction 5
1.1 Overview 5
1.2 Report structure 5
2 Methodology 8
2.1 Overview 8
2.2 Modelling approach 8
2.3 Available data 9
2.3.1 Topography 9
2.3.2 Soil and land suitability 9
2.3.3 Geotechnical assessment 10
2.3.4 Geochemistry assessment 10
2.4 Rehabilitation criteria 11
2.5 SIBERIA model parameters 14
2.6 Model calibration 14
2.7 Erosion risk assessment criteria 15
3 Findings 16
3.1 Representative slope assessment 16
3.2 Application to proposed landforms 23
3.2.1 General 23
3.2.2 Jupiter in-pit and Matilda in-pit WRD 23
3.2.3 Ex-pit WRD 23
4 Summary and recommendations 26
4.1 Landform assessment 26
4.2 Recommendations 27
4.3 Limitations 27
5 References 28

List of Figures

Figure 1.2 – Final landform and rehabilitation areas at the Vulcan Coal Mine _____ 7
Figure 2.1 – Cover design to optimise plant growth _____ 11
Figure 3.1 – Predicted rill/gully erosion for Scenario 1 – Bare earth (pre-vegetation) for representative slope, 100 year simulation _____ 18
Figure 3.2 – Predicted rill/gully erosion for Scenario 2 – 30% rock mulch (pre-vegetation) for representative slope, 100 year simulation _____ 19
Figure 3.3 – Predicted rill/gully erosion for Scenario 3 – 30% rock mulch and 30% grass cover for representative slope, 100 year simulation _____ 20
Figure 3.4 – Predicted rill/gully erosion for Scenario 4 – 30% rock mulch and 50% grass cover for representative slope, 100 year simulation _____ 21
Figure 3.5 – Predicted rill/gully erosion for Scenario 5 – 30% rock mulch and 70% grass cover for representative slope, 100 year simulation _____ 22
Figure 3.6 – Predicted rill/gully erosion for Scenario 5 – 30% rock mulch and 70% grass cover for the Jupiter and Matilda in-pit waste rock dumps, 100 year simulation _____ 24
Figure 3.7 – Predicted rill/gully erosion for Scenario 5 – 30% rock mulch and 70% grass cover for the ex-pit waste rock dump, 100 year simulation _____ 25

List of Tables

Table 2.1 – Predicted soil erosion rates of the Limpopo SMU as a factor of slope and cover from *Table 6-4* of the Draft PRCP _____ 9
Table 2.2 – Rehabilitation objectives, indicators and completion criteria outlined in *Table 5-1* of the Draft PRCP (METServe, 2022) _____ 12
Table 2.3 – SIBERIA model parameters _____ 14
Table 2.4 – Adopted SIBERIA model parameters _____ 14
Table 2.5 – Representative slope calibration results _____ 15
Table 2.6 – Erosion risk assessment criteria _____ 15
Table 3.1 – Erosion risk assessment results _____ 16
Table 4.1 – Summary of erosion risk _____ 26

1 Introduction

1.1 OVERVIEW

The Vulcan Coal Mine (VCM) is a small-scale open-cut mine located to the southeast of Moranbah, in Central Queensland. Queensland Coking Coal Pty Ltd (QCC) and Queensland Coal Aust. No. 1 Pty. Ltd. (QCA1) hold the coal tenure associated with the VCM. Vitrinite Pty. Ltd. (Vitrinite) is the majority owner of both companies and, as such, Vitrinite is the proponent of the VCM. The Project is located on Mining Lease (ML) 700060. The location of the Exploration Permits (Coal) (EPCs) and the Project ML area are shown in Figure 1.1.

A Progressive Rehabilitation and Closure Plan (Draft PRCP) (METServe, 2022) for the Project is being prepared to meet the requirements of section 126C and 126D of the Environmental Protection Act 1994 (EP Act) and the *Guideline – Progressive rehabilitation and closure plans* (PRCP guideline) (DES, 2021). Section 3.6.1 of the PRCP guideline (DES, 2021) outlines that final landform design is a key component of rehabilitation and closure planning.

The Draft PRCP provides rehabilitation goals and the methodology proposed to meet these goals including the proposed cover designs for the three Post-closure Mining land use (PMLU) rehabilitated landforms. The Department of Environment and Science (DES) has reviewed the Draft PRCP and has requested further information on the following:

- *'The level of environmental risk will be substantially increased by placing rejects materials in the waste rock dumps. This can be expected to increase the risk of potential environmental contaminants being released should the landform not be in a stable condition post closure. The current slope stability assessment and erosion assessment is no longer sufficient to demonstrate long-term stability of the final landform design'*; and
- *'As set out in the paragraphs on Landform design in Section 3.6.1 of the PRCP guideline, landform evolution modelling (LEM) is required to provide an analysis of future stability of the final landform and justify that the targeted landform design objectives are reasonable and can be met.'*

WRM Water & Environment Pty Ltd (WRM) has been engaged to undertake the LEM assessment to address the above information request for the three waste rock dump (WRD) landforms. These WRD's are shown in Figure 1.2 and defined as Rehabilitation Area 1 (RA1) and Rehabilitation Area 2 (RA2) in Table 6-1 of the Draft PRCP and include the:

- Ex-pit WRD (RA1);
- Jupiter in-pit WRD (RA2); and
- Matilda in-pit WRD (RA2).

The LEM assessment undertaken as part of this report tests the adequacy of the proposed WRD embankment slope and cover design detailed in the Draft PRCP. The results of the assessment can be used to inform landform rehabilitation design, demonstrate how the results support the current targeted landform rehabilitation objectives and demonstrate the requirements for long-term stability of the landforms.

1.2 REPORT STRUCTURE

The report has been structured as follows:

- Section 2 presents the methodology used to undertake the LEM assessment;
- Section 3 summarises the findings of the assessment;
- Section 4 discusses recommendations as an outcome of the study; and
- Section 5 is a list of references.

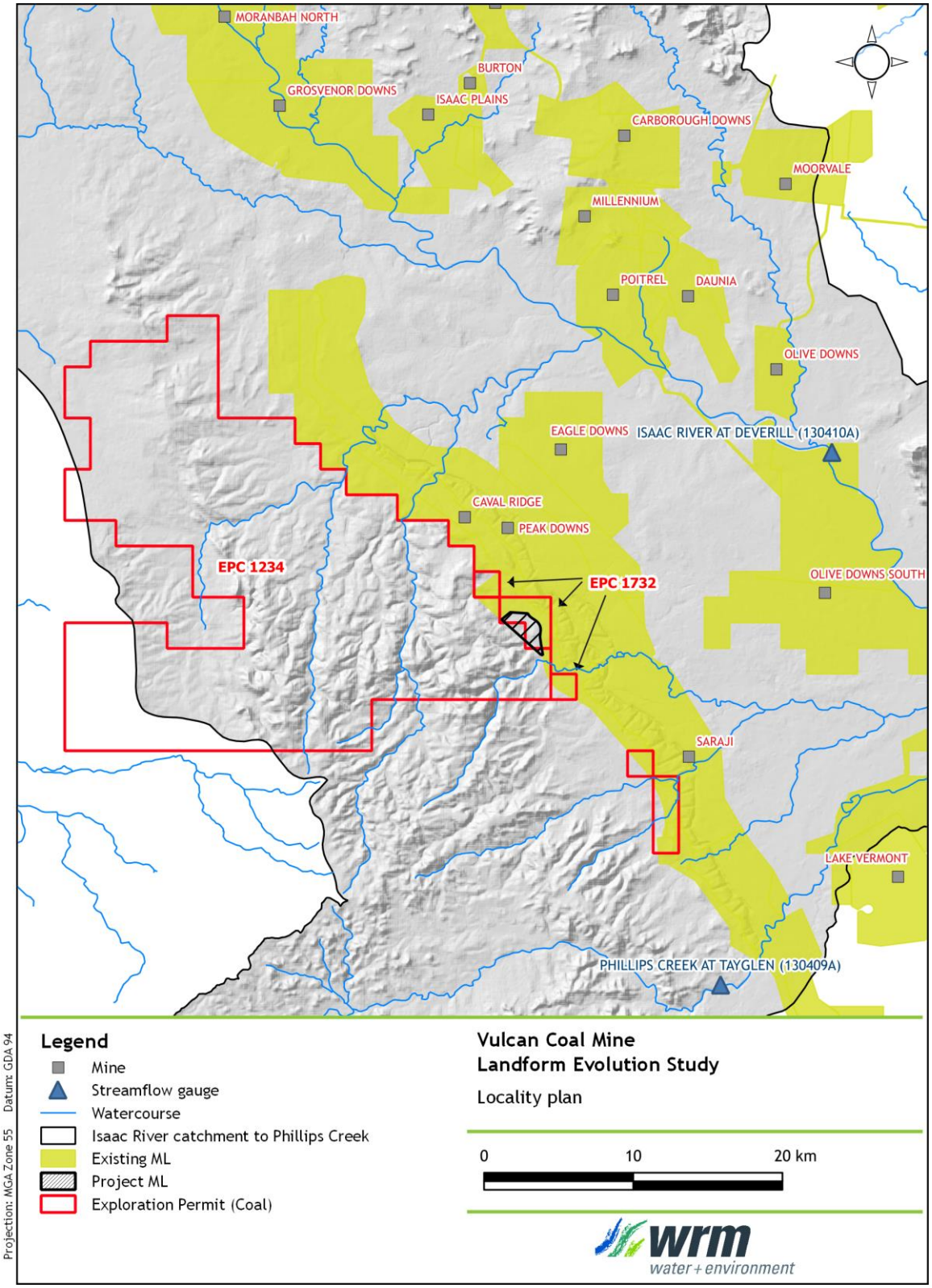


Figure 1.1 – Locality

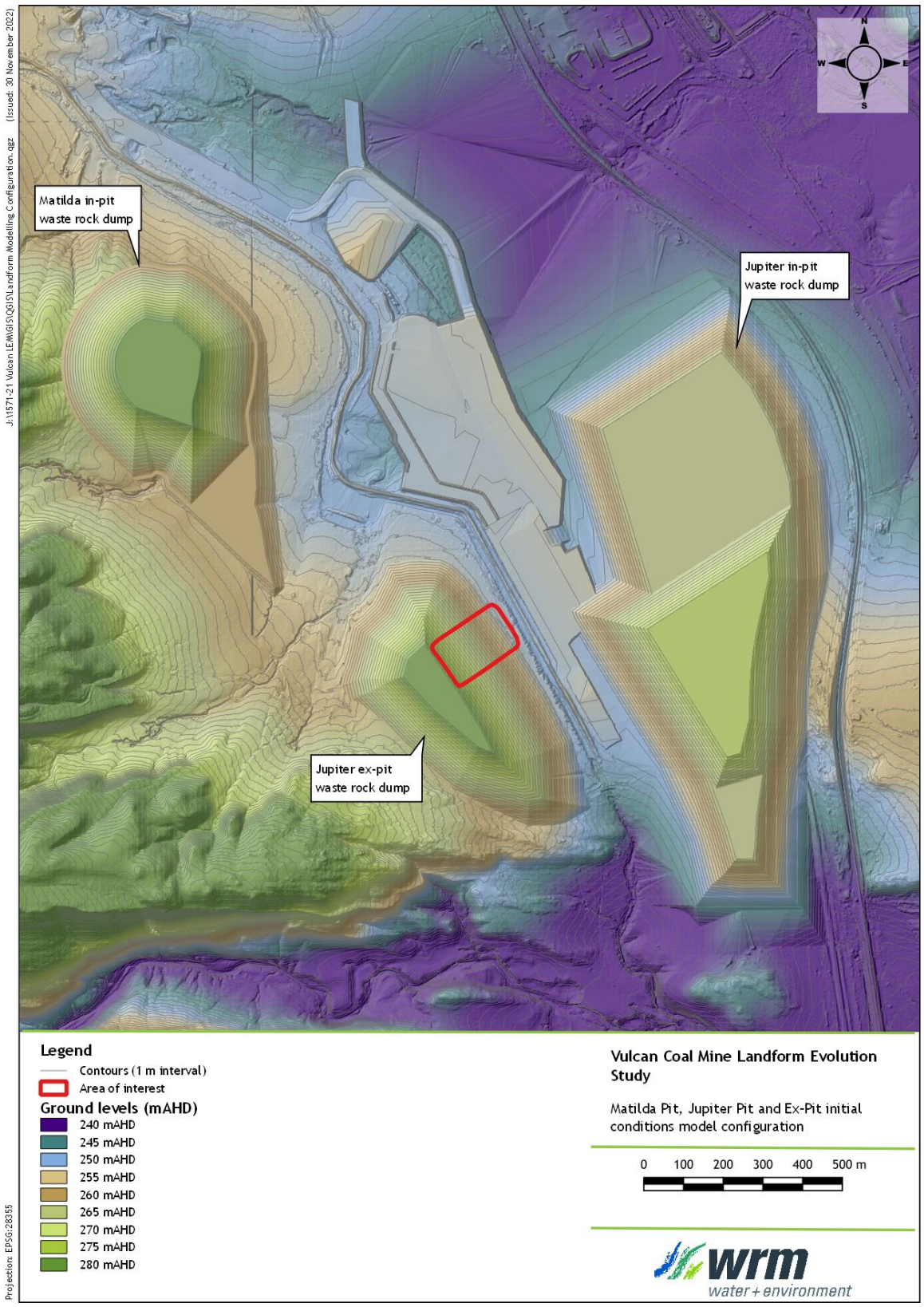


Figure 1.2 – Final landform and rehabilitation areas at the Vulcan Coal Mine

2 Methodology

2.1 OVERVIEW

This section of the report describes the methodology used to undertake the LEM assessment. Construction of the final landform including the cover, final slope and drainage has not yet been completed and detailed designs of the landforms have not been developed. To address the information request, the LEM assessment has focussed on the design of the embankment slope and cover.

Figure 1.2 shows a digital elevation model (DEM) of the final landform at VCM. The three WRDs incorporate batter slopes of 15% and a relatively flat plateau. The longest batter slope on the three landforms (excluding proposed batter drainage) is located on the ex-pit WRD at the area of interest shown in Figure 1.2. This batter slope is 180 m long from the crest to the toe. The longest batter slope on the Matilda in-pit WRD is 140 m and on the Jupiter in-pit WRD is 160 m.

The assessment has therefore focussed on the ex-pit WRD batter slope, which is called the representative batter slope in this report. If this batter slope is shown to be acceptable, it can be inferred that the other batter slopes would be acceptable because they have the same slope and cover design.

The following rehabilitation scenarios, obtained from the Draft PRCP, were assessed using the LEM:

- Scenario 1: Bare earth/unvegetated landform slope representing a failed vegetative establishment phase during early years of rehabilitation;
- Scenario 2: Rock mulched landform (30% rock mulching) prior to vegetation establishment;
- Scenario 3: Rock mulched landform (30% rock mulching) with 30% grass/vegetation cover;
- Scenario 4: Rock mulched landform (30% rock mulching) with 50% grass/vegetation cover; and
- Scenario 5: Rock mulched landform (30% rock mulching) with 70% grass/vegetation cover representing successful rehabilitation of the landform.

The assessment provides information on the ability of different cover management scenarios to resist erosion assuming no drainage works are undertaken. The proposed drainage would potentially reduce the batter slopes, at least in the short term to further assist in the management of erosion of the batter.

2.2 MODELLING APPROACH

The LEM tool SIBERIA within the CAESAR-lisflood (CAESAR) platform was used for the assessment. SIBERIA is a geomorphological / landscape evolution model that simulates catchment erosion and depositions for time scales from hours to 1000's of years. SIBERIA models soil erosion and deposition of the landforms by assessing rainfall-runoff drainage directions which are used to determine the area contributing/flowing through grid cells of the model. The model then calculates continuity equations for flow and sediment transport which determines erosion rates/depths output by the model.

The model parameters were first validated against the predicted soil loss rates provided in the Draft PRCP which are based on localised parameters (local rainfall erosivity, Limpopo soil erodibility, etc.). The validated parameters were then used to assess the erosion potential of the representative batter slope. The above rehabilitation scenarios for the representative batter slope were assessed for two timescales including:

- The first 10 years post mining to represent the establishment phase of site rehabilitation; and

- A period of 100 years post mining.

The LEM assessment was then undertaken for all three WRD's to provide an indication of what the landforms would look like after 100 years.

2.3 AVAILABLE DATA

The key input parameters to SIBERIA include:

- The proposed landform design in .DXF file format (see Section 2.3.1);
- Sediment and particle distribution information and sediment transport information representative of the materials proposed to be used for rehabilitation of the landform (see Section 2.3.2);
- Geotechnical data of the rehabilitated WRDs (see Section 2.3.3); and
- Geochemistry of the waste rock material (see Section 2.3.4).

2.3.1 Topography

Figure 1.2 shows the digital elevation model (DEM) of the proposed concept final landform provided by Vitrinite. The DEM of the Jupiter in-pit, Matilda in-pit and the ex-pit WRDs were provided by Vitrinite and dated 21 October 2021, 15 July 2022, and 1 October 2021, respectively. The DEMs were processed using 12D and QGIS software prior to input to the CAESAR model. The input resolution to CAESAR was a 2 m grid cell size.

The concept DEMs do not include the suite of drainage measures that are proposed for the WRD plateau and embankments. Therefore, model results using the concept DEMs are slightly conservative as the inclusion of these drainage measures would reduce erosion risks.

2.3.2 Soil and land suitability

AARC prepared the *Vulcan Complex Project Soil and Land Suitability Assessment* (AARC, 2021) report for the Project, herein referred to as the soils report. The soils report documents the characteristics of the existing material available for use for the rehabilitation of the WRDs.

The soils report (AARC, 2021) notes that the surface soils across the Project area mainly consist of the Limpopo soil management unit (SMU) and these soils are proposed to be used for the rehabilitation of the WRD's. The topsoil is dominated by sand (88%) with 8% silt, 3% clay and 1% gravel. The sandy surface soils are non-sodic and not likely to be vulnerable to dispersion. However, clay subsoils (below 0.5 m) are sodic and susceptible to dispersion.

The soils report derived the erosion rates specific to the Limpopo SMU using the Revised Universal Soil Loss Equation (RUSLE). RUSLE is calculated using rainfall erosivity (for local conditions), soil erodibility, slope-length gradients, cover and management, and conservation/support practice factors. Table 2.1 summarises the predicted erosion rates for the proposed cover management strategies using the Limpopo SMU.

Table 2.1 – Predicted soil erosion rates of the Limpopo SMU as a factor of slope and cover from *Table 6-4* of the Draft PRCP

Scenario	Cover management	C	Gradient (%)	A (t/ha.y)
1	Bare ground (pre-vegetation)	1.000	15	306.4
2	30% rock mulch (pre-vegetation)	0.325	15	99.58
3	30% rock mulch with 30% grass cover	0.100	15	30.64
4	30% rock mulch with 50% grass cover	0.050	15	15.32
5	30% rock mulch with 70% grass cover	0.018	15	5.52

2.3.3 Geotechnical assessment

Blackrock Mining Solutions Pty Ltd (Blackrock) prepared the geotechnical assessment memorandum *Vulcan Complex – Jupiter Final Landform Slope Stability Assessment* (Blackrock, 2020) for the Project, herein referred to as the geotechnical report. The geotechnical report assessed the stability of the proposed WRD embankment design, which was based on a 15% batter slope and the proposed cover design. The following methodology was used to undertake the slope stability assessment:

- *Circular failure analyses using the auto-refine search algorithm and the general limit equilibrium method (GLE) for spoil failures;*
- *A basal saturated spoil layer of approximately 5 m thickness was assumed for both scenarios; and*
- *Adopting the generally accepted Factor of Safety (FoS) criteria for long-term slopes of greater than 1.5.*

The geotechnical report found that the Jupiter in-pit, Matilda in-pit and the ex-pit WRD landforms would meet the final landform design, and long-term geotechnical stability criteria.

2.3.4 Geochemistry assessment

RGS Mine Waste and Water Management prepared the following waste rock material geochemistry assessment reports for the Project (herein referred to as the geochemistry reports):

- VI010_VCM Matilda Pit Geochemistry Assessment_ September 2022 (RGS, 2022a); and
- Geochemical Assessment of Waste Rock, Coal Reject and Coal (RGS, 2022b)

The geochemistry reports document the characteristics of the waste rock material proposed to be emplaced to form the post-mining Jupiter in-pit, Matilda in-pit and the ex-pit WRD landforms. A summary of the conclusions of the geochemistry reports on the waste rock material are as follows:

- *The overwhelming majority of the waste rock materials have low sulfide content, excess ANC, and are classified as NAF (Barren). These materials have a very low risk of acid generation and a high factor of safety with respect to potential for generation of acidity.*
- *Coal reject materials have relatively low sulfide content and excess ANC. As a bulk mixed material, it is expected that coal reject will be classified as NAF and have a relatively low risk of generating acidic drainage. Co-disposal of reject materials in waste rock dumps is likely to have a beneficial impact on the quality of the reject leachate.*
- *Coal is likely to have similar geochemical characteristics to coal reject materials and will be temporarily stockpiled at the ROM area prior to being transferred to the CHPP. As is standard practice at coal mining operations in the Bowen Basin, any surface runoff and seepage from the ROM coal stockpile will be monitored for quality and managed in the mine water management system as part of the Water Management Plan.*
- *Initial and ongoing surface runoff and seepage from mining waste materials is expected to be pH neutral to slightly alkaline and have a low level of salinity.*
- *There is no significant metal/metalloid enrichment in mining waste materials compared to applied guideline values and median crustal abundance in un-mineralised soils.*
- *Most metals/metalloids are sparingly soluble at the neutral to slightly alkaline pH of leachate expected from bulk NAF mining waste materials. Dissolved metal/metalloid concentrations in surface runoff and leachate from bulk NAF mining waste materials are expected to be low and unlikely to pose a significant risk to the quality of surface and groundwater resources at relevant storage facilities.*
- *NAF waste rock materials should be amenable to revegetation as part of rehabilitation activities, although, gypsum and fertiliser addition may need to be considered for sodic*

materials to limit dispersion and erosion and to provide a reasonable growth medium for revegetation and rehabilitation.

2.4 REHABILITATION CRITERIA

Figure 2.1 shows the recommended cover design to optimise plant growth for rehabilitation of the Jupiter in-pit and Matilda in-pit WRD landforms, obtained from the Draft PRCP. The topsoil layer is proposed to allow a suitable vegetative cover to establish to prevent erodibility of the landform. Due to timing, there will be insufficient subsoil material available for the ex-pit WRD. For this landform, the cover design will consist of the topsoil layer emplaced directly onto the waste rock layer. Where required, gypsum, organic matter and fertilizer will be mixed with the waste rock materials to reduce the sodicity and reduce the potential for dispersion and erosion (RGS, 2022b).

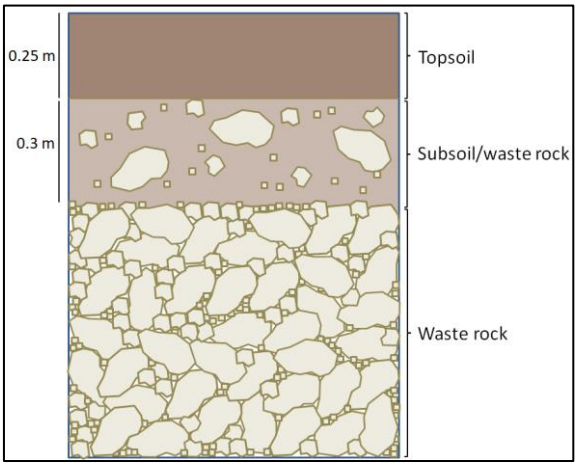


Figure 2.1 – Cover design to optimise plant growth

The Draft PRCP also provides defined rehabilitation goals for each PMLU. The criteria of relevance to this assessment are summarised in Table 2.2. The following is of note from the Draft PRCP:

- *Despite no need for a cover that protects waste rock from oxidation, waste rock will be placed in such a way to facilitate vegetation re-establishment. Following the return of waste rock to the open cut pit, at least 300 mm of subsoil (removed from the pits prior to mining and stockpiled) is to be spread over the rock. This will enhance the water-holding capacity of the soil and provide a more favourable growing environment for vegetation. Given the vulnerability of local subsoils to dispersion, some waste rock will be mixed with the subsoil (approximate ratio of rock to subsoil of 1:3), to provide protection from erosion, in the unexpected event that that rock mulch cover and developing grass cover doesn't provide adequate protection, and the overlying topsoil becomes eroded in places.*
- *Topsoil will be spread over the subsoil/rock mix at a depth of 250 mm to provide a favourable medium for plant establishment. Note that this cover design varies slightly between rehabilitation areas due to material availability and rehabilitation requirements. In addition a number of topsoil and subsoil ameliorative measures will be implemented, wherever required, to ameliorate poor soil structure, low moisture retention and low nutrient concentrations that may be encountered with the Limpopo SMU.*
- *Amelioration measures that can be utilised where required, include the application of organic matter, fertiliser, rapid establishing cover crops, and hydro mulching.*

Table 2.2 – Rehabilitation objectives, indicators and completion criteria outlined in *Table 5-1* of the Draft PRCP (METServe, 2022)

ID	Rehabilitation Objective	Rehabilitation Indicator	Assessment Timing	Completion Criteria	Justification
PMLU A: Low-intensity cattle grazing					
A1	Land is to be stable	a) Indices of Landscape Function Analysis (Tongway and Hindley 2004). b) Depth of active rills and gullies	Sites are to be monitored at the time of planting and then every two years for 10 years after planting.	a) Landscape function analysis scores for soil stability, infiltration/runoff and nutrient cycling have started to plateau, and the plateau values predicted from sigmoidal curves fitted to the data are equivalent to or exceed values at analogue sites. b) No active rill or gully erosion deeper than 15 cm present.	a) This methodology has been widely applied to rehabilitated mine sites across Australia, and is strongly correlated with soil aggregate stability, soil nutrient cycling and water infiltration (Tongway and Hindley, 2004). b) Provides a supplementary observational method of early erosion detection and early intervention.
		Percentage cover of rock, woody debris, litter, grasses and herbs within a 10 m x 50 m plot.	Late wet season (February-May), every two years for 10 years after planting.	Grazed land maintains a percentage groundcover of between 50% and 96% on slopes up to 10% and between 70% and 96% on slopes between 10-15%.	A percentage cover of ^{3}50% protects slopes from erosion (Loch 2000; Waters 2004; Carroll *et al.* 2010). Cover ^{3}70% is required to achieve background rates of erosion on slopes steeper than 10% (AARC 2021). Excessive groundcover inhibits the recruitment of trees and shrubs, and a maximum value of 96% cover was observed within reference sites in stable, unmined vegetation communities (METServe 2020).
A2	Land is to be non-polluting	Levels of contamination present following remediation efforts that take place after infrastructure decommissioning and removal.	Prior to the commencement of topsoil placement.	A site suitability statement prepared by an approved auditor is to conclude that land is not contaminated and is suitable for the PMLU.	This indicator requires assessment to achieve rehabilitation milestone 2, but does not need to be re-assessed at rehabilitation completion unless a new source of potential contamination occurs (e.g., a hydrocarbon spill).
		Water quality at permanent monitoring locations downstream of the Mine.	Annually, following rain events.	Surface water in downstream monitoring locations is to remain within site-specific water quality monitoring limits listed in environmental authority EA0002912 (Table 5-3 of the PRCP).	Site-specific surface water quality triggers are based on baseline surveys undertaken at the site.
		Groundwater quality within permanent monitoring bores.	Quarterly.	Groundwater in downstream monitoring bores remains within site-specific water quality monitoring limits detailed in environmental authority EA0002912 (Table 5-3 of the PRCP).	Site-specific surface water quality triggers are based on baseline surveys undertaken at the site.

ID	Rehabilitation Objective	Rehabilitation Indicator	Assessment Timing	Completion Criteria	Justification
A3	Koala food trees are to have a similar dominance within rehabilitated vegetation communities (except RA1) as they did in vegetation present on site prior to mining.	Proportion of the total basal area of woody vegetation at the site that comprises *Eucalyptus crebra*, *Eucalyptus populnea* or *Eucalyptus camaldulensis*.	Sites are to be monitored six and ten years after planting.	*Eucalyptus crebra* and/or *Eucalyptus populnea* are to constitute ≥21% of the total basal area of woody vegetation on sand plains. **AND** *Eucalyptus camaldulensis* is to constitute ≥33% of the total basal area of woody vegetation along Ripstone Creek and Drainage Line 2.	Relative dominance of Koala food trees is based on secondary site data gathered from nine sand plain reference sites and three riparian reference sites (METServe 2020).
	Trees are to be sufficiently tall to be used by Koalas and to escape browsing by cattle (except RA1).	Mean height of the tallest ten trees per hectare	Sites are to be monitored six and ten years after planting.	The mean height of the tallest ten trees per hectare is ≥4 m.	The Queensland Environmental Offsets Policy defines non-juvenile Koala habitat trees to be those with a height greater than 4 m (DES 2020). Such trees are also beyond the reach of cattle.
A4	Density of woody vegetation within rehabilitated areas (except RA1) is to be sufficient for Squatter Pigeons.	The mean Normalised Difference Vegetation Index (NDVI) calculated using Landsat imagery captured following at least two months without rain (e.g., late dry season).	Sites are to be monitored at the time of planting and then every two years for 10 years after planting.	Rehabilitated areas have a mean NDVI between 0.1240 and 0.1778	Ecological surveys of the local region found that Squatter Pigeons are confined to vegetation with a density that falls within the range of NDVI values used as the completion criterion (METServe 2020).

2.5 SIBERIA MODEL PARAMETERS

Table 2.3 shows the SIBERIA model parameters that are used to define the landform evolution and mean annual erosion. The Beta1 parameter represents the different cover types, which was derived iteratively to match the predicted erosion rates given in the draft PRCP for each cover type. Table 2.4 shows adopted parameters for each cover management scenario.

Table 2.3 – SIBERIA model parameters

Parameter	Description
Beta1	*Coefficient b1 in the fluvial sediment transport formula*
Beta3	*Coefficient between discharge and area in the sediment transport formula*
m1	*Exponent on the discharge m1 in the sediment transport formula*
m3	*Exponent on the area in discharge used in the sediment transport*
n1	*Exponent on this slope n1 in the sediment transport formula*

Source: User Manual for SIBERIA (Version 8.30) (Wilgoose, G., 2005)

Table 2.4 – Adopted SIBERIA model parameters

Scenario (see Section 2)	Parameter				
	Beta1	Beta3	m1	m3	n1
1	*0.01780*	*1*	*1.5*	*1*	*2*
2	*0.00560*	*1*	*1.5*	*1*	*2*
3	*0.00164*	*1*	*1.5*	*1*	*2*
4	*0.00082*	*1*	*1.5*	*1*	*2*
5	*0.00030*	*1*	*1.5*	*1*	*2*

2.6 MODEL CALIBRATION

Table 2.5 compares the average erosion rates in tonnes per hectare per year predicted by the SIBERIA model and those given in the Draft PRCP and shown in Table 2.1 for the five proposed landform cover management scenarios. To be consistent with the values given in the Draft PRCP, the SIBERIA model results are provided for the average erosion rate for the 15% landform slope after 100 m of slope travel across 100 m. The average erosion rate was calculated using a cross sectional average of erosion depths across the landform embankment (at 100 m) over a 10-year simulation.

Overall, the adopted SIBERIA model parameters shown in Table 2.4 produces erosion rates similar to the values estimated in the Draft PRCP (using the RUSLE) for the five proposed landform surfaces. Note that the predicted erosion rates are based on theoretical assessments and are not derived from field observed erosion data, meaning they are only suitable for comparative purposes only. The erosion rates within the model were scaled to match theoretical calculations for predicted soil losses and therefore predictions produced by the model are somewhat predetermined.

The approach used for this assessment should be validated once the post-mining landform is established. This can be undertaken once data has been collected from the rehabilitated landform by comparing observed rill/deposition depths over cross-sectional areas of the landform to the calculated rates.

Table 2.5 – Representative slope calibration results

Scenario	Average erosion rate (t/ha.y)		Difference
	RUSLE[a]	Siberia Model	
1 – Bare earth (pre-vegetation)	306.40	306.95	0.2%
2 - 30% rock mulch (pre-vegetation)	99.58	98.70	-0.9%
3 - 30% rock mulch with 30% grass cover	30.64	30.74	0.3%
4 - 30% rock mulch with 50% grass cover	15.32	15.32	0.0%
5 - 30% rock mulch with 70% grass cover	5.52	5.58	1.1%

[a] Values adopted from Table 6-4 of the Draft PRCP

2.7 EROSION RISK ASSESSMENT CRITERIA

For this assessment, erosion depth has been used as the erosion risk assessment criteria as given in Table 2.6. Erosion risk assessment criteria was derived from the rehabilitation criteria (see Section 2.4) for the landforms and the milestones outlined in the Draft PRCP. It was deemed that erosion model outcomes which achieved a very low erosion risk would satisfy the rehabilitation criteria and the landform cover design could be considered stable.

Table 2.6 – Erosion risk assessment criteria

Erosion risk	Erosion depth (m)	Observations
Very Low	< 0.15	• Erosion depth only affecting uppermost topsoil layer. • Land is stable, only minor active rills or gully erosion no deeper than 0.15 m. • Negligible effects on receiving environment. • Vegetative cover established and effective.
Low	0.15 – 0.25	• Erosion depth affecting up to the topsoil layer. • Land is stable, only minor active rills or gully erosion no deeper than 0.25 m. • Minor risk of sedimentation to downstream waterways. • Reduced ability for topsoil layer to restore cover over time.
Moderate	0.25 – 0.55	• Erosion depth affecting topsoil layer and subsoil layers in some areas of the landform. • Increased sedimentation of downstream waterways. • Exposure of subsoil/waste rock material to runoff (however classified NAF and unlikely to generate saline runoff).
High	> 0.55	• Erosion depth greater than topsoil layer and rehabilitative cover has failed. • Great risk of sedimentation of downstream waterways. • Exposure of compacted waste rock material to runoff (however classified NAF and unlikely to generate saline runoff). • Rehabilitation works required to restore cover.

Note: Erosion risk criteria was derived based on rehabilitation objectives outlined in the Draft PRCP

3 Findings

3.1 REPRESENTATIVE SLOPE ASSESSMENT

Table 3.1 summarises the erosion risk assessment results for the full length of the representative slope for the five proposed cover management scenarios. Results are provided for the maximum erosion depths across the representative slope after 180 m. This is the longest slope length proposed across the proposed final landform. To minimise error caused by boundary effects, the maximum erosion depth along the slope was assessed above the end of the batter slope and landform toe drain as the drainage configuration along the toe of the landforms are yet to be finalised and will likely include some form of keying to prevent erosion.

Table 3.1 – Erosion risk assessment results

Scenario	Maximum erosion depth (m)	
	10-year model simulation	100-year model simulation
1 – Bare earth (pre-vegetation)	0.61	1.65
2 - 30% rock mulch (pre-vegetation)	0.27	1.30
3 - 30% rock mulch with 30% grass cover	0.17	0.69
4 - 30% rock mulch with 50% grass cover	0.15	0.39
5 - 30% rock mulch with 70% grass cover	0.10	0.14

Figure 3.1 to Figure 3.5 show figures of the final landform along the representative slope for the five rehabilitation scenarios after 100 years. The following is of note:

- Scenario 1 – Bare earth (pre-vegetation) has a high erosion risk for both the 10-year and 100-year simulations. For the 100-year simulation (shown in Figure 3.1):
  - Rilling and gully erosion exceeds high erosion risk criteria along the full length of the embankment. Erosion depth greater than topsoil/subsoil layers;
  - Failure of rehabilitative cover and entire embankment slope and will require remediation works to re-establish cover;
  - Subsoil layer and compacted waste rock material layers would be exposed to environment; and
  - Great risk of sedimentation transported to the existing diversion drain with potential impact downstream receiving waters.
- Scenario 2 – 30% rock mulch (pre-vegetation) has a moderate erosion risk for the 10-year and high erosion risk for the 100-year simulations. For the 100-year simulation (shown in Figure 3.2):
  - Rilling and gully erosion exceeds high erosion risk criteria along the majority of the length of the embankment. Erosion depth greater than topsoil/subsoil layers;
  - Majority of the rehabilitative cover and embankment slope would fail and will require remediation works to re-establish cover;
  - Subsoil layer and compacted waste rock material layers exposed to environment; and
  - Great risk of sedimentation transported to the existing diversion drain with potential impact downstream receiving waters.

- Scenario 3 – 30% rock mulch and 30% grass cover has a low erosion risk for the 10-year and high erosion risk for the 100-year simulations. For the 100-year simulation (shown in Figure 3.3):
  - Rilling and gullying along the majority of the embankment. Erosion depth greater than topsoil/subsoil layers;
  - Embankment fails less than 100 m down the face of the slope;
  - Subsoil/waste rock material layer exposed to environment; and
  - Great risk of sedimentation transported to the existing diversion drain with potential impact downstream receiving waters.
- Scenario 4 – 30% rock mulch and 50% grass cover has a low erosion risk for the 10-year and moderate erosion risk for the 100-year simulations (shown in Figure 3.4):
  - Rilling/gullying exceeding the low erosion risk threshold toward lower half of the proposed landforms as slope lengths increase and therefore erosion rates increase.;
  - The upper slopes are relatively stable (but rills exceed rehabilitation criteria depths);
  - Some of the embankment may require remediation to ensure cover remains suitable; and
  - Downstream diversion drain may receive sediment loads greater than background rates.
- Scenario 5 - 30% rock mulch and 70% grass cover has a very low erosion risk for both the 10-year and 100-year simulations. For the 100-year simulation (shown in Figure 3.5):
  - Rilling/gullying exceeding the very low criteria occurs toward the toe of the proposed landforms below about 180 m of slope length;
  - The upper slopes are suitably stable, vegetative cover is established and effective; and
  - Minor sedimentation occurs which is generally captured within the toe drain of the proposed landform (to be diverted to sediment dams). Negligible sedimentation of the receiving waterway occurs as a result.

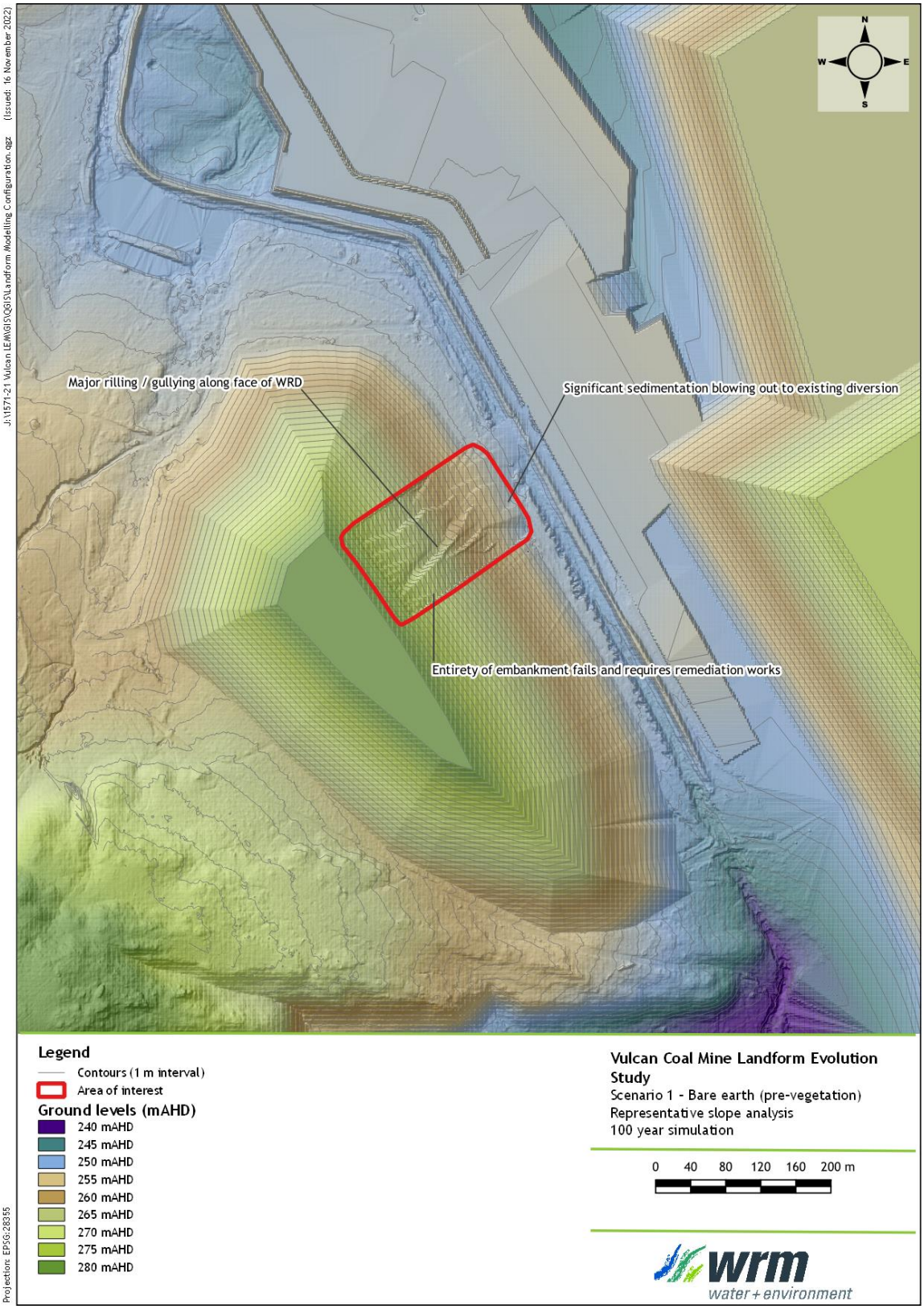


Figure 3.1 – Predicted rill/gully erosion for Scenario 1 – Bare earth (pre-vegetation) for representative slope, 100 year simulation

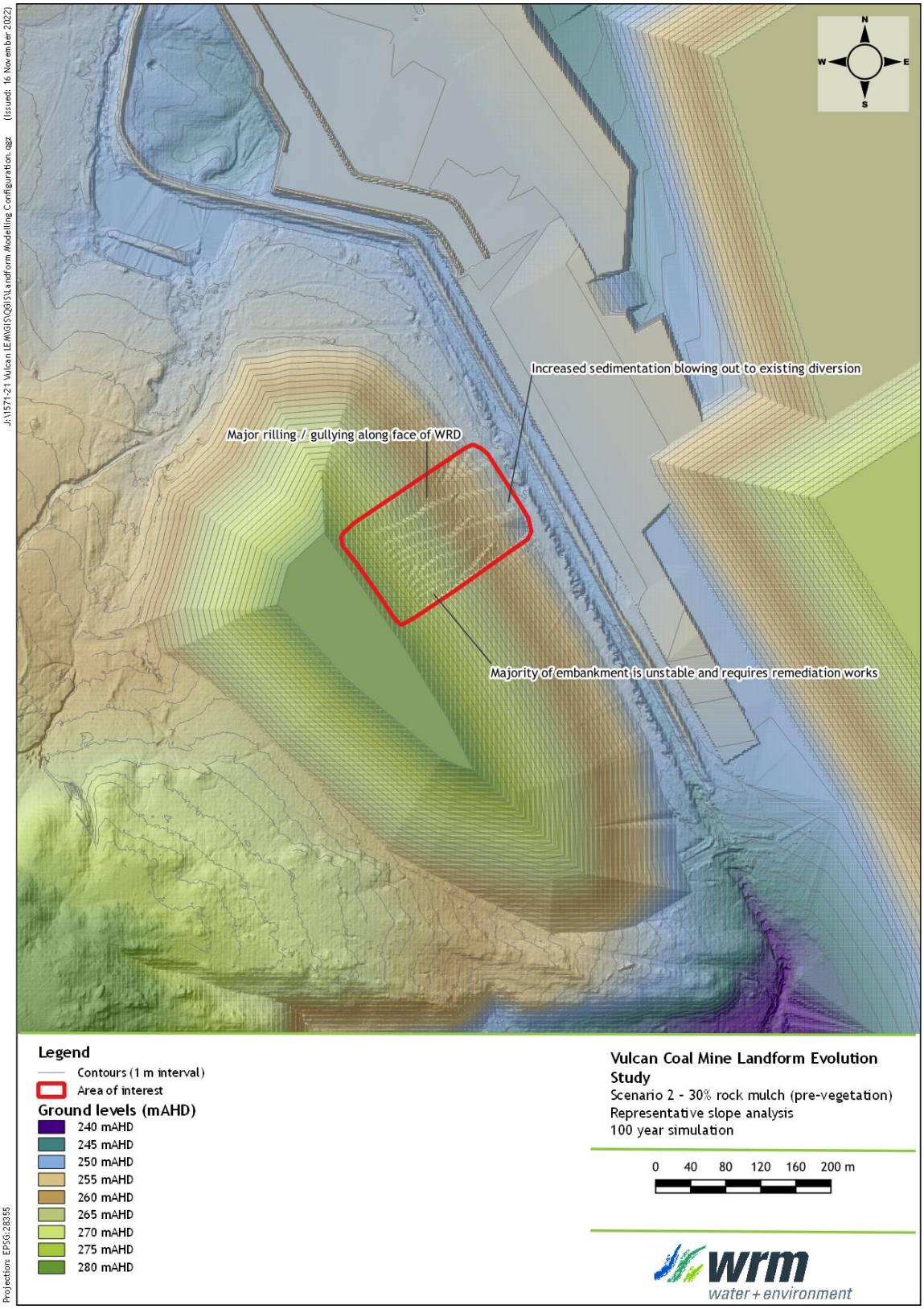


Figure 3.2 – Predicted rill/gully erosion for Scenario 2 – 30% rock mulch (pre-vegetation) for representative slope, 100 year simulation

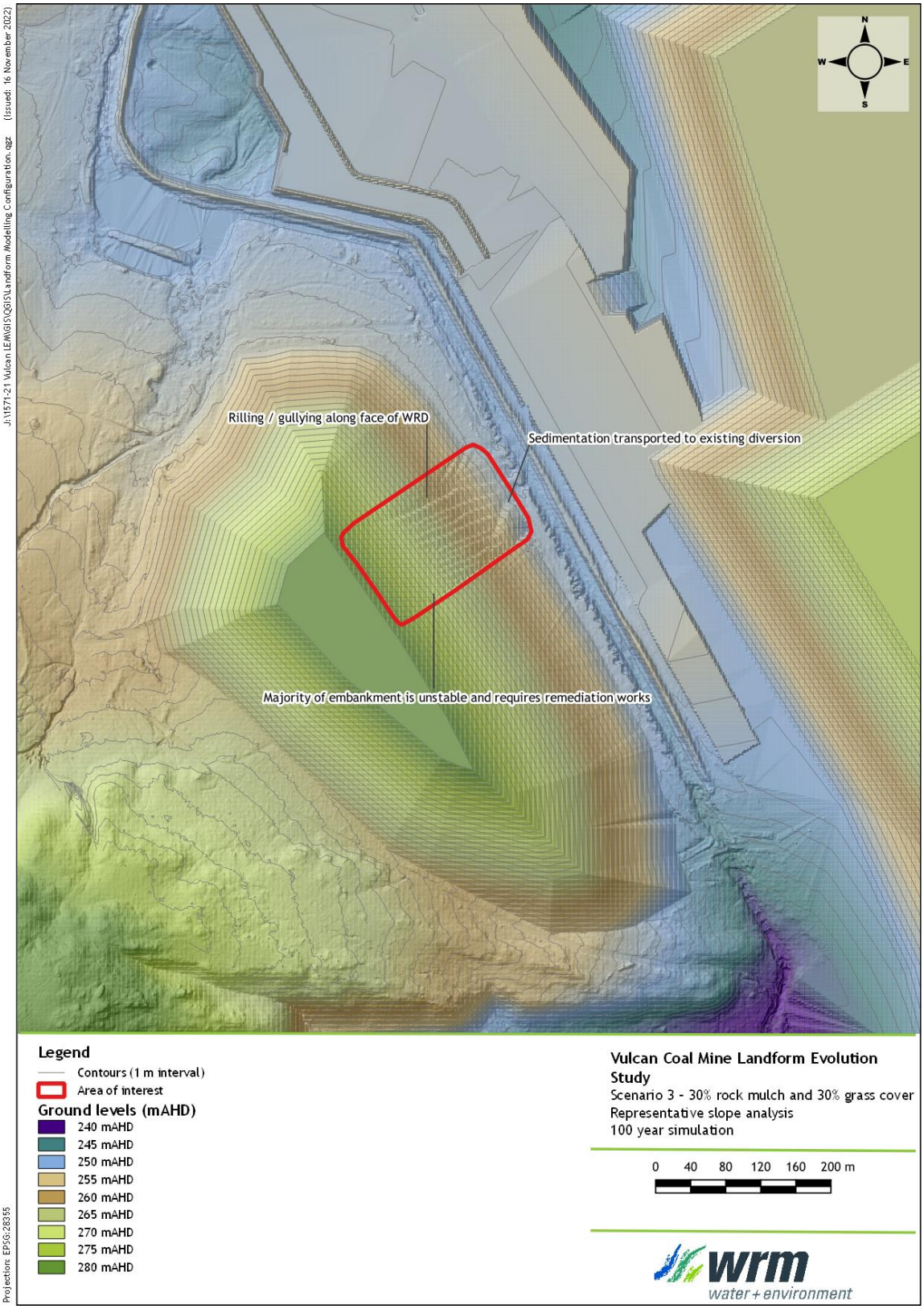


Figure 3.3 – Predicted rill/gully erosion for Scenario 3 – 30% rock mulch and 30% grass cover for representative slope, 100 year simulation

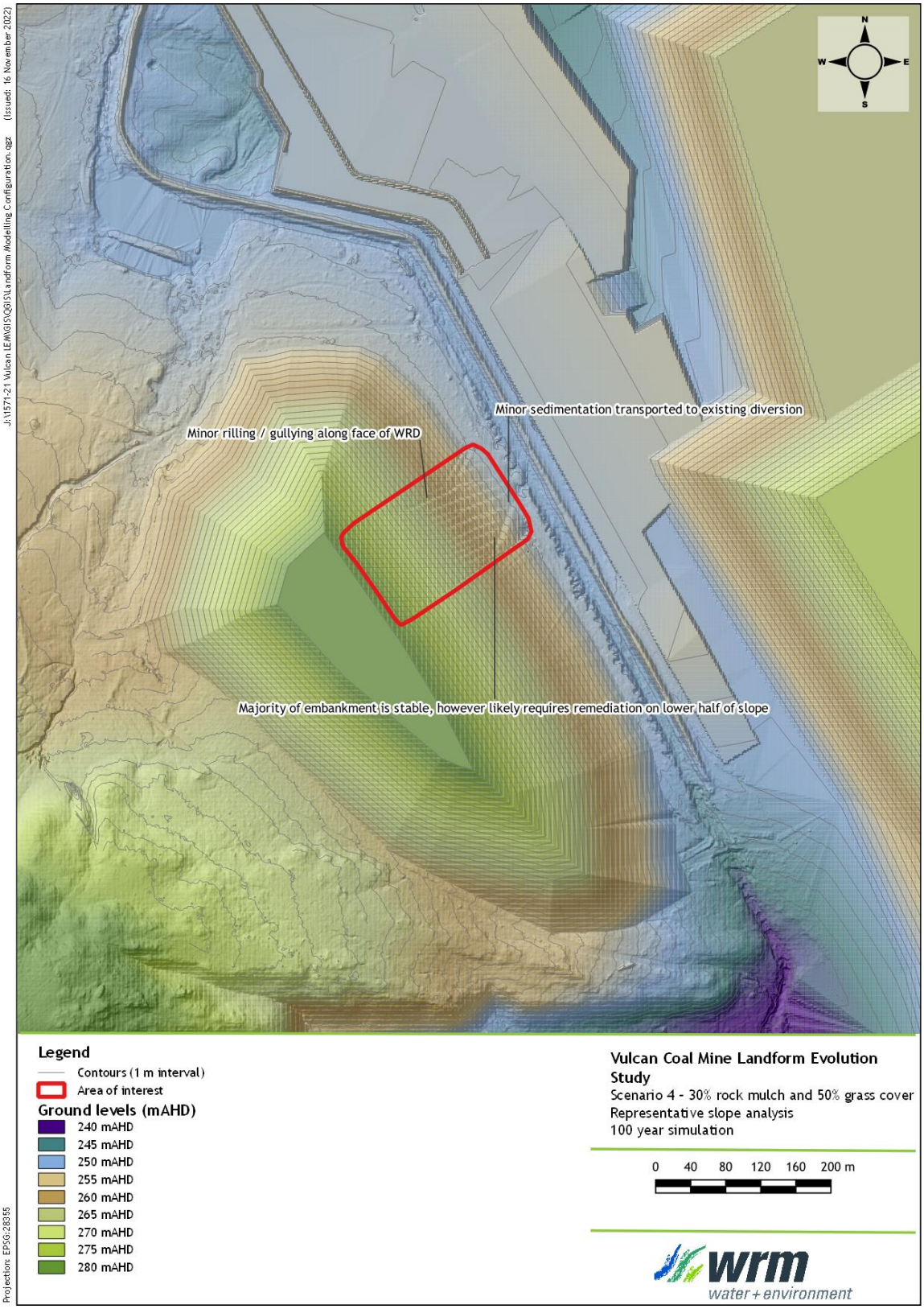


Figure 3.4 – Predicted rill/gully erosion for Scenario 4 – 30% rock mulch and 50% grass cover for representative slope, 100 year simulation

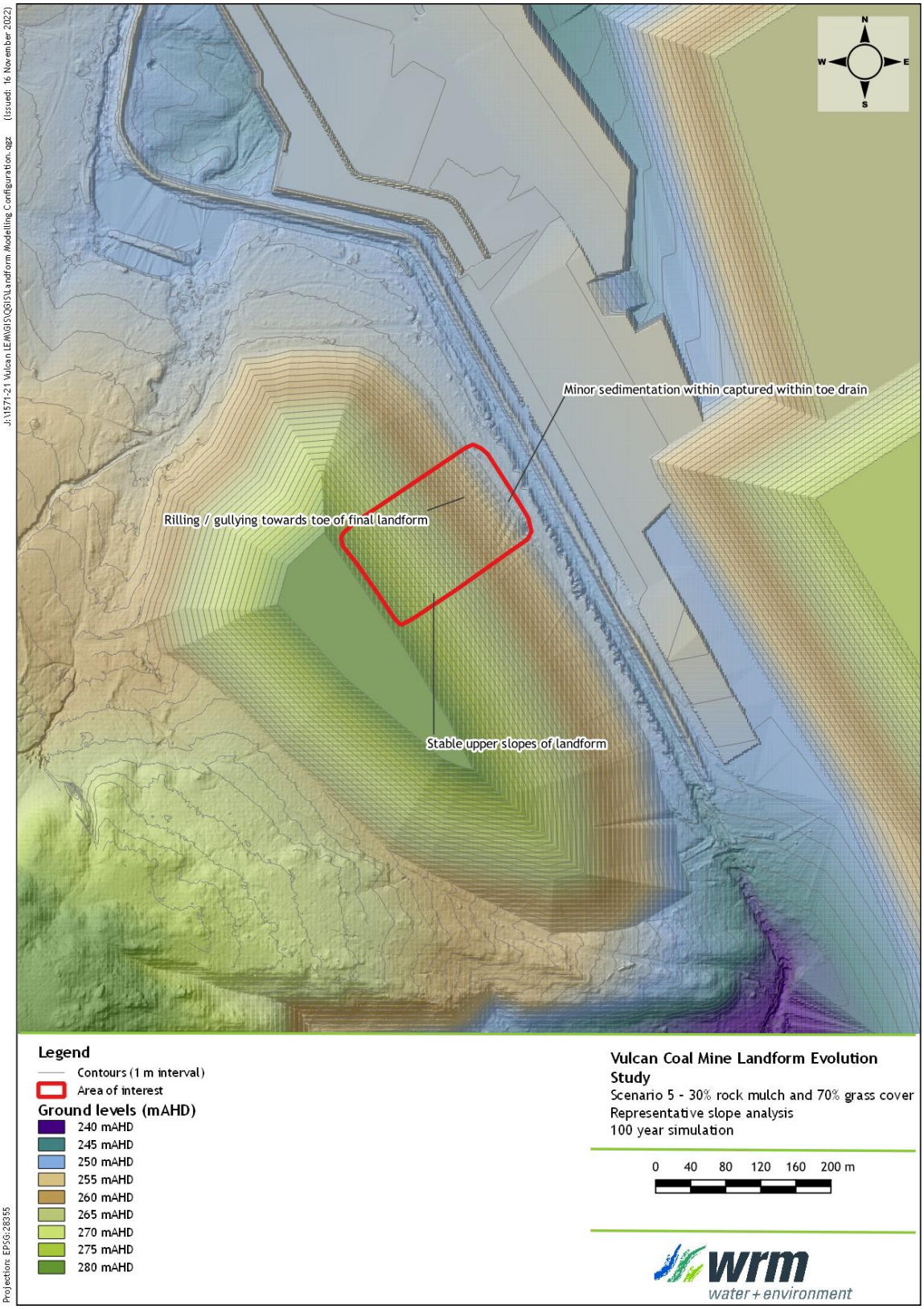


Figure 3.5 – Predicted rill/gully erosion for Scenario 5 – 30% rock mulch and 70% grass cover for representative slope, 100 year simulation

3.2 APPLICATION TO PROPOSED LANDFORMS

3.2.1 General

The representative slope assessment shows that slope lengths up to 180 m with fully established Scenario 5 vegetative cover has a 'very low' erosion risk and therefore should be suitably stable against long-term erosion as the risk of erosion. On this basis, all batter slopes on the site would achieve this criteria because they have the same slope, cover design and are not as long.

The adopted model parameters used for the representative slope assessment were used to highlight the potential erosion risk locations (areas of concern) for the full concept landform designs for the Jupiter in-pit, Matilda in-pit and the ex-pit WRDs. The model was run for the 100 year timeframe assuming Scenario 5 (30% rock mulch with 70% grass cover) rehabilitative cover management for the assessment.

3.2.2 Jupiter in-pit and Matilda in-pit WRD

Figure 3.6 shows the predicted areas of concern for the concept Jupiter and Matilda in-pit WRD designs (RA2). The maximum slope length for the Jupiter and Matilda in-pit WRDs is approximately 160 m and 140 m, respectively.

The Jupiter in-pit and Matilda in-pit WRDs are predicted to have marginally less rilling towards the toe of the slopes because the slope length is marginally shorter compared to the highest risk slope length of 180 m. Concave sections of the proposed concept landform designs are subject to higher erosion risk as runoff naturally converges to these points along the landforms. Minor sedimentation would occur along the toe drains of the proposed in-pit WRDs, however, the upper slopes would generally be considered stable in the long-term and have low risk of rilling / gully erosion.

3.2.3 Ex-pit WRD

Figure 3.7 shows the predicted areas of concern for the concept ex-pit WRD design (RA1). The maximum slope length of the ex-pit WRD is approximately 180 m along the eastern face of the landform and the results show that the eastern face of the ex-pit WRD is the section with the highest risk of rilling / gully erosion. Minor sedimentation would occur along the toe drains of the proposed ex-pit WRD, however, the upper slopes would generally be considered stable in the long-term if the target rehabilitation cover management (Scenario 5) is achieved.

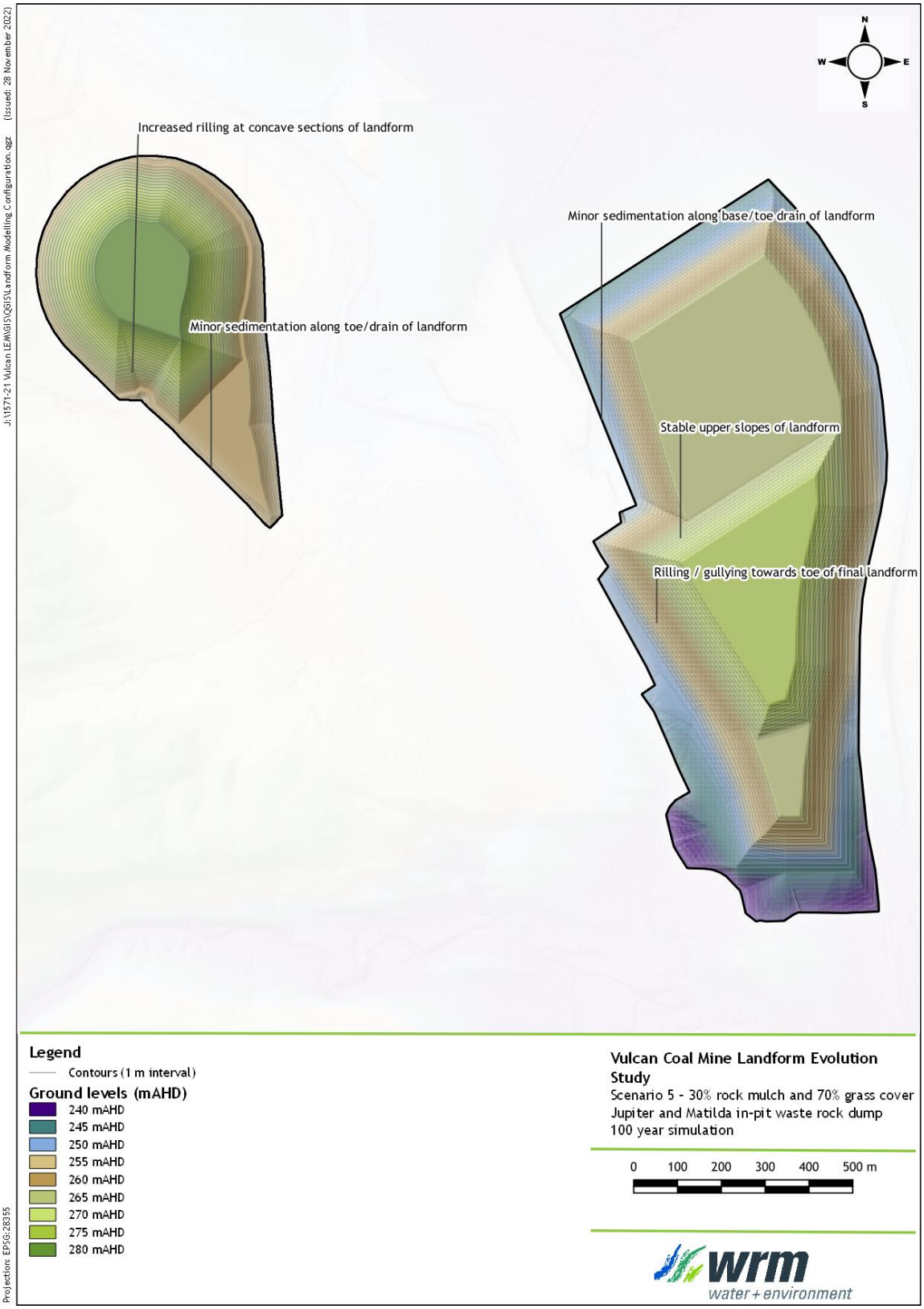


Figure 3.6 – Predicted rill/gully erosion for Scenario 5 – 30% rock mulch and 70% grass cover for the Jupiter and Matilda in-pit waste rock dumps, 100 year simulation

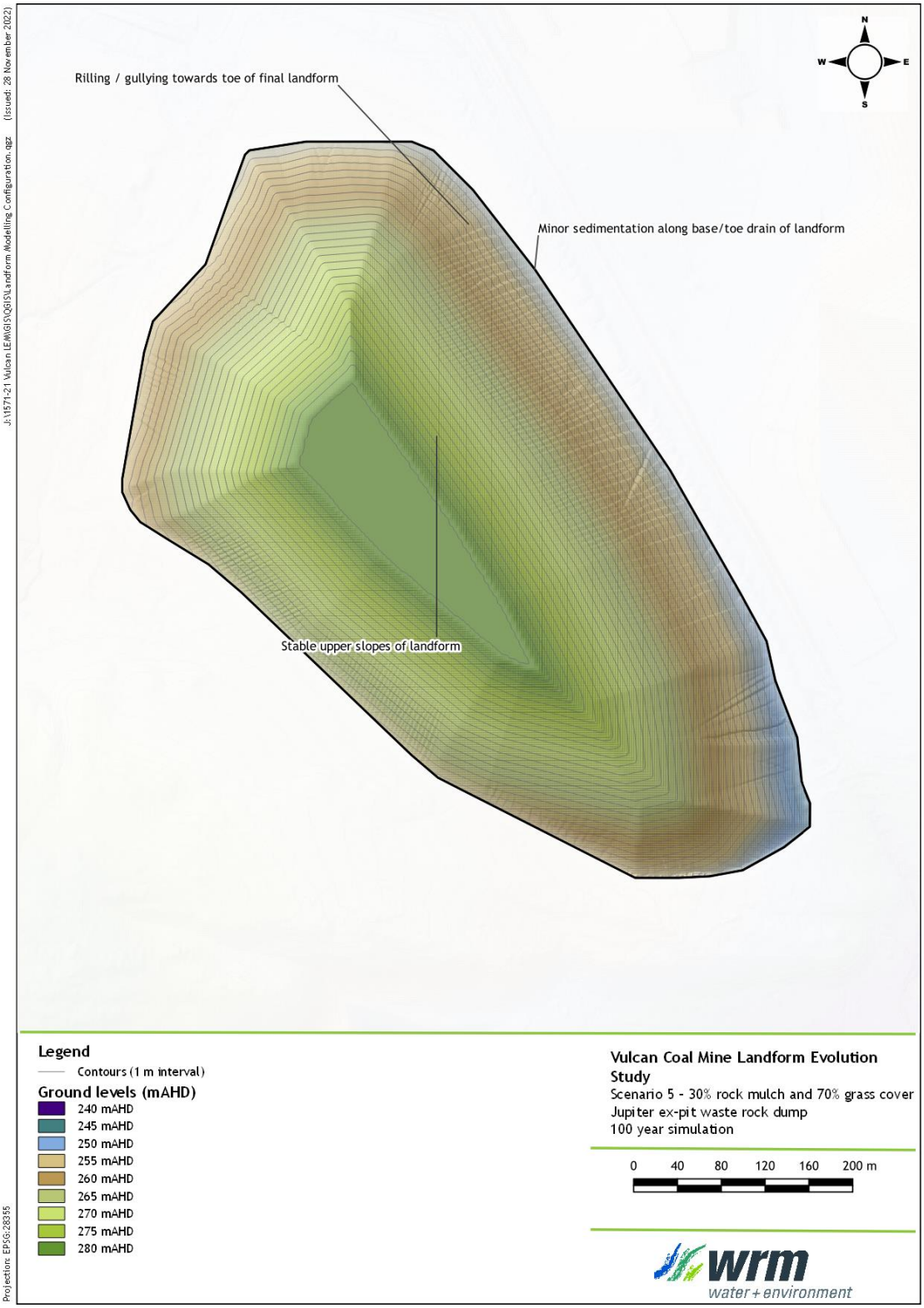


Figure 3.7 – Predicted rill/gully erosion for Scenario 5 – 30% rock mulch and 70% grass cover for the ex-pit waste rock dump, 100 year simulation

4 Summary and recommendations

4.1 LANDFORM ASSESSMENT

Table 4.1 summarises the erosion risk for the modelled scenarios against the erosion risk criteria. The LEM results show that the erosion of the landform under Scenario 5 achieves a 'very low' erosion risk rating due to the implementation of rock mulch (30% cover) and widespread vegetation establishment (70% cover) over the 100 year timeframe. The erosion objectives achieved include:

- Erosion depth only affecting uppermost topsoil layer;
- Land is stable, only minor active rills or gully erosion no deeper than 0.15 m;
- Negligible sedimentation effects on downstream waterways; and
- Vegetative cover is considered widely established and effective however may have reduced ability to recover in some areas.

The Scenario 5 vegetation cover would achieve the rehabilitation criteria objective for the Project, as outlined in the Draft PRCP. Once the Scenario 5 rehabilitation cover management has been established across RA1 and RA2, rilling and gully erosion risk decreases. If the detailed design of the proposed landforms includes implementation of contour banks to reduce slope lengths along the WRDs, it is likely that erosion risk ratings would be reduced even further.

Table 4.1 – Summary of erosion risk

Scenario	10-year model simulation	100-year model simulation
1 – Bare earth (pre-vegetation)	High	High
2 - 30% rock mulch (pre-vegetation)	Moderate	High
3 - 30% rock mulch with 30% grass cover	Low	High
4 - 30% rock mulch with 50% grass cover	Low	Moderate
5 - 30% rock mulch with 70% grass cover	Very Low	Very Low

During the vegetation establishment 10-year timeframe, the cover management scenario likely to be in place is Scenario 2 which includes the rock mulch (30% cover) and limited vegetation. Scenario 2 achieves a 'moderate' erosion risk rating over the 10-year timeframe, characterised as follows:

- Erosion depth affecting topsoil layer and subsoil layers in some areas of the landform;
- Increased sedimentation of downstream waterways; and
- Exposure of subsoil/waste rock material to runoff (however classified NAF and unlikely to generate saline runoff).
- The model results show that during the 10-year vegetation establishment period, contour banks would be required to reduce slope lengths and erosion rates.

Overall, the SIBERIA erosion modelling indicates that the rehabilitation areas RA1 and RA2 (Jupiter in-pit, Matilda in-pit and the ex-pit WRDs) achieve the long-term rehabilitation criteria objectives outlined in the Draft PRCP once the Scenario 5 vegetative cover is established. The likelihood that the underlying waste rock material will be exposed is low.

4.2 RECOMMENDATIONS

It is recommended that the proposed rehabilitation areas (RA1 and RA2) are monitored up until the Scenario 5 rehabilitation cover management scenario has been fully established, and any rilling or gully erosion up until the target vegetative cover is established is remediated to the proposed landform design.

If it is found that Scenario 5 vegetative cover is difficult to achieve or the maximum slope length of 180 m is exceeded, it is likely that erosion risk would be greater for the proposed concept WRD proposed designs and contour bank structures should be included to decrease the slope lengths and therefore decrease the erosion risk. Landform reshaping and surface water management to decrease drainage areas along extended slope lengths could also be undertaken during detailed design.

4.3 LIMITATIONS

The erosion results are representative of the nominated 10-year and 100-year post mining timeframes. The modelling does not evaluate timeframes longer than 100-years. The LEM assessment erosion rates would continue and erosion rill depths will increase when longer timeframes are considered as the erosion modelling does not consider vegetative growth or soil replenishment over the model simulation period.

Although the soil report and geotechnical report provide information on soil characteristics and slope stability, once detailed design of the landforms are available, field observations should be undertaken to monitor and gather site specific erosion data with proposed landform cover in place to compare against the predicted erosion rates, which are based on theoretical assessments and only suitable for comparative purposes only. The erosion rates within the model were scaled to match theoretical calculations for predicted soil losses and therefore predictions produced by the model are somewhat predetermined. The potential effects of climate change have also not been considered.

5 References

AARC, 2021	*'Vulcan Complex Project Soil and Land Suitability Assessment'* Revision 9, prepared for METServe by AARC Environmental Solutions Pty Ltd, April 2021.
Blackrock, 2020	*'Vulcan Complex – Jupiter Final Landform Slope Stability Assessment'*, prepared for Vitrinite Pty Ltd by Blackrock Mining Solutions Pty Ltd, March 2020.
DES, 2021	*'Guideline – Progressive rehabilitation and closure plans (PRC plans)'*, Department of Environment and Science, Queensland Government, March 2021.
METServe, 2022	*'Progressive Rehabilitation and Closure Plan – Vulcan Coal Mine'*, Draft PRCP prepared for Vitrinite Pty Ltd by METServe, 2022.
RGS, 2022a	*'VI010_VCM_ Matilda Pit Geochemistry Assessment'*, Revision 1, prepared for METServe by RGS Environmental Consultants Pty Ltd, September 2022.
RGS, 2022b	*'01_2022014_Geochemical Assessment of Waste Rock, Coal Reject and Coal_Rev 01'*, prepared for METServe by RGS Environmental Consultants Pty Ltd, March 2022.
Tongway and Hindley, 2004	*'Landscape Function Analysis: Procedures for monitoring and assessing landscapes – with special reference to minesites and rangelands'*, Tongway, D.J. and N.L. Hindley, CSIRO Sustainable Ecosystems, Canberra, 2004.
Willgoose, 2005	*'User Manual for SIBERIA (Version 8.30)'*, Professor Gary Willgoose, Telluric Research, July 2005.

Appendix G- Geotechnical Assessment- July 2022

MEMORANDUM

To:	Vitrinite Pty Ltd
Attention:	Gary Robertson
Prepared By:	James Grindey
Reviewed By:	Ty Grantham
Date:	14 July 2022
Memo Ref:	BMS-P22017C-VIT-VUL-M-1-V1.0
Subject:	Matilda Pit - Preliminary Geotechnical Assessment

1 INTRODUCTION AND SCOPE

At the request of Vitrinite Pty Ltd (Vitrinite), a geotechnical assessment was carried out Blackrock Mining Solutions (Blackrock) to support the proposed Matilda Pit, immediately to the west of the Jupiter Pit. The proposed mine plan includes a 'tear-drop' shape pit, approximately 900 m long (striking approximately 333º), 550 m wide and 40 m deep, with both pre-split and softwall faces. It was indicated that at end-of-mining, the pit would be back filled with spoil/tailings.

A rail loop encircles the pit offset from the crest by approximately 30 - 35 m, with estimated rail loading parameters supplied by Vitrinite.

The scope of work for the assessment is as follows:

- Develop representative two-dimensional, limit equilibrium models to confirm the suitability of pit slope geometries in accordance with the proposed strip designs;
- Application of static rail locomotive loading to assess the influence on overall slope stability;
- Review strip orientation with respect to faults and geological structures extraploted from the Jupiter Pit to assess the potential for kinematic failure mechanisms; and
- Provision of recommendations for geotechnically stable operational and final slopes and the mitigation of geotechnical risk.

2 MINE PLAN AND STRIP DESIGN

The Matilda Pit is planned to depths of between 16 m to 40 mbgl, and extends to the floor of the Matilda Seam. As indicated by Vitrinite personnel, slopes to the southwest of Strip 1 would comprise a continuous 45º softwall batter to account for the variability in the base of weathering, as shown in Figure 2-1.

As the mine advances down-dip, the eastern portion of each strip highwall is oriented to the south, then to the southwest for the western portion of each strip. The slopes then transition to 45º batters in

the weathered Permian and Cenozoic horizons and a 70º pre-split batter to the top of the Matilda Seam to the north and east of Strip 1.

The lowwall would be formed up dip of the highwall and spoil is to be dumped on the floor of the Matilda Seam which dips at approximately 3º to the northeast. The maximum height of the lowwall was indicated to be approximately 40 m (corresponding to the pit crest) in the vicinity of Strip 8.

Representative section locations are shown in Figure 2-2 and Figure 2-3.

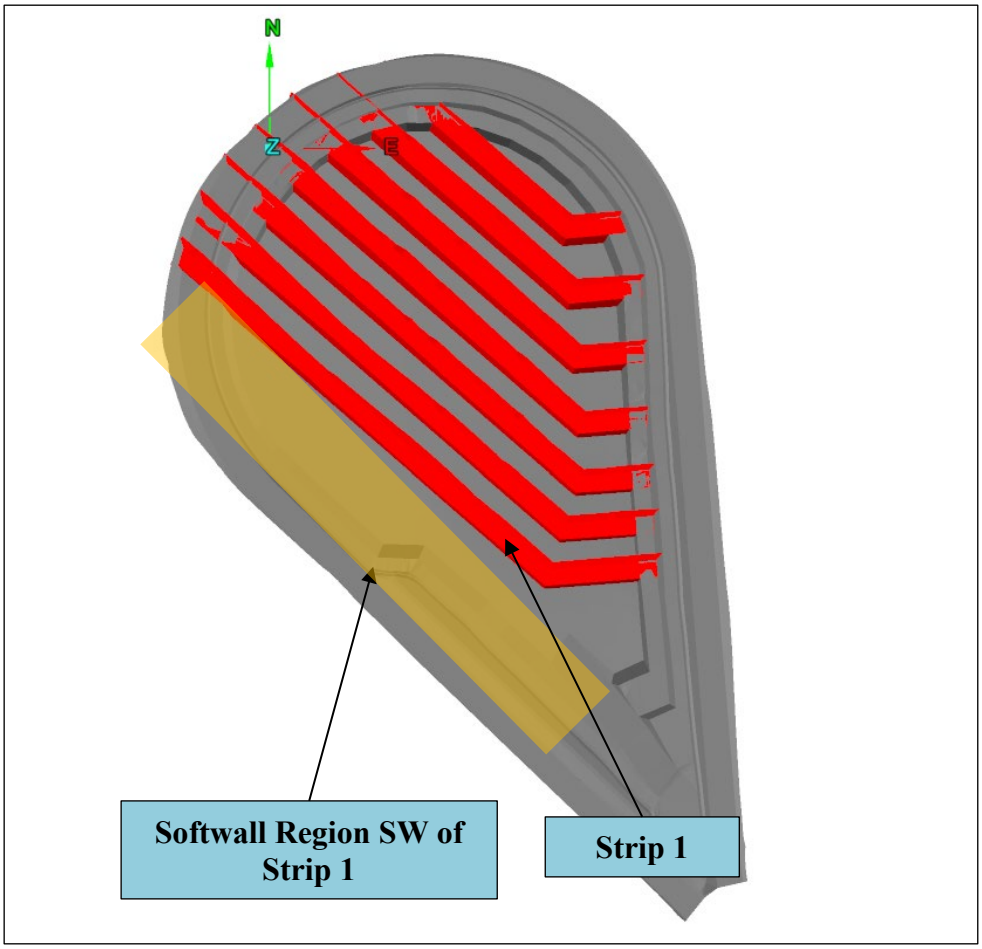


Figure 2-1: Strip Design and Softwall Region

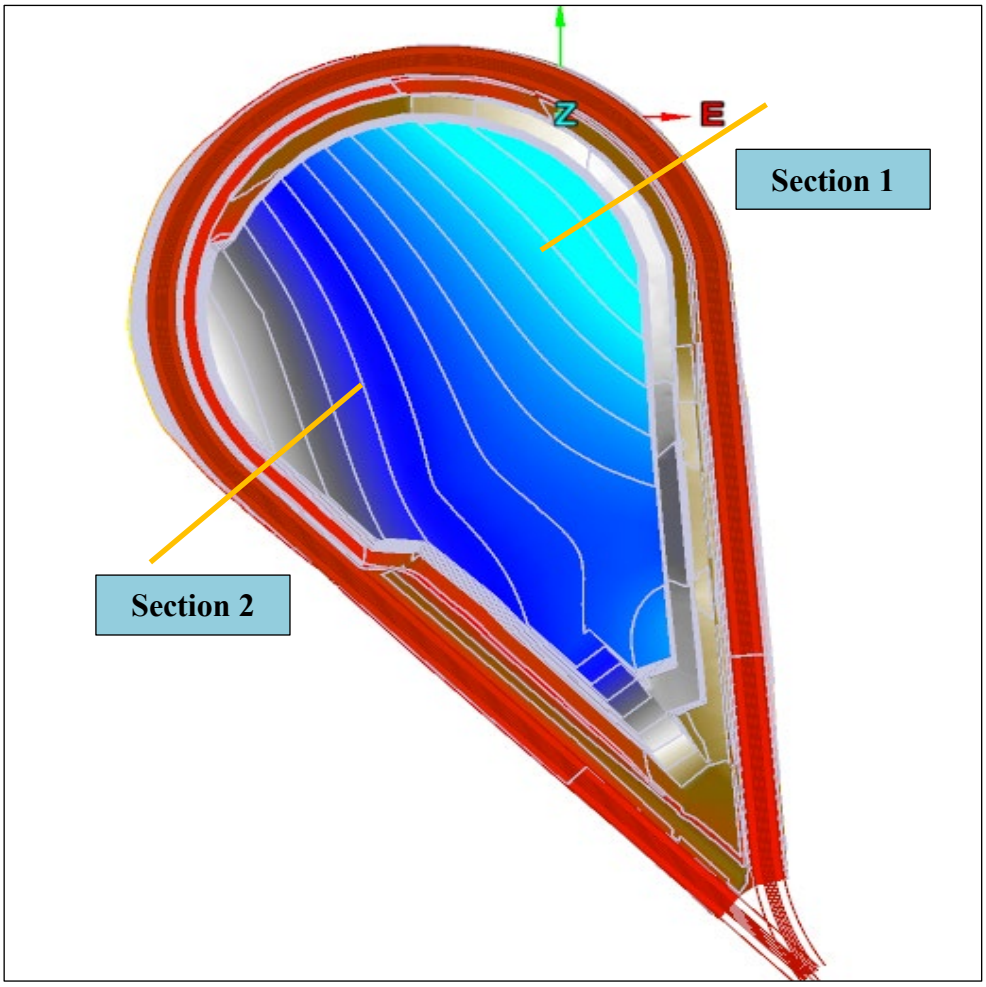


Figure 2-2: Represetative Section Locations

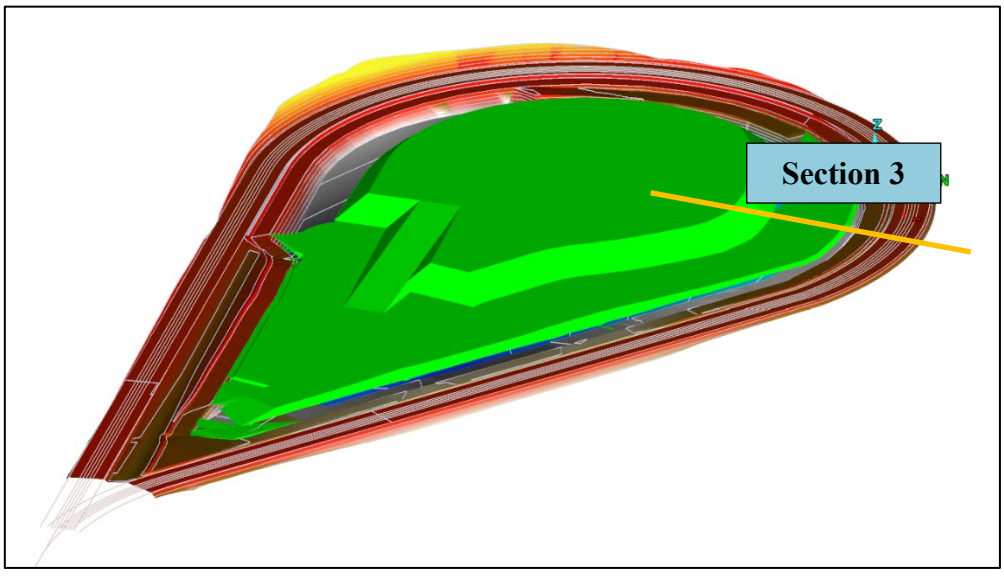


Figure 2-3: Cat 2.5 Spoil Section

2.1 Rail Locomotive Loading

Slope stability analysis scenarios incorporated static loading of coal trains operating around the pit crest. Review of client provided data showed that the QR3800 Series Locomotive was the single heaviest item per unit length on the rail.

The worst case scenario suggests the momentary passing of two locomotives on adjacent sections of track above the highwall. The rail line was assumed to evenly distribute the locomotive mass, negating the requirement for a point load calculation under each axle. Locomotives weights were divided by the metre length to provide a per linear metre unit weight. The total static load was estimated with the use of two locomotives on 4 sections of rail to simulate the maximum, static load.

Total instantaneous load per linear metre being: (2*63412 N/m)+(4*588 N/m) = 129,176 N/m.

The per linear metre load was then applied over the Client provided rail corridor width which appeared to be two 3 m wide rail corridors, adjacent to each other (6 m in total).

Table 2-1: Comparative Rail Loading Estimate

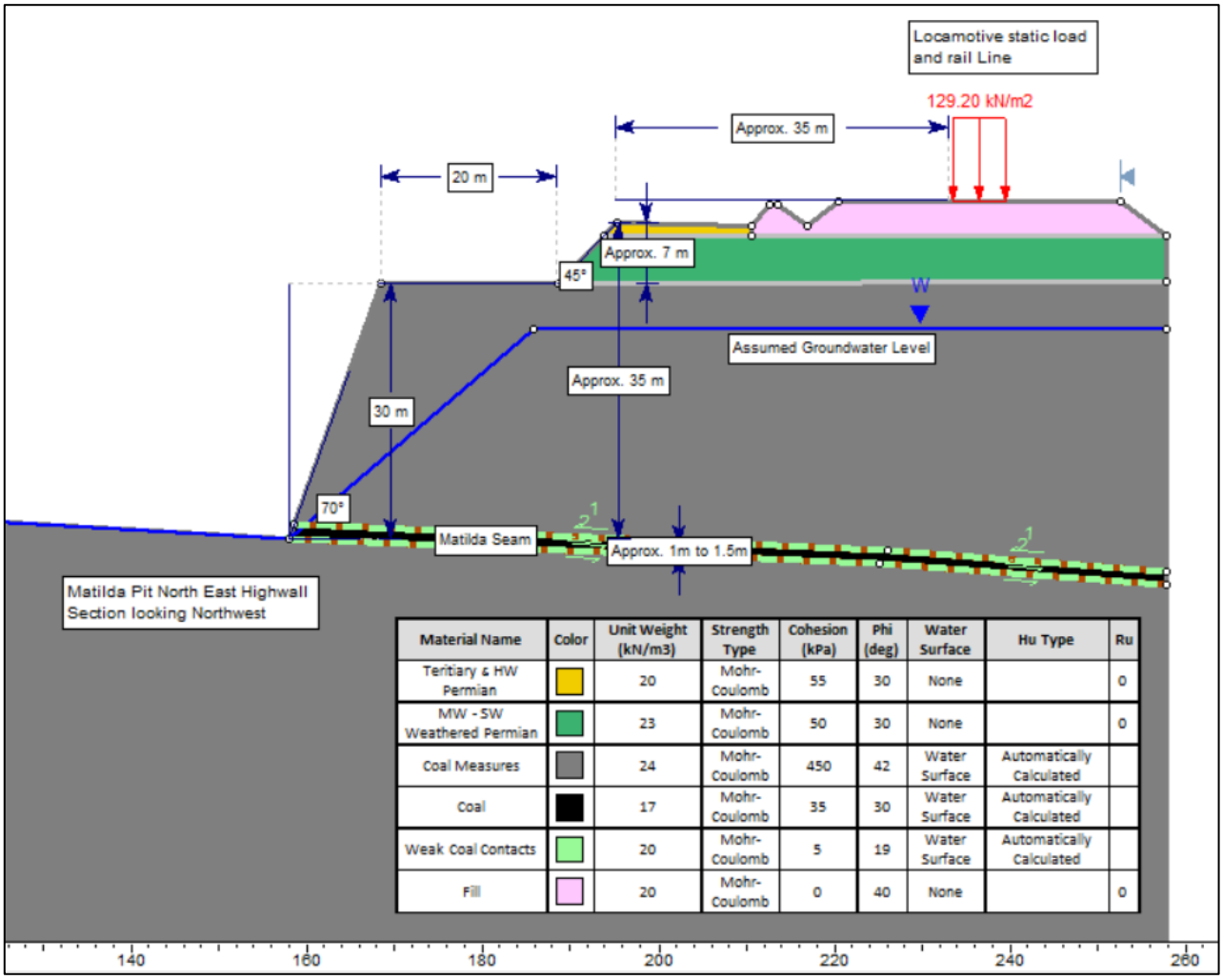
Parameter	Tonnes (t)	Length (m)	Tonnes/ Linear Metre (t/m)	Force/Linear Metre (KN/m)	Width of Distributed Load (Sleeper Length)
QR3800 Series Locomotive	132	20.4	6.471	63.4	2.4
Loaded Coal Wagon Weight	106	20	5.300	51.9	2.4
Rail Line Weight	0.06	1	0.060	58.8	2.4

3 SLOPE DESIGN SCENARIOS

The following representative scenarios were examined:

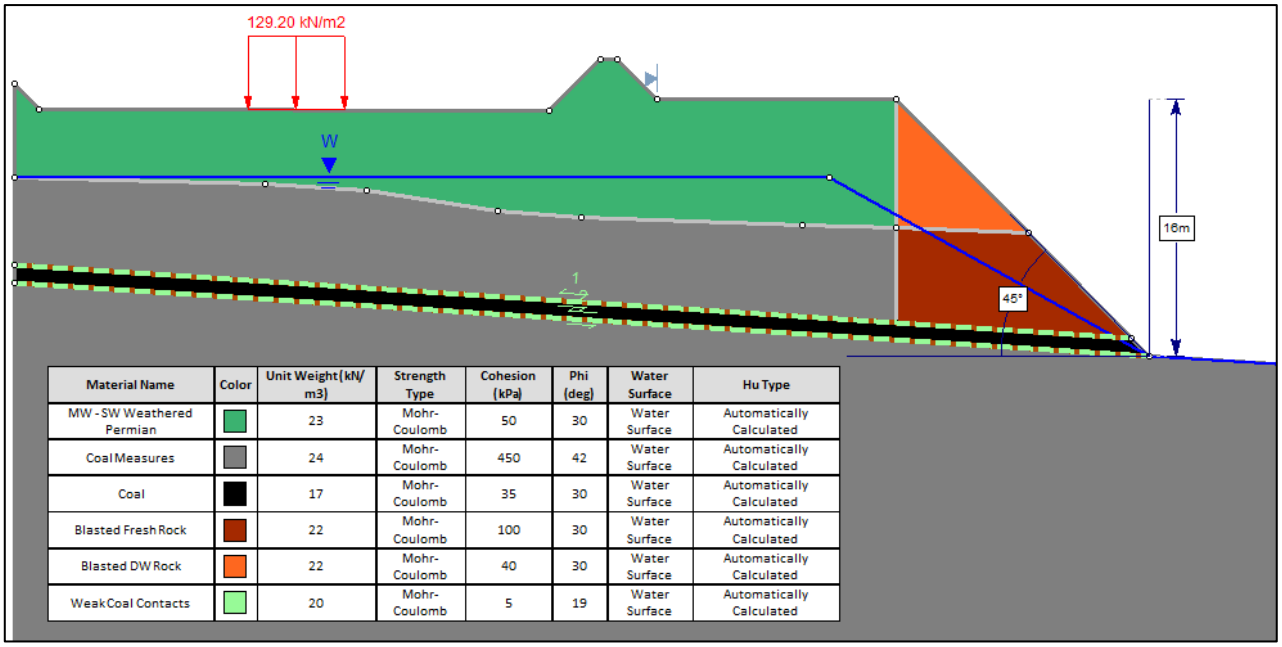
- Scenario 1 - 70^{o} pre split batter profile through the fresh coal measures to top of Matilda Seam and 45^{o} batter in the weathered Permian and Tertiary horizons. A maximum bench height of 30 m was considered in the model, as shown in Figure 3-1. This scenario is applied to the advancing and final highwall to the northeast of Strip 1 and corresponds to representative section - Section 1 (Figure 2-2);
- Scenario 2 – Continuous 45^{o} softwall profile to the top of the Matilda Seam, in the southwest pit area, southwest of Strip 1, as shown in Figure 3-2. This scenario corresponds to representative section - Section 2 (Figure 2-2);
- Scenario 3 – 37^{o} angle of repose batter angle in Category 2.5 spoil for an advancing in-pit spoil dump, comprising 2 x 20 m lifts completed to the topography, shown in Figure 3-3. This section has been generated along the existing Section 1 profile;

- Scenario 4 – 37° angle of repose batter angle in Category 2.5 spoil for fully backfilled pit, completed to a final lift of 20 m (elevation of 280 m RL), as shown in Figure 3-4; and
- Scenario 5 - Partially filled pit with tailings/co-disposed spoil materials. Void water level to provide 5 m freeboard from pit crest, as shown in Figure 3-5. It should be noted that this water level may not reflect of the final void water level at post mining or at closure.



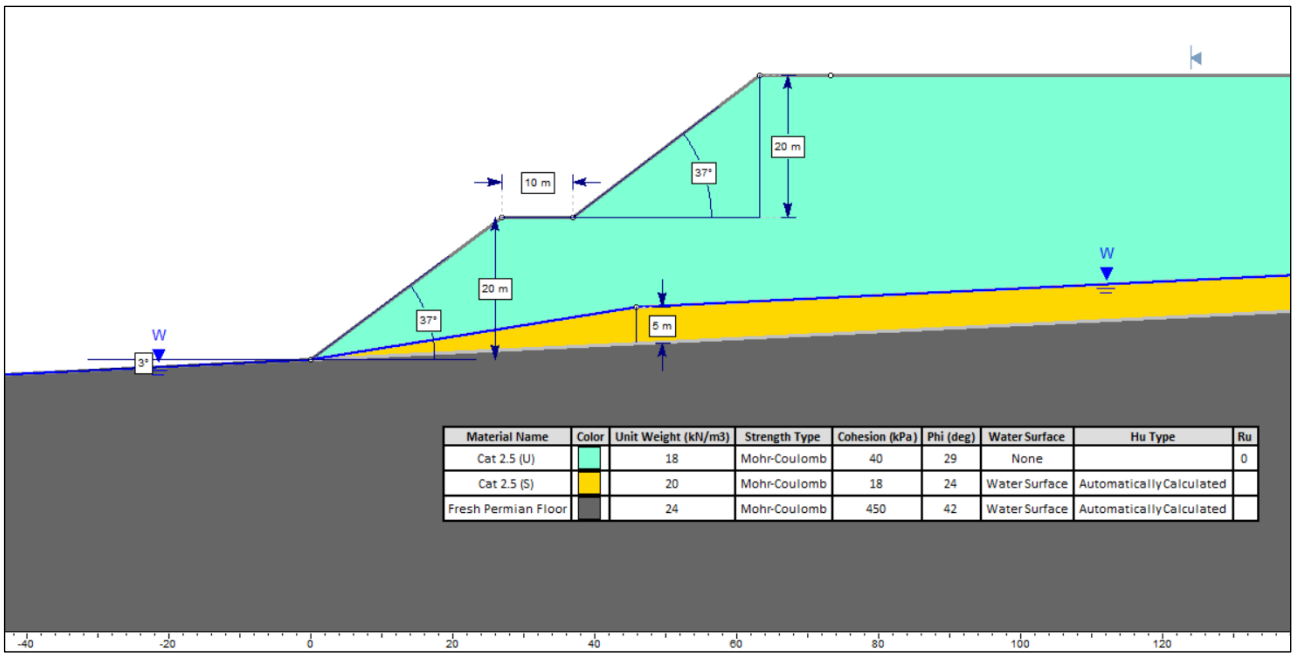
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Ru
Teritiary & HW Permian		20	Mohr-Coulomb	55	30	None		0
MW - SW Weathered Permian		23	Mohr-Coulomb	50	30	None		0
Coal Measures		24	Mohr-Coulomb	450	42	Water Surface	Automatically Calculated	
Coal		17	Mohr-Coulomb	35	30	Water Surface	Automatically Calculated	
Weak Coal Contacts		20	Mohr-Coulomb	5	19	Water Surface	Automatically Calculated	
Fill		20	Mohr-Coulomb	0	40	None		0

Figure 3-1: Scenario 1 Slope Profile



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type
MW - SW Weathered Permian		23	Mohr-Coulomb	50	30	Water Surface	Automatically Calculated
Coal Measures		24	Mohr-Coulomb	450	42	Water Surface	Automatically Calculated
Coal		17	Mohr-Coulomb	35	30	Water Surface	Automatically Calculated
Blasted Fresh Rock		22	Mohr-Coulomb	100	30	Water Surface	Automatically Calculated
Blasted DW Rock		22	Mohr-Coulomb	40	30	Water Surface	Automatically Calculated
Weak Coal Contacts		20	Mohr-Coulomb	5	19	Water Surface	Automatically Calculated

Figure 3-2: Scenario 2 Slope Profile



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Ru
Cat 2.5 (U)		18	Mohr-Coulomb	40	29	None		0
Cat 2.5 (S)		20	Mohr-Coulomb	18	24	Water Surface	Automatically Calculated	
Fresh Permian Floor		24	Mohr-Coulomb	450	42	Water Surface	Automatically Calculated	

Figure 3-3: Scenario 3 Slope Profile

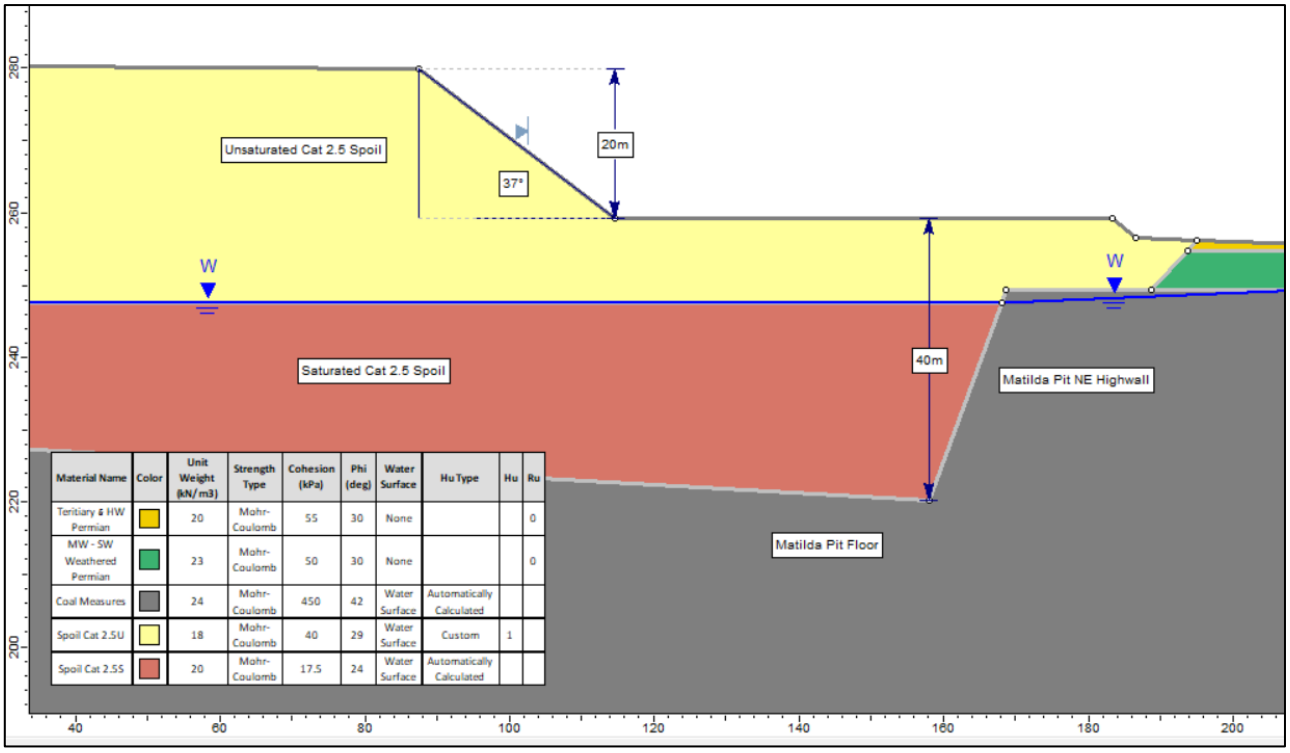


Figure 3-4: Scenario 4 Slope Profile

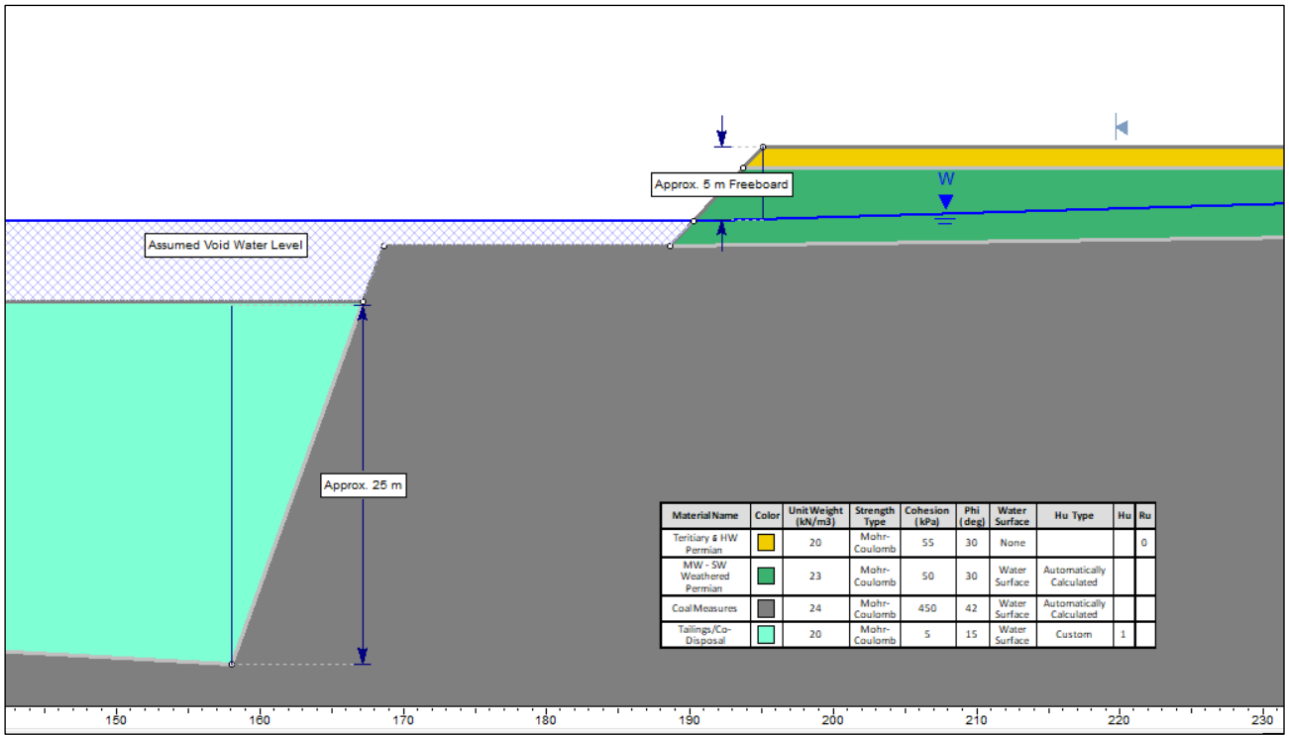


Figure 3-5: Scenario 5 Slope Profile

3.1 Material Properties

Material properties were derived from the Vulcan Mine Project geotechnical investigations report (BMS-VIT-VUL-201910-01-V4.0). Table 3-1 summarises the geotechnical strength parameters for each overburden geomechanical unit identified and used for geotechnical analysis.

It was assumed that enginnered fill used to construct the rail foundations had a unit weight = 20 KN/m, cohesion = 0 kPa and phi = 40º.

The Category 2.5 spoil material parameters were derived from the coal spoil shear strength framework developed by Simmons & McManus (2004).

Table 3-1: Material Properties

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Ru
Teritiary & HW Permian		20	Mohr-Coulomb	55	30	None		0
MW - SW Weathered Permian		23	Mohr-Coulomb	50	30	None		0
Coal Measures		24	Mohr-Coulomb	450	42	Water Surface	Automatically Calculated	
Coal		17	Mohr-Coulomb	35	30	Water Surface	Automatically Calculated	
Blasted Fresh Rock		22	Mohr-Coulomb	100	30	Water Surface	Automatically Calculated	
Blasted DW Rock		22	Mohr-Coulomb	40	30	None		0
Blasted Tertiary & HW Permian		20	Mohr-Coulomb	40	20	None		0
Weak Coal Contacts		20	Mohr-Coulomb	5	19	Water Surface	Automatically Calculated	
Fill		20	Mohr-Coulomb	0	40	None		0
Tailings/Co-Disposal		20	Mohr-Coulomb	5	15	None		0
Spoil Cat 2.5U		18	Mohr-Coulomb	40	29	None		0
Spoil Cat 2.5S		20	Mohr-Coulomb	17.5	24	Water Surface	Automatically Calculated	

3.2 Limit Equilibrium Modelling and Results

Two-dimensional, limit equilibrium (LE) stability analyses were carried out to assess the Factor of Safety (FoS) for the proposed design, using both circular and non-circular failure methods for excavated slopes, and the General Limit of Equilibrium/Morgenstern-Price (GLE/M-P) method. A minimum FoS of ≥ 1.2 was applied.

For the non-circular failure analysis methods, both Cuckoo and Block search methods were considered in the analysis to assess the critical failure surface using different search algorithms. In some cases, different search algorithmns can result in differences in FoS. In general, the Cuckoo search produces a flatter backscarp angle which increases the driving forces on an active wedge higher up in the failure envelope, whereby the backscarp produced using the Block search method is constrained to a steep angle (typically 63°), with failure translating along a weak surface – i.e. weak floor or roof coal contact or saturated basal layer in a spoil dump.

The results indicated the following:

- Scenario 1 indicated a critical FoS of 3.41 and 3.20 for non-circular failure mechanisms using the Cuckoo and Block search methods, respectively, which exceeds the minimum FoS of 1.2, based on the assumptions, as shown in Figure 3-6 and Figure 3-7;

- Scenario 2 indicated a critical FoS of 1.67 and 1.59, for non-circular failure mechanisms using the Cuckoo and Block search methods, respectively, which exceeds the minimum FoS of 1.2, based on the assumptions, as shown in Figure 3-8 and Figure 3-9;
- Scenario 3 indicated a critical FoS of 1.55, for non-circular failure mechanisms using the Block search method, which exceeds the minimum FoS of 1.2, based on the assumptions, as shown in Figure 3-10;
- Scenario 4 indicated a critical FoS of 1.86, for circular failure mechanisms using the grid search, which exceeds the minimum FoS of 1.2, based on the assumptions, as shown in Figure 3-11; and
- Scenario 5 indicated a critical FoS of 2.94, for non-circular failure mechanisms using the Cuckoo search method, which exceeds the minimum FoS of 1.2, based on the assumptions, as shown in Figure 3-12.

A summary of the FoS LE slope stability analyses results is presented in Table 3-2.

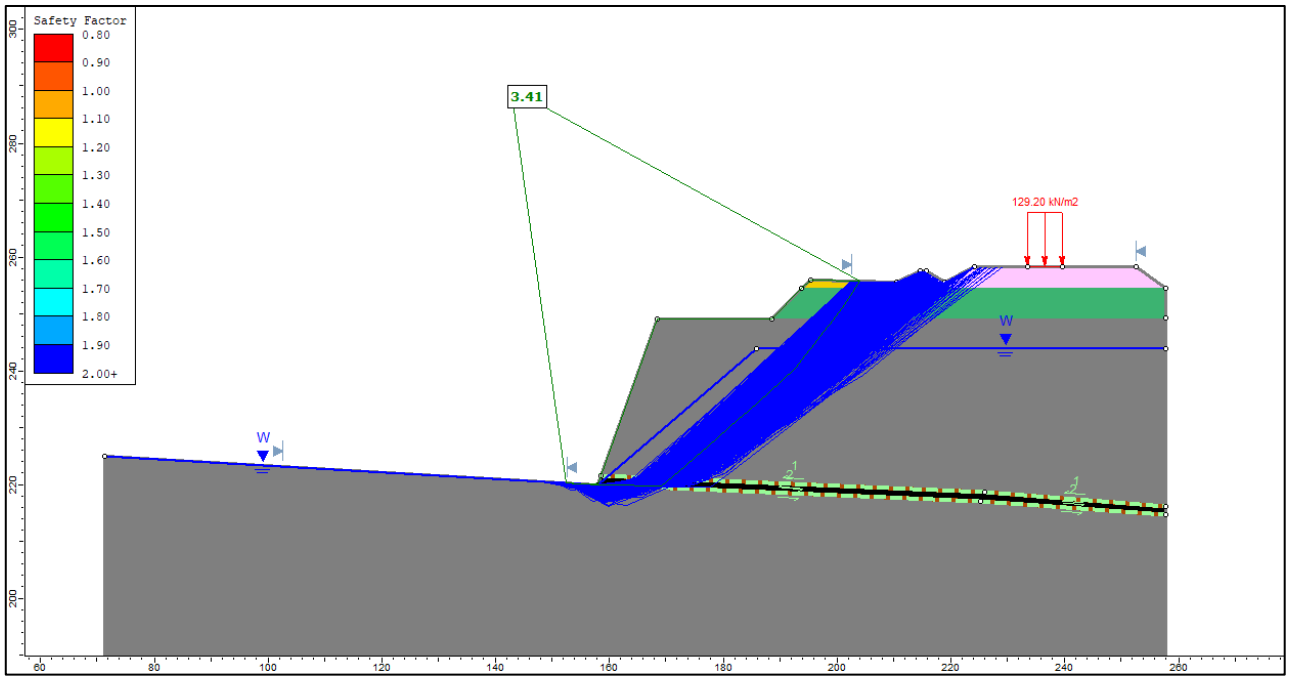


Figure 3-6: Scenario 1 - 2D LE Analysis Result – FoS = 3.41 (Cuckoo Search)

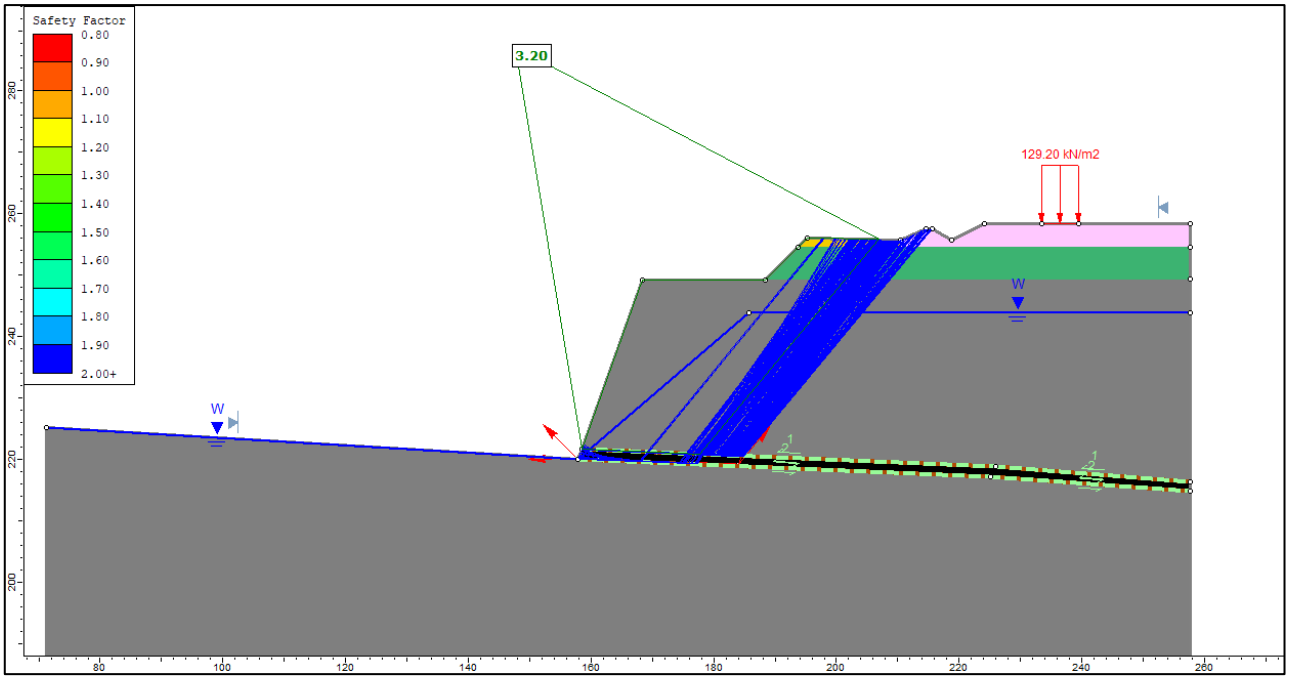


Figure 3-7: Scenario 1 - 2D LE Analysis Result – FoS = 3.20 (Block Search)

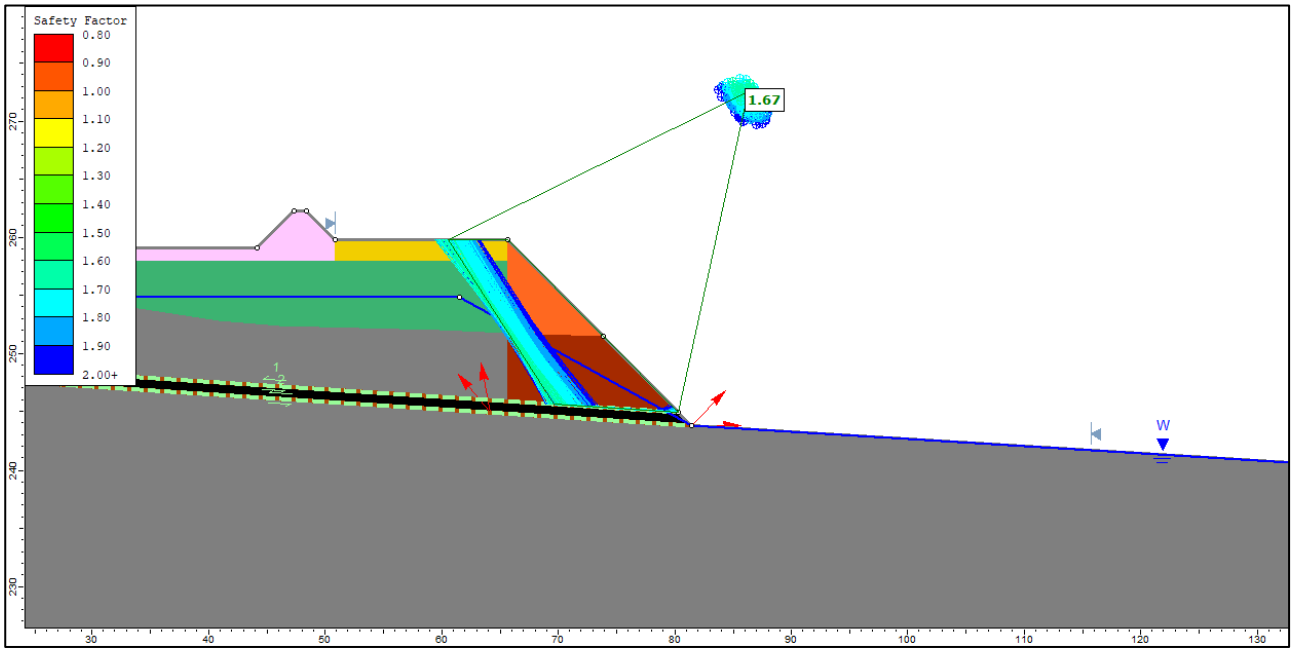


Figure 3-8: Scenario 2 - 2D LE Analysis Result – FoS = 1.67 (Block Search)

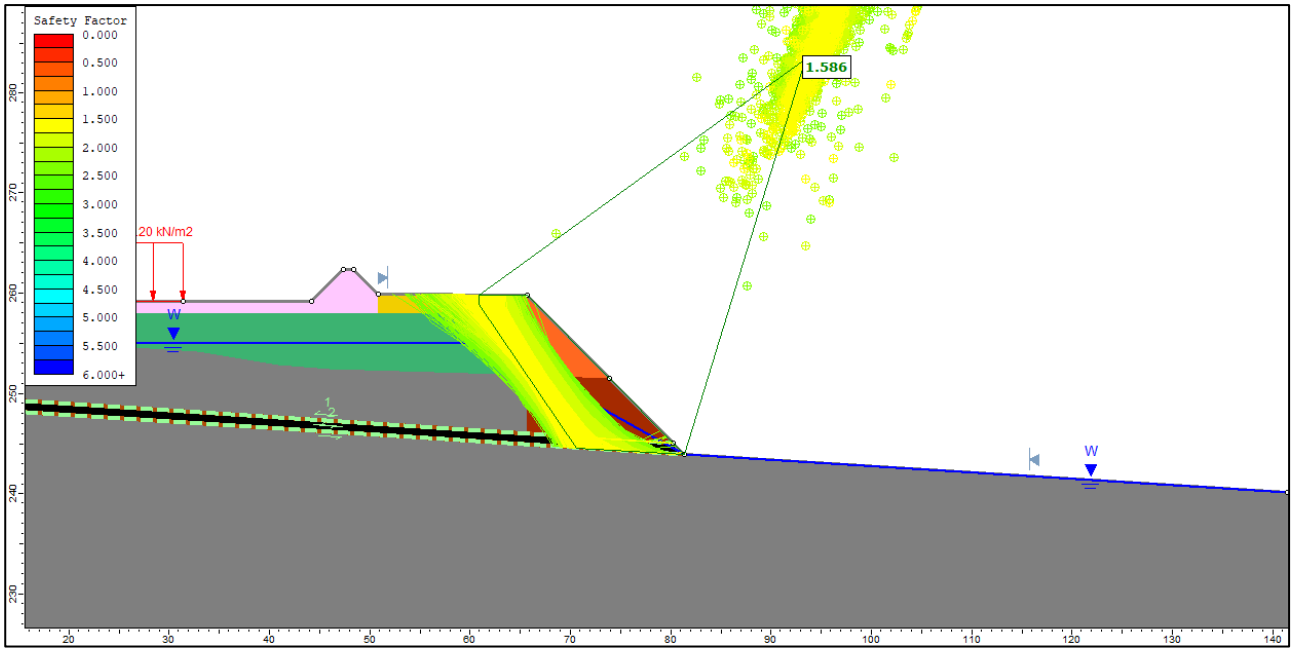


Figure 3-9: Scenario 2 - 2D LE Analysis Result – FoS = 1.59 (Cuckoo Search)

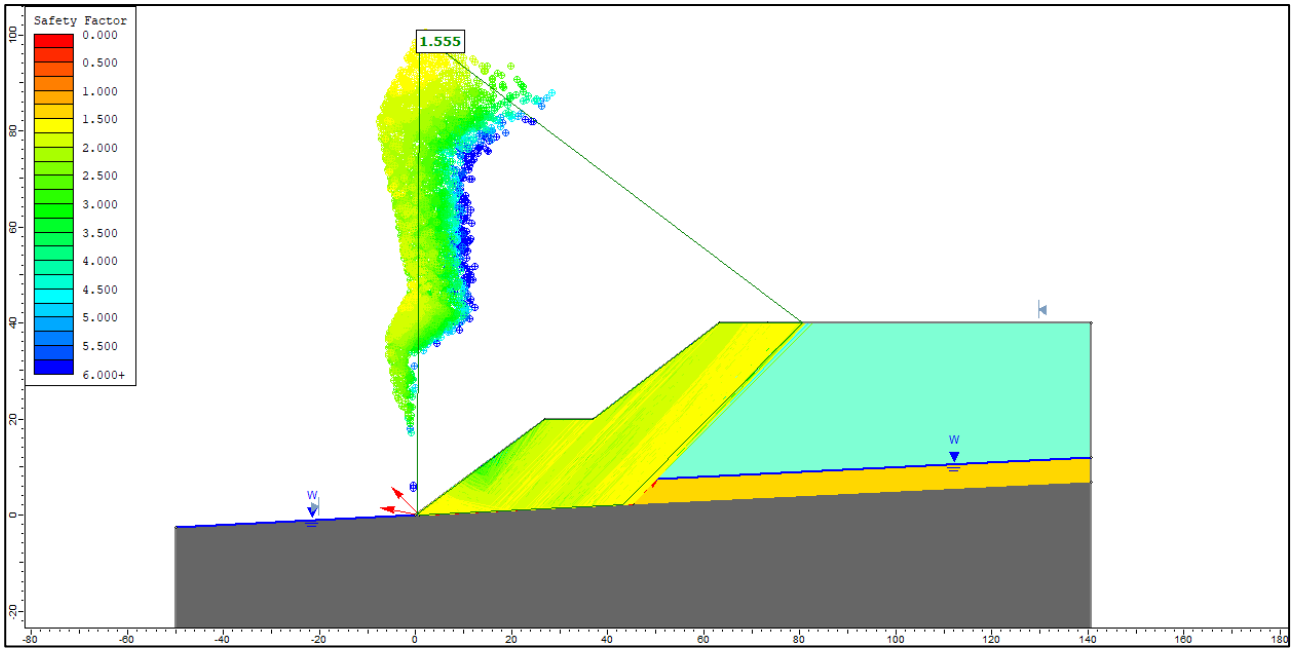


Figure 3-10: Scenario 3 - 2D LE Analysis Result – FoS = 1.86 (Block Search)

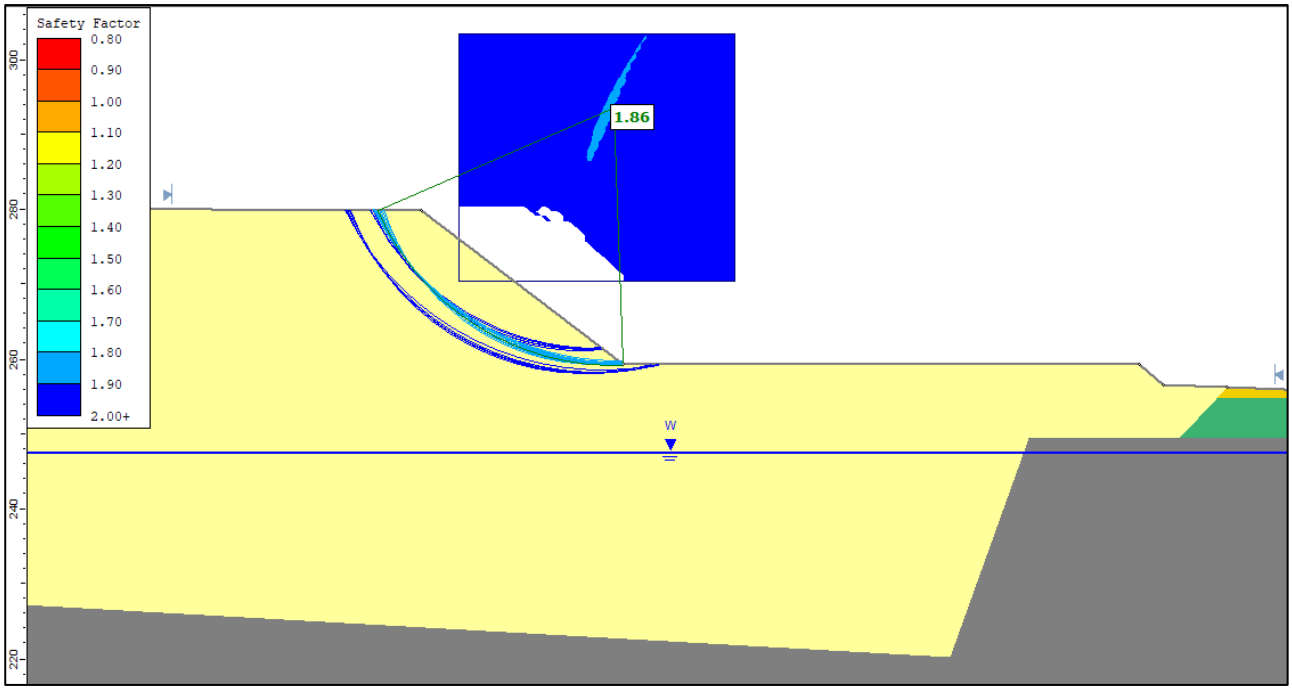


Figure 3-11: Scenario 3 - 2D LE Analysis Result – FoS = 1.86 (Circular Failure)

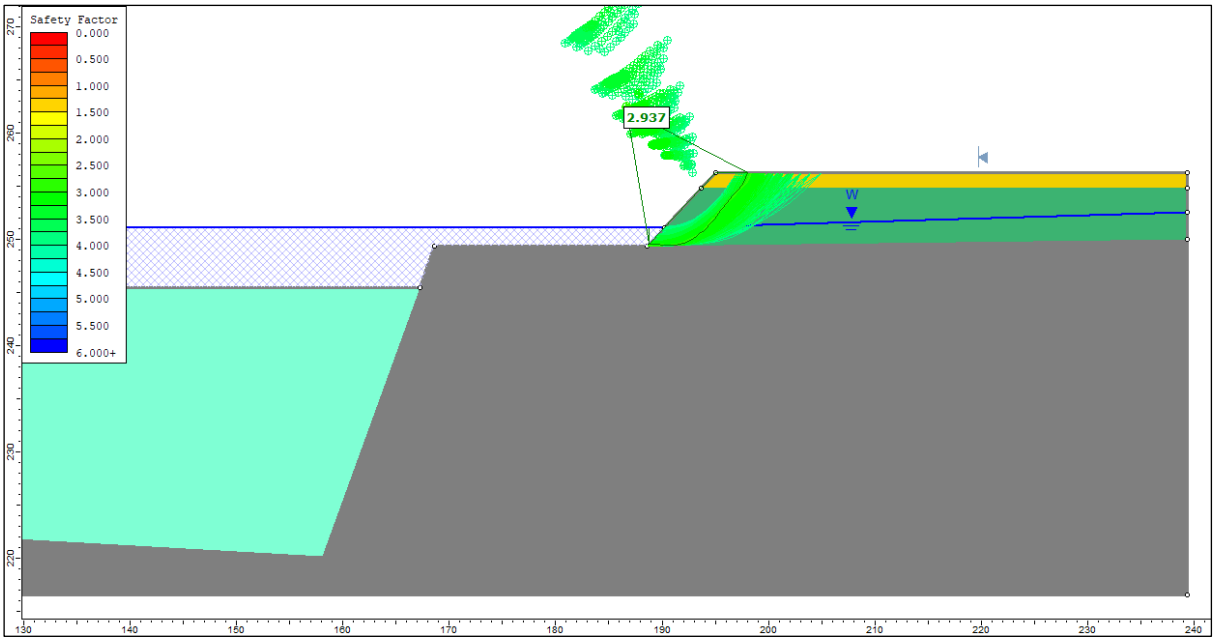


Figure 3-12: Scenario 4 - 2D LE Analysis Result – FoS = 2.94 (Cuckoo Search)

Table 3-2: Summary of Limit Equilibrium Results

Scenario		Failure Surface	Search Method	Factor of Safety (FoS)
1	Pre-split slope of 70º in fresh rock to Matilda Seam, 45º slope in weathered rock - rail loading applied.	Non-Circular	Cuckoo	3.41
		Non-Circular	Block	3.20
2	Continuous 45º softwall slope to Matilda Seam roof – rail loading applied.	Non-Circular	Cuckoo	1.58
		Non-Circular	Block	1.67
3	37º slope in Category 2.5 spoil – 2 x 20 m lifts	Non-Circular	Block	1.55
4	37º slope in Category 2.5 spoil	Circular	Grid	1.86
5	Partially backfilled with tailings/co-disposed spoil	Non-Circular	Cuckoo	2.93

4 KINEMATIC ANALYSIS AND POTENTIAL FAILURE MECHANISMS

Stereographic kinematic analyses were performed for the Matilda Pit based on the data obtained for the Jupiter sub-area in "*Section 8 - BMS Vulcan Complex Geotechnical Assessment Report Final, 20191029 VR Rev 1, 2019"* (BMS, 2019) which was used to assess planar sliding, wedge sliding, and flexural toppling failure mechanisms.

Structures identified from the acoustic televiewer (ATV) interpretation and from structural mapping of the exposed pit faces of the Jupiter Pit, indicated two steeply dipping joint sets dipping approximately towards the northeast and south, respectively. This structural sets are considered likely to be regional scale and is therefore reasonable to assume a similar structural trend in the Matilda Pit.

Bedding was interpreted to dip at approximately 3º to the northeast, based on the floor contours of the Matilda Seam. A summary of the structure sets is presented in Table 4-1.

Table 4-1: Vulcan Coal Mine Structure Set Orientation Summary

Set	Source	Structure Type	Dip (°)	Dip Direction (°)
B1	ATV	Bedding	3	059
J1	ATV	Joint	75	228
J2	ATV	Joint	75	185
J3	Mapping	Joint	75	057
J4	Mapping	Joint	65	354

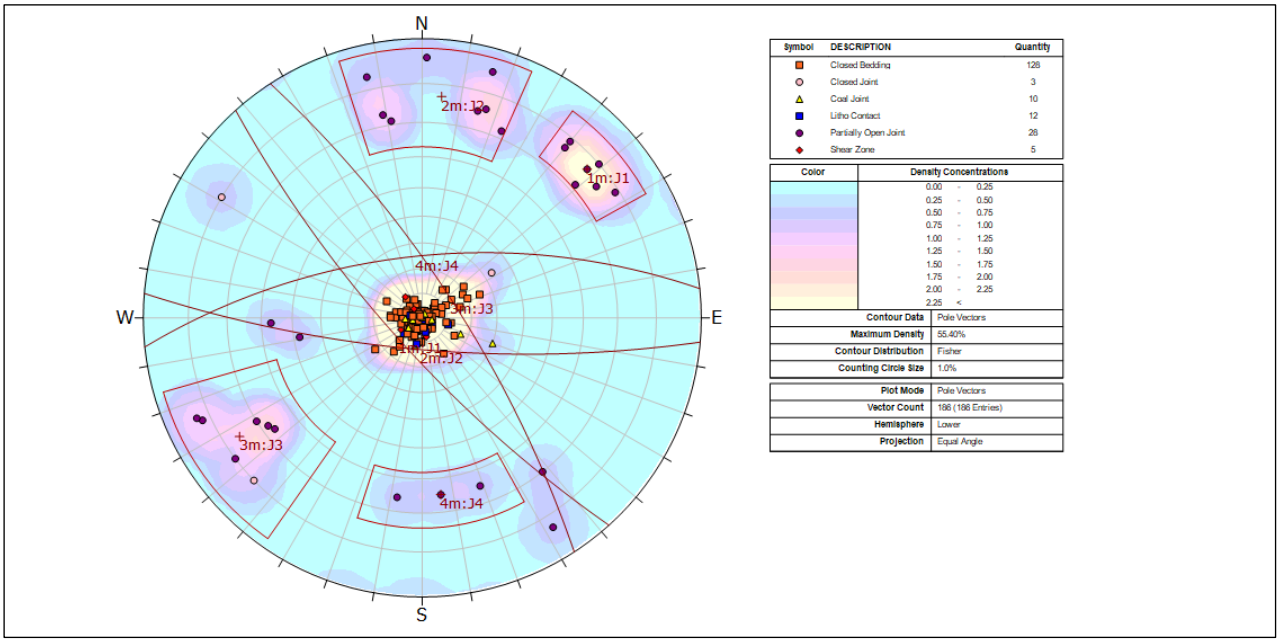


Figure 4-1: All Discontinuity Sets – Matilda Pit (Based on Jupiter Pit Data)

4.1 Assumptions

Key assumptions used for the kinematic analysis are summarised as follows:

- A batter slope dip of 70° was used for the fresh Permian rock below the base of weathering;
- An azimuth of 180° (approx. south) and 225° (approx. southwest) was used for the advancing highwall, respectively;
- An azimuth of 265° was used for the eastern endwall. The northern endwall azimuth is variable due to the curved design; however, slope azimuths would range between approximately 120° to 240°;
- Friction angle of joints and bedding assumed to be approximately 25°;
- Lateral limits of 20° for planar sliding mechanisms and 30° for wedge mechanisms, i.e., planes should be within 20° parallel to the pit face for planar sliding configurations to occur and 30° for wedge sliding; and

- Joint planes are pervasive and continuous throughout the rock mass to permit geometries that are kinematically unstable.

4.2 Results and Discussion

A summary of the potential failure mechanisms and probability of failure is outlined as follows:

- For all highwall and endwall orientations, flexural toppling failure mechanisms (i.e. a steeply dipping joint set or poles shown to fall within the toppling region) are possible, as shown in Figure 4-2. The Probability of Failure (PoF) for this discontinuity set is low, based on the number of poles in the set; however, this should be monitored during operations as this failure mechanism has been recorded from the adjacent Jupiter Pit;
- For highwall and endwall wedge failure mechanisms, only random intersections were recorded in the critical intersection region, as shown in Figure 4-3. In this case, the PoF is low, based on the number of discontinuities identified; however, this should be monitored during operations, due to asymmetrical wedge failures being recorded at the adjacent Jupiter Pit; and
- No discontinuity poles were indicated to fall within the sliding region, therefore planar failure mechanisms are unlikely. In this case, joint planes are generally too steep to permit this configuration, as shown in Figure 4-4; however, this should be monitored during operations.

The kinematic analysis PoF summary is presented in Table 4-2.

As discussed in the geotechnical assessment (BMS, 2019), whilst it is accepted that a 'set' of discontinuities daylighting on the pit face would have a higher probability of failure than randomly oriented structures, structural failures are normally the result of individual discontinuities or the interaction of individual discontinuities.

Discontinuity persistence will also affect the likelihood of these geometries forming and the size of the failure. Failure mechanisms would be identified and confirmed as part of routine pit wall mapping and periodic inspections.

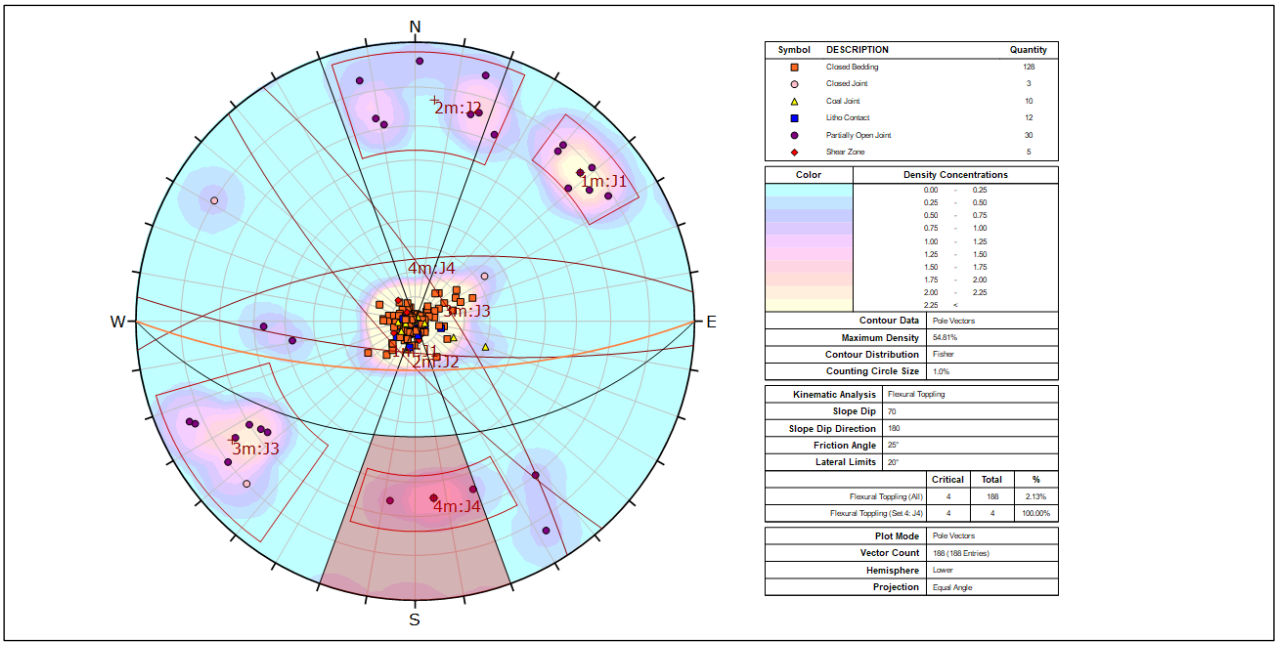


Figure 4-2: Potential Flexural Toppling Mechanisms – 180º Azimuth Advancing Highwall

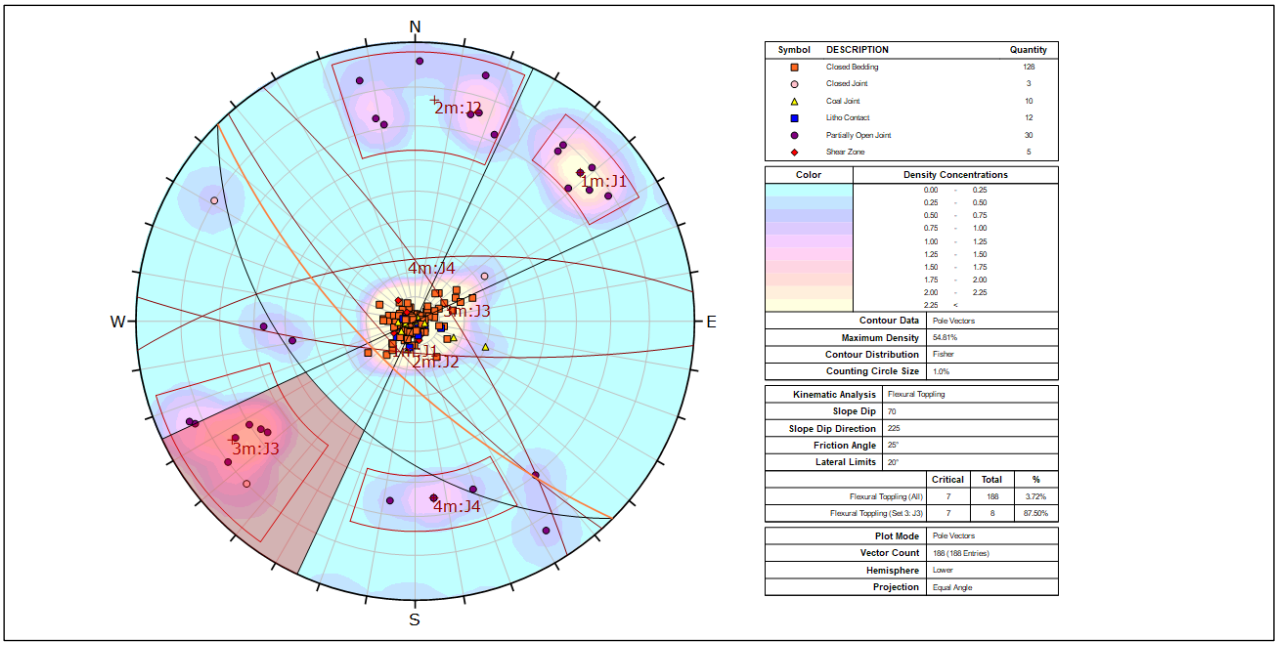


Figure 4-3: Potential Flexural Toppling Mechanisms – 225º Azimuth Advancing Highwall

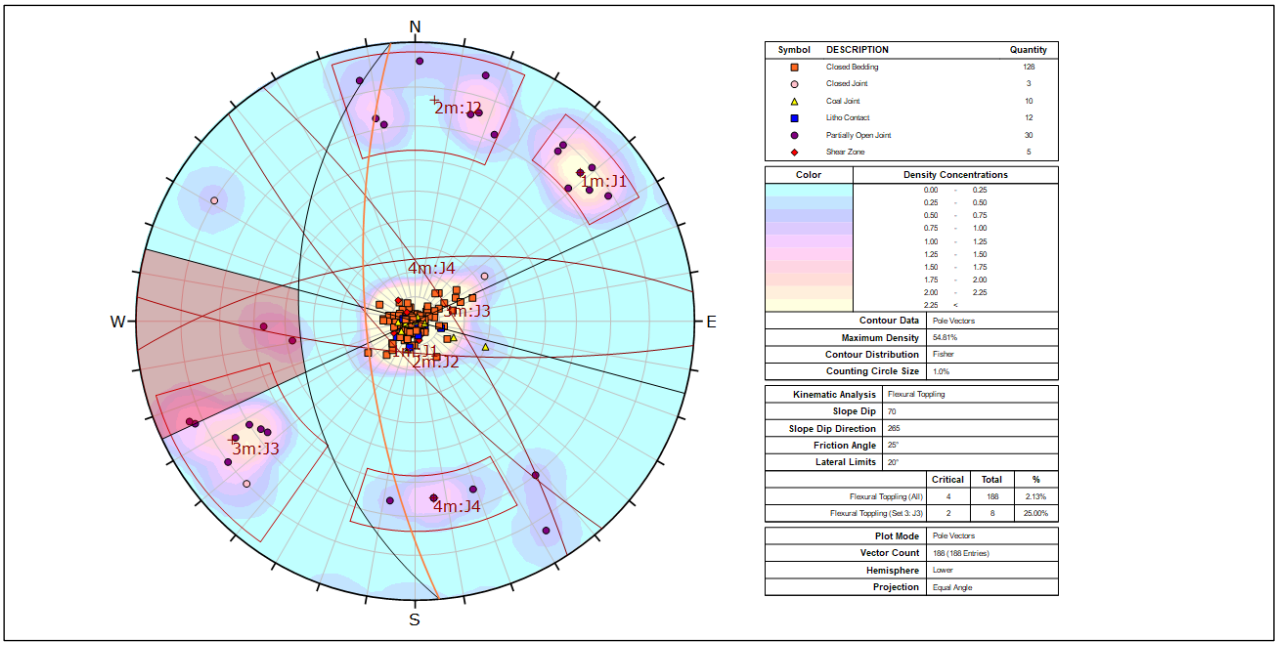


Figure 4-4: Potential Flexural Toppling Mechanisms – 265º Azimuth Endwall

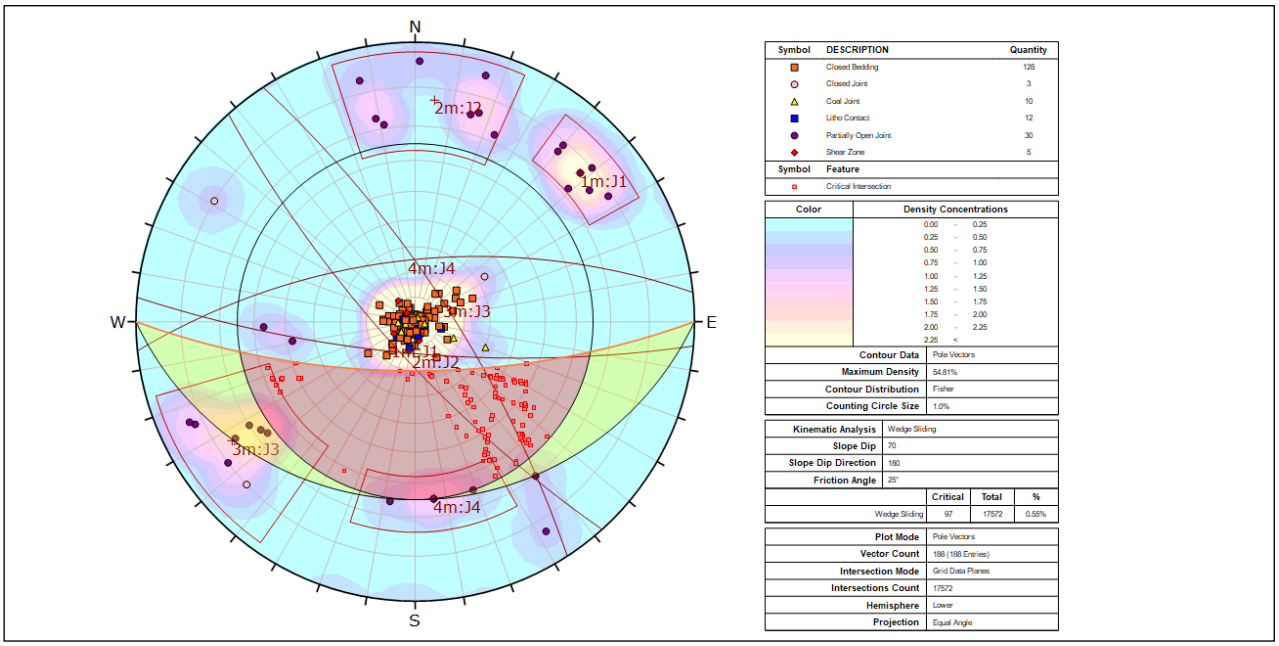


Figure 4-5: Potential Wedge Mechanisms - 180º Azimuth Advancing Highwall

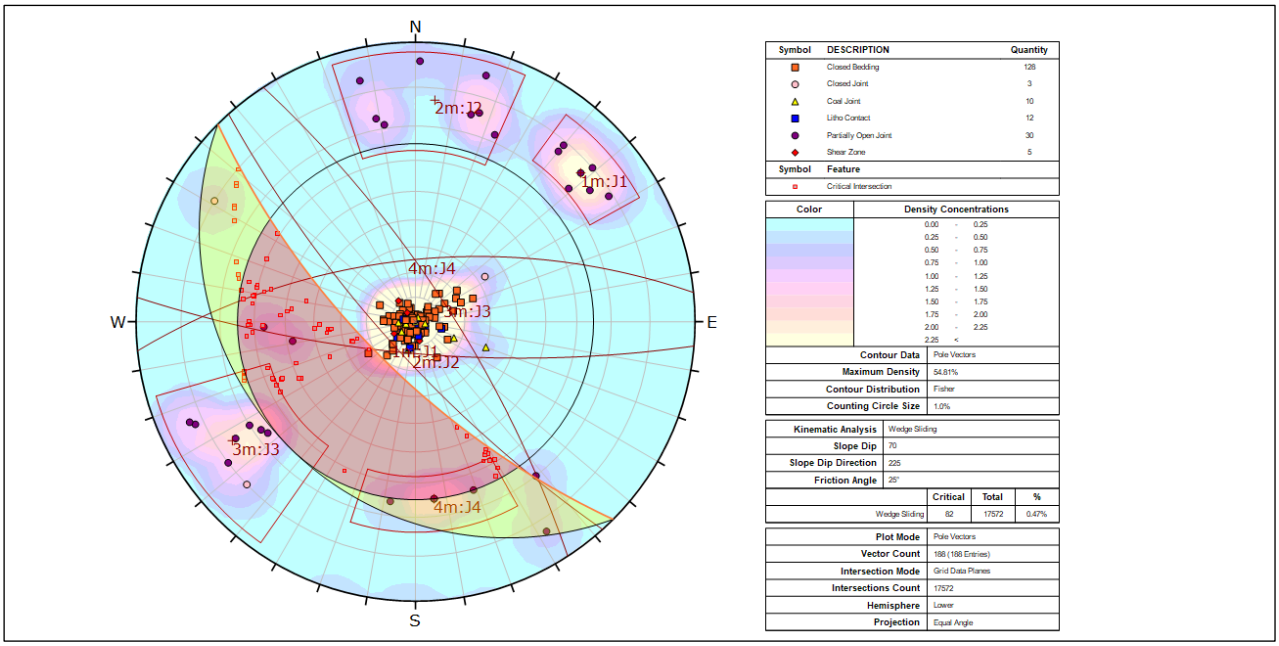


Figure 4-6: Potential Wedge Mechanisms - 225º Azimuth Advancing Highwall

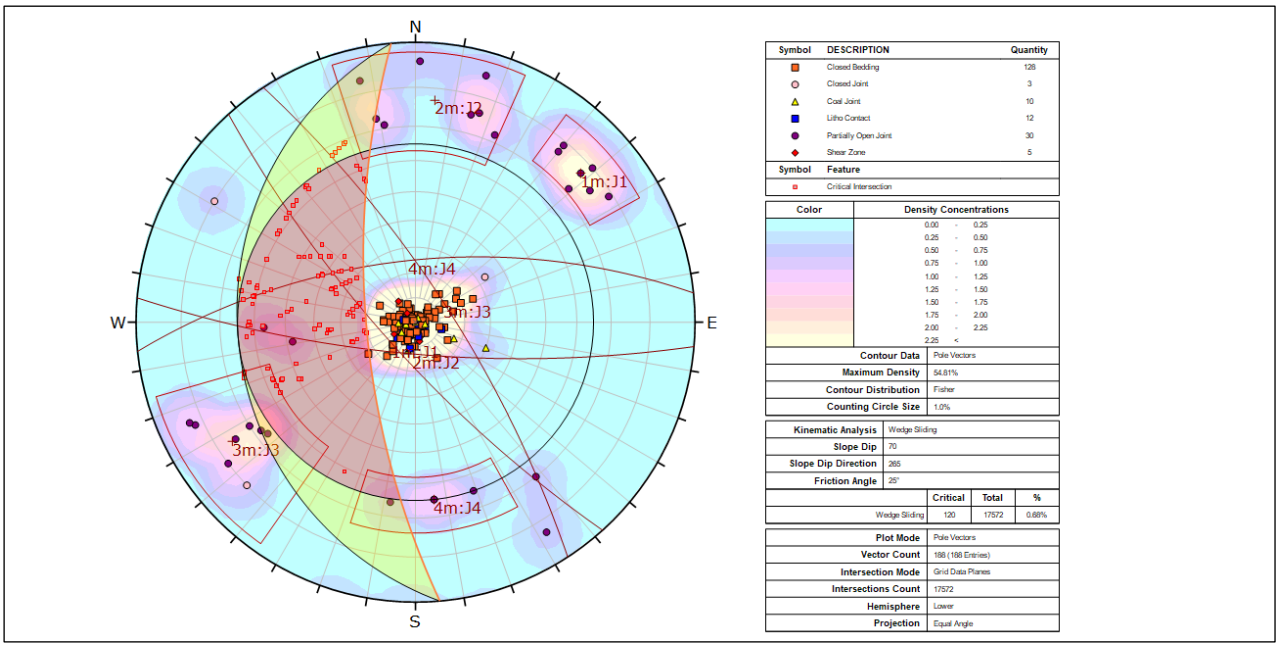


Figure 4-7: Potential Wedge Mechanisms - 265º Azimuth Endwall

Table 4-2: Kinematic Analysis Probability of Failure Summary – Highwall and Endwall

Slope	PoF Planar Sliding	PoF Wedge Sliding	PoF Flexural Toppling
180º Azimuth Highwall	0.00%	0.55%	2.13%
225º Azimuth Highwall	0.00%	0.47%	3.72%
265º Azimuth Endwall	0.00%	0.68%	2.13%

5 CONCLUSIONS AND RECOMMENDATIONS

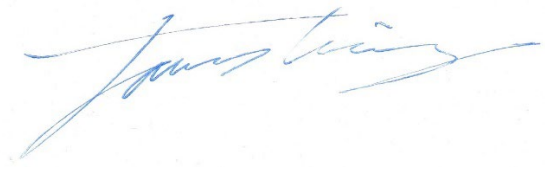
It can be concluded that:

- Slope stability modelling indicated that the critical FoS values calculated were above target FoS of 1.2; therefore geotechnical risks associated with weak materials is unlikely. In this case, slope stability would be governed mainly by structural mechansims;
- The rail loop is offset at a sufficient distance from the pit crest not have any influence in pit stability;
- Softwall slopes to the southwest and south of Strip 1 are expected to be stable from a global slope stability perspective, based on the assumptions, which includes loading from locomotives on the rail loop; and
- Kinematic analyses indicated that structurally governed failure mechanisms are expected to be unlikely; however, there was a comparatively higher PoF from toppling failure mechanisms, and this is consistent with observations at the adjacent Jupiter Pit.

It is recommended that:

- Chamfering of any 'bullnose' edges should be carried out to meet the design geometry, particular where the final pit is circular in geometry. This would be a preferred option from a geotechnical perspective as it would eliminate geotechnical hazards associated with 'bullnose' geometries;
- Further investigations be carried out to assess in more detail the presence of geological structures on the pit walls;
- Routine geotechnical mapping and periodic inspections be carried out to identify and confirm potential kinematic geometries as they arise. Proposed mitigation strategies would be advised as required.





Ty Grantham
Principal Consultant
BAppSc, MEngSc, CP Geotechnical,
RPEQ #18482
Blackrock Mining Solutions Pty Ltd

M: +61 437 881 075
E: t.grantham@blackrockmining.net

James Grindey
Geotechnical Engineer
BSc, MSc, Engineering Geology

Blackrock Mining Solutions Pty Ltd

M: +61 456 048 162
E: j.grindey@blackrockmining.net

6 RERFERENCES

Blackrock Mining Solutions (BMS) (2019). Vulcan Complex Geotechnical Assessment Report Final 20191029 VR Rev1. Issued Report.

Blackrock Mining Solutions (BMS) (2020). Vulcan South Saraji Road Slope Stability Assessment Memo_20200206_VR_Rev1. Issued Report.

Read, J & Stacey, P (2009). "Guidelines for Open Pit Slope Design". CSIRO Publishing.

Simmons, JV & McManus, DA (2004). ″Shear Strength Framework for Design of Dumped Spoil Slopes for Open Pit Coal Mines″. Proceedings - Bowen Basin Symposium.

Appendix H- Geotechnical Assessment- March 2020

MEMORANDUM

To:	Vitrinite Pty Ltd
Attention:	James Richardson, Michael Callan
Prepared By:	Tom Sullivan
Approved By:	Ty Grantham
Date:	4th March 2020
Memo Ref:	BMS-20200304-VIT
Subject:	Vulcan Complex – Jupiter Final Landform Slope Stability Assessment

1 INTRODUCTION

This memorandum presents the results of a geotechnical assessment for the Jupiter final landforms, i.e. rehabilitated in-pit and ex-pit spoil dumps.

The assessment was carried out by Blackrock Mining Solutions Pty Ltd (Blackrock) at the request of Vitrinite Pty Ltd (Vitrinite) as part of their Progressive Rehabilitation and Closure Plan (PRCP).

2 SLOPE STABILITY ANALYSIS

2.1 Slope Stability Analysis Methodology and Assumptions

Limit equilibrium analyses were performed to determine the overall slope stability in terms of a Factor of Safety (FoS), which is a commonly employed measure in slope stability analysis to determine the likelihood of slope failure. The FoS is generally a measure of driving forces versus resisting forces in a system, where a FoS of 1 equates to a 50% probability that failure will occur. FoS values > 1 are indicative that a system is likely to be stable.

Analyses were made for representative cross-sections, and were carried out using industry standard 2D limit equilibrium methods in Slide 2018 developed by Rocscience.

Two scenarios were examined:

- Ex-pit dump final landform on natural ground; and
- In-pit dump final landform.

The following methodology and criterion were used for the assessment:

- Circular failure analyses using the auto-refine search algorithm and the general limit equilibrium method (GLE) for spoil failures;
- A basal saturated spoil layer of approximately 5 m thickness was assumed for both scenarios; and

- The generally accepted Factor of Safety (FoS) criteria for long-term slopes is ≥ 1.5.

2.2 Material Properties

The current assessment is based on the same Mohr-Coulomb shear strength parameters and material types specified in Blackrock's Vulcan Complex Geotechnical Assessment Report BMS Report No. 20191029_VR_Rev1 (Ref 1), as summarised in Table 2-1.

Table 2-1: Jupiter Pit Mohr-Coulomb Shear Strength Parameters

Material	Unit Weight γ′ (kN/m³)	Cohesion c′ (kPa)	Friction Angle ϕ′ (°)
Cat 2.5 (U)	18	40	29
Cat 2.5 (S)	20	18	24
Quaternary/Tertiary	20	55	21
Weathered Permian	23	50	30
Fresh Permian	24	450	42

2.3 Design Geometry

Final landform designs were provided to Blackrock by Vitrinite on 25th February 2020. Final landform dump slopes were designed to 15% (8°), as shown in Figure 2-1.

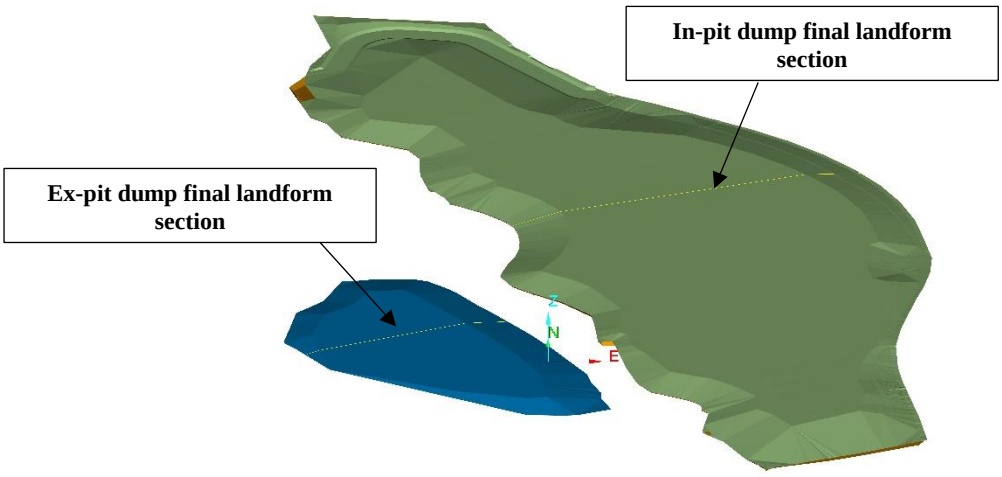


Figure 2-1: Jupiter Pit – Final Landform Design –North Facing View Showing In-Pit (Green) and Ex-Pit (Blue) Final Landform Footprints and Section Lines

2.4 Limit Equilibrium Analysis and Results

Limit equilibrium analyses were assessed in terms of a circular failure mechanism acting through the unsaturated, and saturated Category 2.5 spoil material, for the in-pit and ex-pit dump final landforms, respectively.

Analyses returned critical Factor of Safety values of 3.88 and 5.10 for the in-pit and ex-pit final landforms, respectively. These results exceed the minimum FoS of 1.5, and are therefore considered satisfactory in terms of meeting final landform design, and long-term geotechnical stability criteria.

The results of the limit equilibrium analyses are summarised in Table 2-2, and presented in Figure 2-2 and Figure 2-3, for in-pit and ex-pit dump final landforms, respectively.

Table 2-2: Jupiter Final Landform Slope Stability Analysis Results

Final Landform	Failure Surface	Search Method	FoS
In-Pit Dump	Circular	Auto-Refine	3.88
Ex-Pit Dump	Circular	Auto-Refine	5.10

GLE/Morgenstern-Price FoS reported

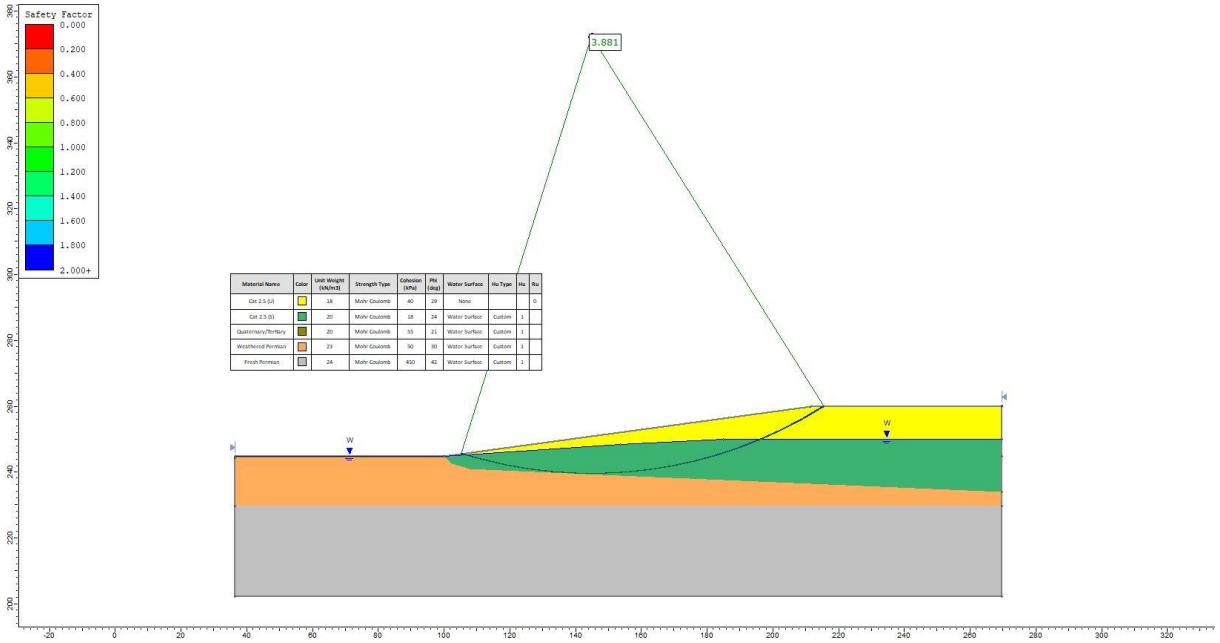


Figure 2-2: Jupiter Pit – In-Pit Dump Final Landform – Circular Failure (Auto-Refine)

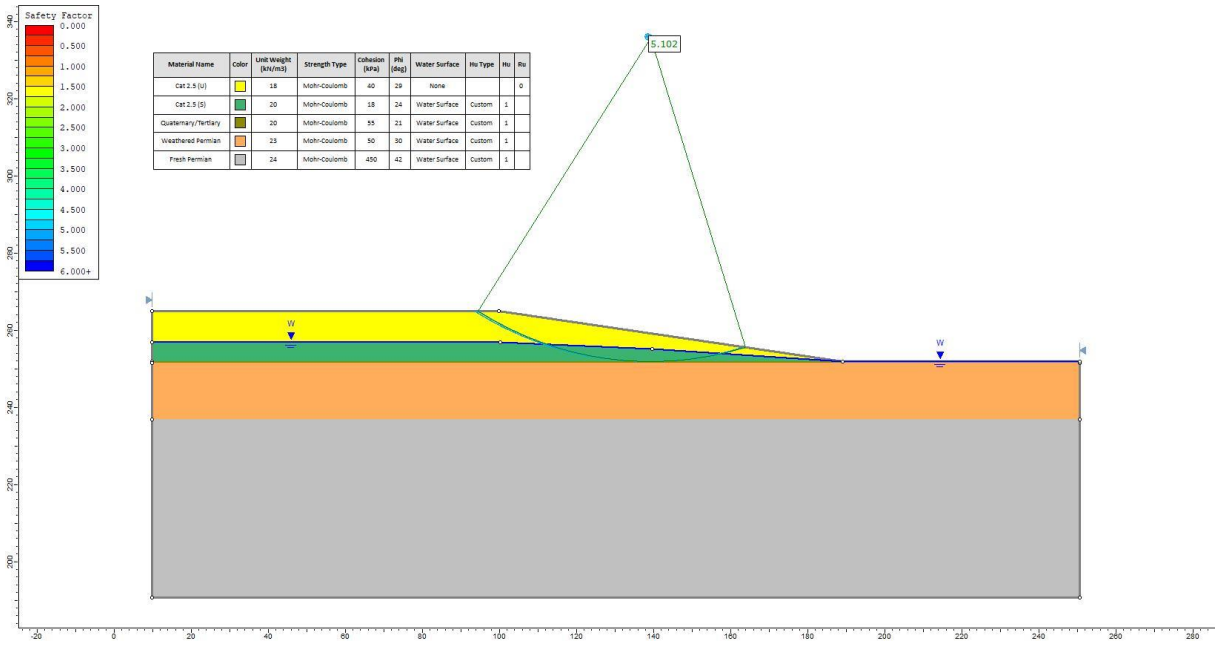


Figure 2-3: Jupiter Pit – Ex-Pit Dump Final Landform – Circular Failure (Auto-Refine)

3 CONCLUSIONS

It can be concluded from the limit equilibrium analyses that:

- The proposed final landform design exceeds the minimum FoS of 1.5 for long-term stability, and is therefore acceptable from a geotechnical perspective.

4 REFERENCES

Ref 1: Blackrock Mining Solutions Pty Ltd (2019). "Vulcan Complex Geotechnical Assessment Report". Report No. 20191029_VR_Rev1.

Ty Grantham
Senior Geotechnical Engineer
BAppSc, MEngSc, CP Geotechnical, RPEQ #18482
Blackrock Mining Solutions Pty Ltd
M: +61 437 881 075
E: t.grantham@blackrockmining.net

Tom Sullivan
Senior Engineering Geologist
BSc (Geology Hons 1)
MAusIMM
Blackrock Mining Solutions Pty Ltd
M: +61 418 613 610
E: t.sullivan@blackrockmining.net

Appendix I- Geochemical Assessment- September 2022

TECHNICAL REPORT

VI010_VCM Matilda Pit Geochemistry Assessment_ September 2022

Vulcan Coal Mine

Prepared for: Mining & Energy Technical Services on behalf of Vitrinite Pty Ltd

MINE WASTE AND WATER MANAGEMENT

© RGS Environmental Consultants Pty Ltd. .....3/30 Lensworth Street, Coopers Plains QLD 4108…….....www.rgsenv.com

TECHNICAL REPORT

VI010_VCM Matilda Pit Geochemistry Assessment_ September 2022

Vulcan Coal Mine

Prepared for: **Mining & Energy Technical Services on behalf of Vitrinite Pty Ltd**

DOCUMENT CONTROL	
Document Number	**01**
Project Number	**2022049**
File Location	**Z:\004_Projects\Projects 2022\2022049 (Vulcan Matilda Pit Geochem)\Reporting\01_2022049_Vulcan Matilda Pit Geochemistry Assessment_Rev 01_30092022.docx**

DOCUMENT DISTRIBUTION			
Document Name	**Revision**	**Distributed to**	**Date distributed**
01_2022049__VI010_VCM Matilda Pit Geochemistry Assessment_ September 2022_Rev 01_30092022	**Rev 01**	**Mining & Energy Technical Services on behalf of Vitrinite Pty Ltd**	**30.09.2022**

Limitations and disclaimer:

This report documents the work undertaken by RGS Environmental Consultants Pty Ltd (RGS).

This report should be read in full. While the findings presented in this report are based on information that RGS considers reliable unless stated otherwise, the accuracy and completeness of source information cannot be guaranteed, although RGS has taken reasonable steps to verify the accuracy of such source data. RGS has made no independent verification of this information beyond the agreed scope of works and RGS assumes no responsibility for any inaccuracies or omissions outside of RGS's direct control. Furthermore, the information compiled in this report addresses the specific needs of the Client, so may not address the needs of third parties using this report for their own purposes. Thus, RGS and their employees accept no liability for any losses or damage for any action taken or not taken on the basis of any part of the contents of this report. Those acting on information provided in this report do so entirely at their own risk.

This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

Table of Contents

1 Introduction 7
1.1 Background 7
1.2 Geology and stratigraphy 7
1.3 Objective 8
1.4 Scope of works 8
2 Methodology 11
2.1 Sample selection and preparation 11
2.1.1 Waste rock (overburden, interburden, roof, and floor material) 11
2.1.2 Coal rejects 13
2.1.3 Raw coal 13
2.1.4 Sample preparation 13
2.2 Geochemical test program 15
3 Geochemical characterisation results 16
3.1 Acid Base Account 16
3.1.1 Waste rock 16
3.1.2 Coal rejects 21
3.1.3 Raw coal 25
3.2 Multi-element concentration in solids 29
3.2.1 Geochemical abundance index 29
3.3 Soil characteristics and sodicity 30
3.3.1 Soil characteristics 30
3.3.2 Sodicity 31
3.4 Water quality static tests 31
4 Discussion 33
4.1 AMD potential and management 33
4.2 Multi-element composition and water quality 33
4.1.1 Multi-element composition and enrichment 33
4.1.2 Water quality 34
4.2 Revegetation and rehabilitation 34
4.3 Management measures 34
5 Conclusions and recommendations 35
5.1 Conclusions 35
5.2 Recommendations 35
6 References 36
7 Attachments A-1
Attachment A: Geochemical Assessment of Mining Materials A-1
Attachment B: Static Geochemical Test Results B-1
Attachment C: ALS Laboratory Results C-1

List of Figures

Figure 1-1: Project location 9
Figure 1-2: Indicative stratigraphic column for the Project area 10
Figure 2-1: Drillholes sampled for waste rock and coal geochemistry 12
Figure 2-2: Drillholes sampled for coal reject geochemistry 14
Figure 3-1: pH values for waste rock samples from Vulcan Coal Mine Matilda Pit 16
Figure 3-2: EC values for waste rock samples from Vulcan Coal Mine Matilda Pit 16
Figure 3-3: Total sulfur values for waste rock samples from Vulcan Coal Mine Matilda Pit 17
Figure 3-4: Total sulfur, sulfide sulfur, and sulfide proportion values for waste rock samples from Vulcan Coal Mine Matilda Pit 18
Figure 3-5: Total sulfur vs sulfide sulfur values for waste rock samples from Vulcan Coal Mine Matilda Pit . 18
Figure 3-6: NAPP values for waste rock samples from Vulcan Coal Mine Matilda Pit 19
Figure 3-7: MPA vs ANC values for waste rock samples from Vulcan Coal Mine Matilda Pit 19
Figure 3-8: AMD classifications for waste rock samples from Vulcan Coal Mine Matilda Pit 20
Figure 3-9: pH values for coal reject samples from Vulcan Coal Mine Matilda Pit 21
Figure 3-10: EC values for coal reject samples from Vulcan Coal Mine Matilda Pit 21
Figure 3-11: Total sulfur values for coal reject samples from Vulcan Coal Mine Matilda Pit 22
Figure 3-12: Total sulfur and sulfide sulfur values for coal reject samples from Vulcan Coal Mine Matilda Pit 22
Figure 3-13: Total sulfur vs sulfide sulfur values for coal reject samples from Vulcan Coal Mine Matilda Pit 23
Figure 3-14: NAPP values for coal reject samples from Vulcan Coal Mine Matilda Pit 23
Figure 3-15: MPA vs ANC values for coal reject samples from Vulcan Coal Mine Matilda Pit 24
Figure 3-16: AMD classifications for coal reject samples from Vulcan Coal Mine Matilda Pit 25
Figure 3-17: pH values for coal samples from Vulcan Coal Mine Matilda Pit 25
Figure 3-18: EC values for coal samples from Vulcan Coal Mine Matilda Pit 26
Figure 3-19: Total sulfur values for coal samples from Vulcan Coal Mine Matilda Pit 26
Figure 3-20: Total sulfur and sulfide sulfur values for coal samples from Vulcan Coal Mine Matilda Pit 27
Figure 3-21: Total sulfur vs sulfide sulfur values for coal samples from Vulcan Coal Mine Matilda Pit 27
Figure 3-22: NAPP values for coal samples from Vulcan Coal Mine Matilda Pit 28
Figure 3-23: MPA vs ANC values for coal samples from Vulcan Coal Mine Matilda Pit 28

List of Tables

Table 2-1: Waste rock samples by material type 11
Table 3-1: Salinity and pH criteria for assessment of waste rock samples 17
Table 3-1: AMD classification parameters for waste rock samples from Vulcan Coal Mine Matilda Pit 20
Table 3-2: AMD classification parameters for coal reject samples from Vulcan Coal Mine Matilda Pit 24

Table 3-3: AMD classification parameters for coal samples from Vulcan Coal Mine Matilda Pit 29
Table 3-4: Geochemical abundance index values and enrichment factors 29
Table 3-5: Ratings for cation exchange capacity 31
Table 4-1: Material management over mine life 34

Glossary of terms and acronyms

Acidity	A measure of hydrogen ion (H+) concentration and certain dissolved metals in a solution when titrated to a set pH value; generally expressed as mg/L $CaCO_3$ equivalent.
ABA	Acid Base Account. Evaluation of the balance between acid generation and acid neutralisation processes. Determines the maximum potential acidity (MPA) and the inherent acid neutralising capacity (ANC), as defined below.
ALS	Australian Laboratory Services.
AMD	Acid and metalliferous drainage from mine waste materials characterised by low pH, elevated metal concentrations, high sulfate concentrations and high salinity.
ANC	Acid Neutralising Capacity expressed as kg H_2SO_4 per tonne of sample. A measure of a sample's maximum potential ability to neutralise acid.
ANC:MPA	The ratio of the acid neutralising capacity to the maximum potential acidity of a sample. Used to assess the risk of a sample generating acid conditions.
AS	Australian Standards
CEC	Cation exchange capacity provides a measure of the mass of exchangeable cations (Ca, Mg, Na and K) in a sample.
Dispersive	Dispersive soil and rock materials are structurally unstable and disperse into basic particles such as sand, silt and clay in water. When a dispersive soil is wet, the basic structure has a tendency to collapse, whereas when it is dry it is prone to surface sealing and crusting.
EC	Electrical Conductivity, expressed as µS/cm.
ESP	Exchangeable sodium percentage provides a measure of the sodicity of a material and propensity to erode.
FIMS	Flow Injection Mercury System.
GAI	Geochemical Abundance Index
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
ICP-AES	Inductively Coupled Plasma Atomic Emission Spectrometry.
INAP	International Network on Acid Prevention
Interburden	The material found in between ore layers and considered to be of low economic value (i.e., a type of waste material).
MPA	Maximum Potential Acidity. Calculated by multiplying the total sulfur or sulfide-sulfur (CRS) content of a sample by 30.6 (stoichiometric factor) and expressed as kg H_2SO_4 per tonne.
NAF	Non-Acid Forming. Geochemical classification criterion for a sample that will not generate acid conditions.
NAF - Barren	Non-acid forming and barren of sulfur (i.e. less than or equal to 0.1% sulfur).
NAPP	Net Acid Producing Potential, expressed as kg H_2SO_4 per tonne. Calculated by subtracting the ANC from the MPA.
Overburden	The waste rock material found overlying the first ore horizon within the stratigraphic profile.
PAF	Potentially Acid Forming. Geochemical classification criterion for a sample that has the potential to generate acid conditions.

PC Titrator	Potentiometric Compact Titrator. PC Titrators are specially designed for routine applications and simple operation, allowing basic titration analysis from a single device.
pH	A measure of hydrogen ion (H^+) concentration.
Sodic	Sodic soil and rock materials are characterized by a disproportionately high concentration of sodium (Na) in their cation exchange complex and are innately unstable, exhibiting poor physical and chemical properties, which impede water infiltration, water availability, and ultimately plant growth.
Static test	Procedure for characterising the geochemical nature of a sample at a single point in time. Static tests may include measurements of mineral and chemical composition of a sample and the Acid Base Account.
w:v	Weight to volume ratio.

1 Introduction

RGS Environmental Consultants Pty Ltd (RGS) was commissioned by Mining & Energy Technical Services Pty Ltd (METServe) to conduct a geochemical assessment of waste rock (overburden, interburden, roof, and floor), coal rejects (coarse and fine fractions), and coal for the Matilda Pit (the Project) at the Vulcan Coal Mine on behalf of Vitrinite Pty Ltd (Vitrinite). This technical report details the methods, results, and outcomes of the geochemical assessment. Based on the outcomes of the geochemical assessment, this report also contains recommendations for environmental management measures for waste rock, coal, and coal reject materials with respect to stockpiling, emplacement, and rehabilitation.

1.1 Background

The Project is located north of Dysart and approximately 33 km south-east of Moranbah in Queensland's Bowen Basin (**Figure 1-1**). The Project lies to the immediate west of several established mining operations, including BHP's Peak Downs and Saraji mines.

The Project currently has approval under Environmental Authority (EA) EA0002912 to operate for four years and to extract approximately six million tonnes of run of mine (ROM) coal. The project is targeting the Alex and multiple Dysart Lower coal seams through a primary open-cut pit developed using truck and shovel mining. The Project is currently approved to transport ROM coal off-site for toll washing by third parties. An initial out-of-pit waste dump will be established followed by in-pit waste emplacements as the open-cut pit is developed. Ancillary infrastructure, such as a ROM pad, mine infrastructure area, offices, roads, and surface water management infrastructure have been established on site.

Vitrinite is proposing an amendment to the approved EA to establish a Coal Handling and Preparation Plant (CHPP), Train Load-out facility, a dedicated rail loop, and an additional smaller open cut pit at the Project. Minor amendments to existing infrastructure layouts are also proposed, e.g., product stockpiles, updated water management infrastructure, and access roads. The proposed additional open cut pit, referred to as the Matilda Pit, will be located inside the rail loop and be developed concurrently with the main pit of the Project. The development of the Matilda Pit is not expected to have a significant impact on the pre-approved production rate or life of the Project.

The Matilda Pit is intended to have a maximum depth of 40 m and targets the Matilda Coal Seam which underlies the Alex and multiple Dysart Lower coal seams mined in the pit to the east. Waste materials excavated from the Matilda Pit will be placed in the previously approved waste rock dump final landforms. With the establishment of the CHPP at the Project coal will be processed through three circuits to produce a primary and secondary product (metallurgical and thermal). Coarse, fine and dry tailings will be trucked for placement within active waste rock dumps (primarily within the in-pit dump). Product coal will be conveyed and stacked on the product coal stockpiles.

In a previous geochemical assessment of waste rock and tailings for the main pit at the Project RGS found that waste rock and coal reject materials generally had low sulfide content and excess acid neutralising capacity (ANC) and so bulk materials posed a low risk of generating acidic or metalliferous drainage (AMD) (RGS, 2020). Total sulfur concentration results for coal quality samples taken from the Matilda Coal Seam indicate higher total sulfur concentrations relative to similar materials likely to be generated from the main pit.

1.2 Geology and stratigraphy

The Project will target the Alex and multiple Dysart Lower coal seams within the Permian-aged Moranbah Coal Measures. A surficial Tertiary waste rock (overburden) sequence is present in the Project area, consisting of unconsolidated soils and sands. Underlying this is Permian-aged waste rock (overburden), which is comprised of sandstone and siltstone.

The Permian waste rock (interburden) materials in the Project area generally comprise sandstone, siltstone, claystone, and coal that were deposited in a fluvial flood plain environment within the Bowen Basin. Significant mesa hills formed by highly resistant sandstones have provided target coal seams throughout the centre of the Project area. The typical stratigraphic profile encountered at the Project is provided in **Figure 1-2**.

The Alex seam is generally quite shallow and occurs just below the base of weathering in the stratigraphic profile. The Dysart Lower Seam comprises several plys with the waste rock (interburden/parting) in between

generally consisting of fine-grained sedimentary units such as siltstone, mudstone, and claystone, with the occasional carbonaceous or coaly unit.

The May Seam (consisting of carbonaceous claystone and considered uneconomic) and Matilda Seam (consisting of interbedded coal and siltstone and the target seam of the proposed Matilda Pit) underlie the Dysart seam.

1.3 Objective

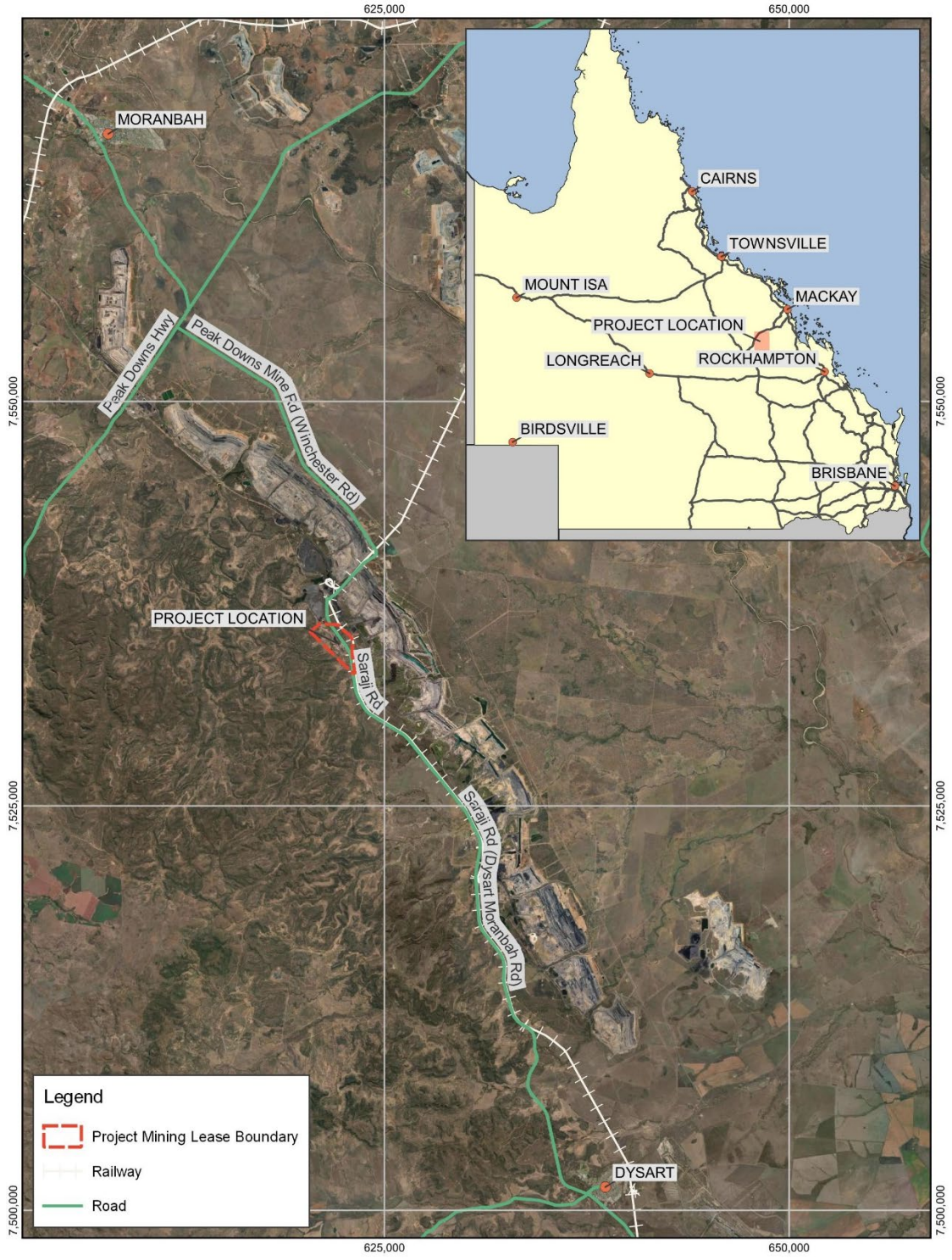
The relatively elevated total sulfur concentrations in the Matilda Coal Seam coal quality samples suggests that the findings of the previous geochemical assessment undertaken on coal and coal reject materials in the pit to the east may not be applicable to the coal and coal reject materials that will be generated from the Matilda Pit. It is on this basis that RGS was requested to undertake a geochemical assessment of waste rock, coal, and coal reject likely to be generated from the proposed Matilda Pit.

The objective of the assessment was therefore to complete a static geochemical assessment of representative samples of waste rock (overburden, interburden, roof, and floor) coal, and coal rejects (coarse and fine fractions) for the proposed Matilda Pit.

1.4 Scope of works

To achieve the above objective, RGS undertook the following scope of work:

- Design of a static geochemical assessment program, including sampling for, and testing of, representative overburden, interburden, roof, floor, coal reject, and coal materials within the Matilda Pit boundary;
- Develop environmental management measures related to waste rock, coal, and coal reject materials with respect to stockpiling and/or emplacement and rehabilitation; and
- Prepare this Geochemical Assessment Report to support the application for an amendment to the EA for the Vulcan Coal Mine.



Source: Vitrinite Pty Ltd; ESRI Satellite

RGS	Scale 1:329,983 Datum: GDA94 / MGA zone 55	Matilda Pit Material Geochemical Assessment	5 0 5 10 km
	2022049 Vulcan Matilda Pit Spatial Data.qgz; Project Location	**Project location**	Figure: 1-1 Job Number: 2022049 07/07/2022 N

Figure 1-1: Project location

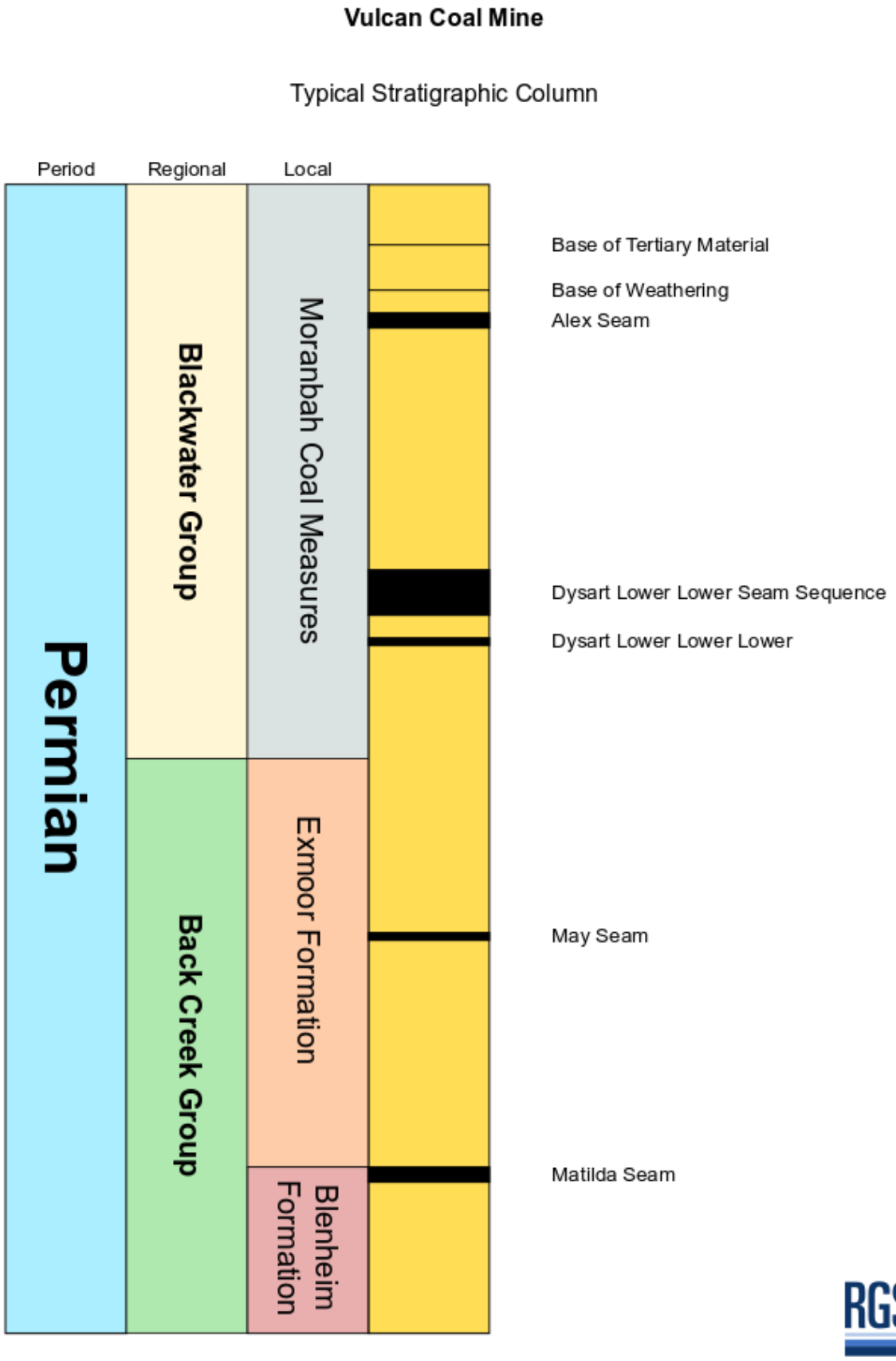


Figure 1-2: Indicative stratigraphic column for the Project area

2 Methodology

RGS personnel worked closely with Vitrinite and METServe personnel to develop an appropriate sampling and geochemical testing plan, which was used to obtain representative samples of waste rock (overburden, interburden, roof, and floor), coal and coal rejects (coarse and fine) associated with the Matilda Pit.

2.1 Sample selection and preparation

The sampling methodology used to obtain representative samples of waste rock, coal, and coal reject materials for the Project was undertaken in accordance with relevant technical guideline documents. While there are no specific regulatory guidelines regarding the number of samples required, existing risk-based technical guidelines for the geochemical assessment of mining waste materials in Australia (AMIRA, 2002; COA, 2016; DEHP, 2013; DME, 1995) and worldwide (INAP, 2022) were used by RGS as a framework for the sampling program.

2.1.1 Waste rock (overburden, interburden, roof, and floor material)

Representative samples of waste rock (overburden, interburden, roof, and floor) materials were identified and collected as drill chips from the 2022 exploration drilling program. A total of 38 waste rock samples were collected from two drill holes at the Project. The locations of the sampled drill holes are shown in **Figure 2-1**.

The samples represented the waste rock (overburden, interburden, roof, and floor materials) expected to be encountered during development activities, from the surface to a depth of approximately 40 m. This covers the entire stratigraphic profile that is currently under consideration for mining at the Project. **Table 2-1** provides the number of samples of each type of material collected and used in the geochemical assessment. Further information on the identity of the 38 individual waste rock samples is provided in **Table B1** (**Attachment B**). The number of samples was selected to provide a good statistical representation of the amount and type of mined material expected to be encountered at the Project, considering the risk profile indicated from the geology and geochemical information from the Project and other nearby coal projects.

Table 2-1: Waste rock samples by material type

Material	Number of Samples Collected
Fresh Sandstone Interburden	3
Fresh Sandstone Overburden	8
Slightly Weathered Sandstone Overburden	5
Fresh Siltstone Floor	2
Fresh Slightly Carbonaceous Siltstone Overburden/Interburden	7
Fresh Siltstone Overburden	6
Fresh Siltstone Roof	2
Slightly Weathered Siltstone Overburden	5
Total:	**38**

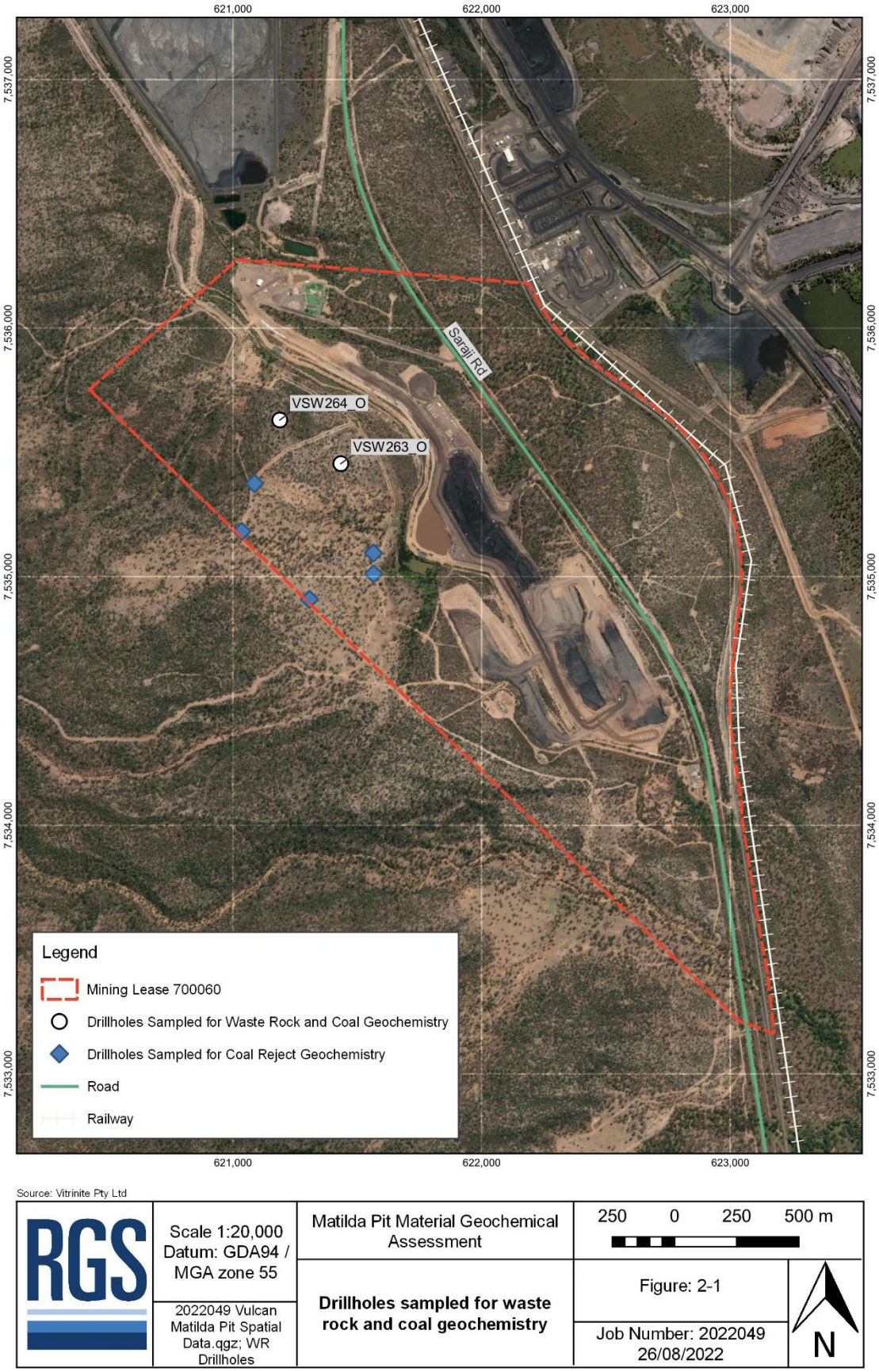


Figure 2-1: Drillholes sampled for waste rock and coal geochemistry

2.1.2 Coal rejects

A total of 14 samples were used for the coal rejects analysis. Two size fractions (coarse: 50 to 2 mm diameter, and fine: less than 0.25 mm diameter) of coal reject materials were selected to best represent the two coal reject streams that are likely to be produced from coal washing on site. Coal core from a total of seven holes was collected by Vitrinite personnel and delivered to the ALS coal quality laboratory in Richlands, Queensland. The locations of the drillholes sampled for coal rejects are shown in **Figure 2-2**. This core was composited into samples of coarse (seven samples) and fine (seven samples) rejects and sent to ALS Environmental Laboratory (ALS) in Stafford, Queensland for geochemical testing.

2.1.3 Raw coal

Two samples of raw coal from the Matilda Seam were collected from the two drillholes (one sample per hole) sampled for waste rock materials (**Figure 2-1**).

2.1.4 Sample preparation

Once received, the waste rock, coal reject, and coal samples were prepared by crushing to less than 20 mm and pulverising to less than 75 µm size, where necessary. This method of sample preparation results in a homogenous sample, but also generates a large sample surface area in contact with the assay solution. This provides a greater potential for dissolution and reaction and represents an assumed initial 'worst case' scenario for these materials.

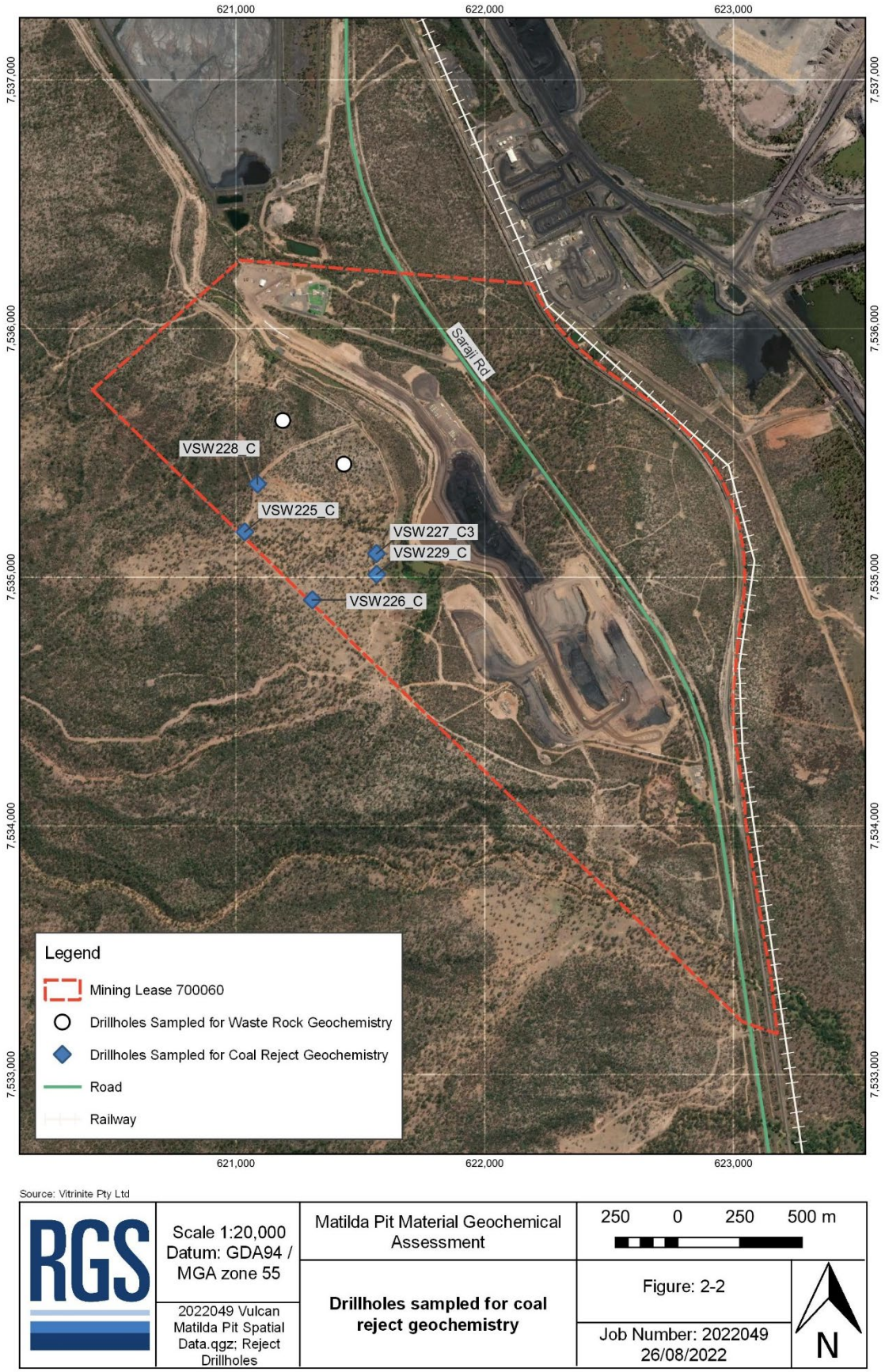


Figure 2-2: Drillholes sampled for coal reject geochemistry

2.2 Geochemical test program

A series of static geochemical and physical tests were completed on the 54 waste rock, coal reject, and coal samples described in **Section 2.1**. The test program was designed to assess the degree of risk from the presence and potential oxidation of sulfides, as well as the generation and the presence/leaching of soluble metals/metalloids, and salts. The assessment also included characterisation of standard soil parameters including salinity, sodicity, cation exchange capacity, exchangeable sodium percentage and major metal/ metalloid concentrations. A detailed summary of the parameters involved in completing a static geochemical characterisation and assessment of mining waste materials is provided in **Attachment A**.

Static geochemical tests provide a 'snapshot' of the characteristics of a sample material at a single point in time. These tests were staged to screen individual samples before selecting either individual and/or composite samples for more detailed static test work.

The Acid Base Account method was used as a screening procedure whereby the acid-neutralising and acid-generating characteristics of the samples were assessed. All 54 samples were screened using the Acid Base Account method, which involved static geochemical testing for the following parameters:

- pH [1:5 w:v. sample:deionised water];
- Electrical conductivity (EC) [1:5 w:v. sample:deionised water];
- Total sulfur [LECO analyser]; and
- Acid Neutralising Capacity (ANC) [AMIRA, 2002 method].

The results of the Acid Base Account screening tests are discussed in **Section 3.1**. After the results of the screening tests were received and interpreted selected samples with a total sulfur content greater than the median crustal abundance for sulfur (0.1 %S) (i.e., 29 waste rock, 14 coal reject, and two coal samples) were also tested for sulfide sulfur, using the chromium reducible sulfur (Scr), Australian Standard (AS 4969.7, 2008) method.

From the total sulfur value (or Scr value, where available), maximum potential acidity (MPA) values were calculated by multiplying using the standard stoichiometric factor of 30.625 for pyrite/marcasite oxidation. Scr data was preferentially used where available, to provide a more accurate representation of the potential MPA, as acid generation primarily forms from the oxidation of reactive sulfide measured by this method.

After the results of the initial static geochemical tests were received and reviewed composite samples were created including eight waste rock, four coal reject (two coarse and two fine), and one coal sample. All 13 composite samples were sent for whole rock multi-element testing at ALS Stafford laboratory. The composite samples were tested for:

- pH and EC [1:5 w:v. sample:deionised water];
- Total major cations (Ca, Mg, K, Na) [HCl and HNO3 acid digest followed by ICP-AES/MS];
- Acidity and alkalinity as $CaCO_3$ mg/L [PC Titrator (1:5 w:v water extracts)];
- Total metals/metalloids (Al, As, B, Ba, Be, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Sb, Se, Th, U, V, and Zn) [HCl and HNO_3 acid digest followed by FIMS and/or ICP-AES/MS]; and
- Soluble major cations (Ca, Mg, K, Na) [ICP-AES/MS (1:5 w:v water extracts)];
- Soluble major anions (Cl, SO_4, F, P, Si) [ICP-AES/MS and PC Titrator (1:5 w:v water extracts)];
- Soluble metals (Al, As, B, Ba, Be, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Sb, Se, Th, U, V, and Zn) [ICPAES/MS (1:5 w:v water extracts)].

Five of the composite waste rock samples representing waste rock were also tested for exchangeable cations (Ca, Mg, Na and K) [ICP-AES], and results were used to calculate the cation exchange capacity (CEC) and exchangeable sodium percentage (ESP). Summary geochemical results tables for the static geochemical test program are provided in **Attachment B**. The ALS laboratory certificates of analysis are provided in **Attachment C**.

3 Geochemical characterisation results

3.1 Acid Base Account

3.1.1 Waste rock

pH: pH results for the waste rock (overburden, interburden, roof, and floor) samples are shown in **Figure 3-1**. The pH results range from 5.5 to 9.4, with a median of pH 8.6. Fresh sandstone overburden, fresh siltstone overburden, and slightly weathered siltstone overburden generally increased in pH with increasing depth. It should be noted that the pH of the deionised water used in the pH tests was 5.4 and therefore most waste rock samples add some alkalinity to initial contact water.

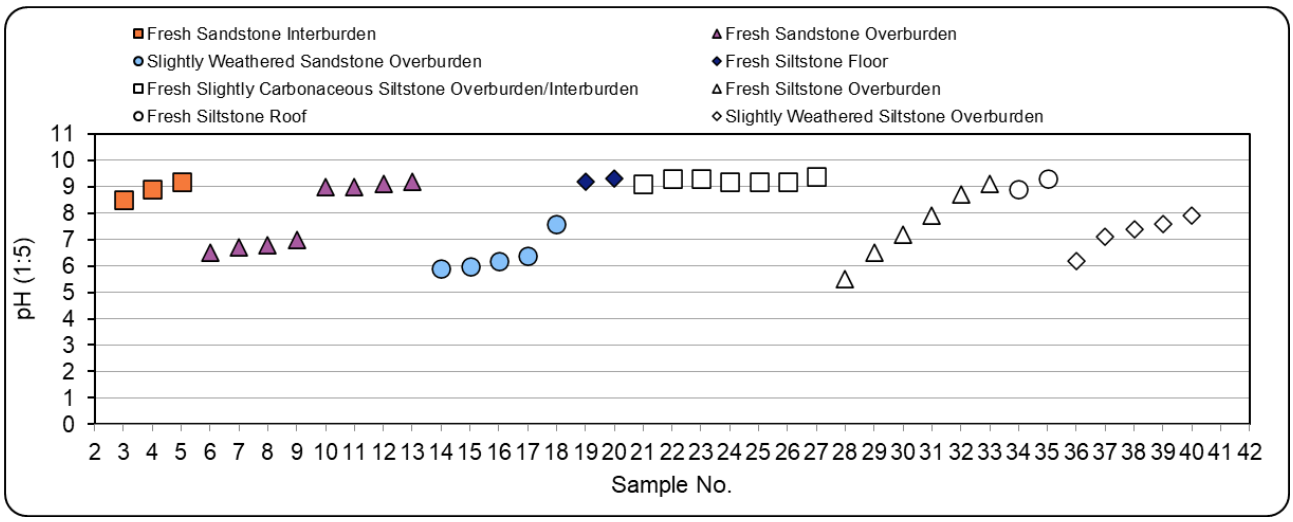


Figure 3-1: pH values for waste rock samples from Vulcan Coal Mine Matilda Pit

EC: EC results for the waste rock samples are shown in **Figure 3-2**. EC results range from 28 to 441 µS/cm, with a median of 184 µS/cm. It should be noted that the EC of the deionised water used in the EC tests was <1 µS/cm and therefore most waste rock samples add some salts to initial contact water.

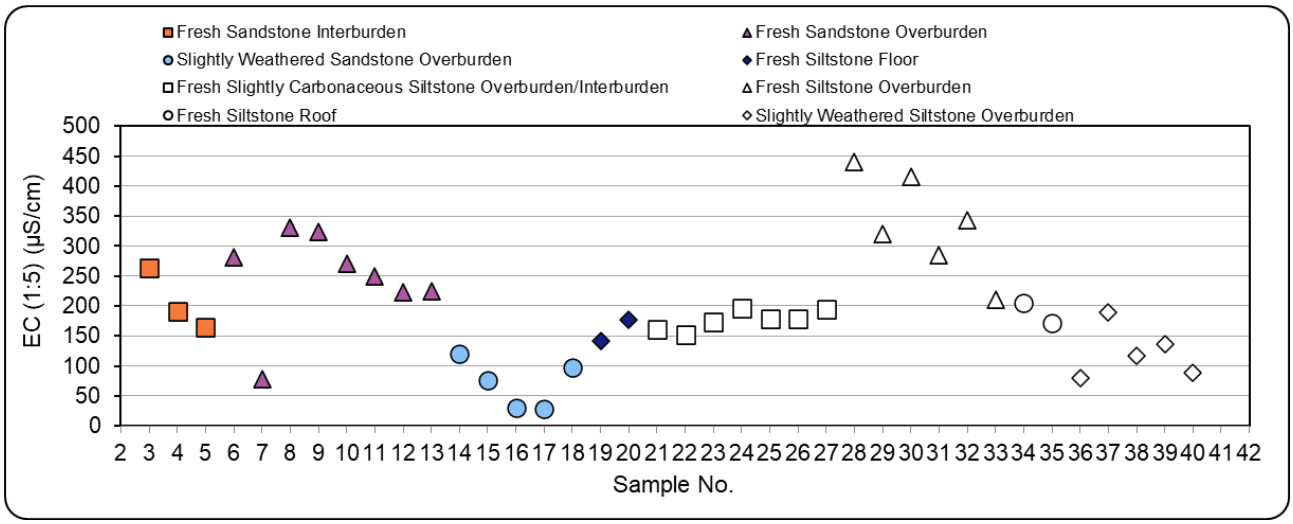


Figure 3-2: EC values for waste rock samples from Vulcan Coal Mine Matilda Pit

To provide additional context, the $EC_{(1:5)}$ and $pH_{(1:5)}$ results for waste rock samples are classified against pH and salinity criteria for mine waste materials, as defined by the Queensland DME (1995) technical guidelines for the environmental management of exploration and mining in Queensland (**Table 3-1**).

Based on the median pH and EC values, the waste rock samples tested are generally regarded as having a 'Medium' to 'High' soil pH and 'Low' salinity characteristics, as indicated by the distribution of samples corresponding to each pH and salinity class.

Table 3-1: Salinity and pH criteria for assessment of waste rock samples

Parameter	Very Low	Low	Medium	High	Very High
$pH_{1:5}$	< 4.5	4.5 – 5.5	5.5 – 7.0	7.0 – 9.0 (Median – 8.6)	> 9.0
$EC_{1:5}$ (µS/cm)	< 150	150 – 450 (Median – 184)	450 – 900	900 – 2,000	> 2,000

Note: Adapted from DME, 1995. Highlighted cells show the category corresponding to the median pH and EC values (orange shading) for the waste rock samples.

The pH and EC tests were completed on pulverised samples (≤ 75 µm) with a large surface area in contact with the leaching solution, thereby providing greater potential for dissolution and reaction, and represent an assumed 'worst case' scenario. It is also expected that the salinity of leachate from low sulfur waste rock materials will diminish with time as salts are flushed from the rock matrix and a state of equilibrium develops. At that point, the salinity of seepage/runoff should stabilise at a lower asymptotic concentration relative to the weathering/erosion of the materials.

Total Sulfur: Total sulfur results for the waste rock samples are shown in **Figure 3-3**. The total sulfur values range from 0.01 to 2.13 % sulfur (%S), with a low median value of 0.18 %S. Some of the fresh siltstone overburden and fresh siltstone roof samples have an elevated total sulfur value relative to other lithologies and weathering extents. In particular overburden samples within the weathering profile (<15 m below ground level) generally have relatively low sulfur content.

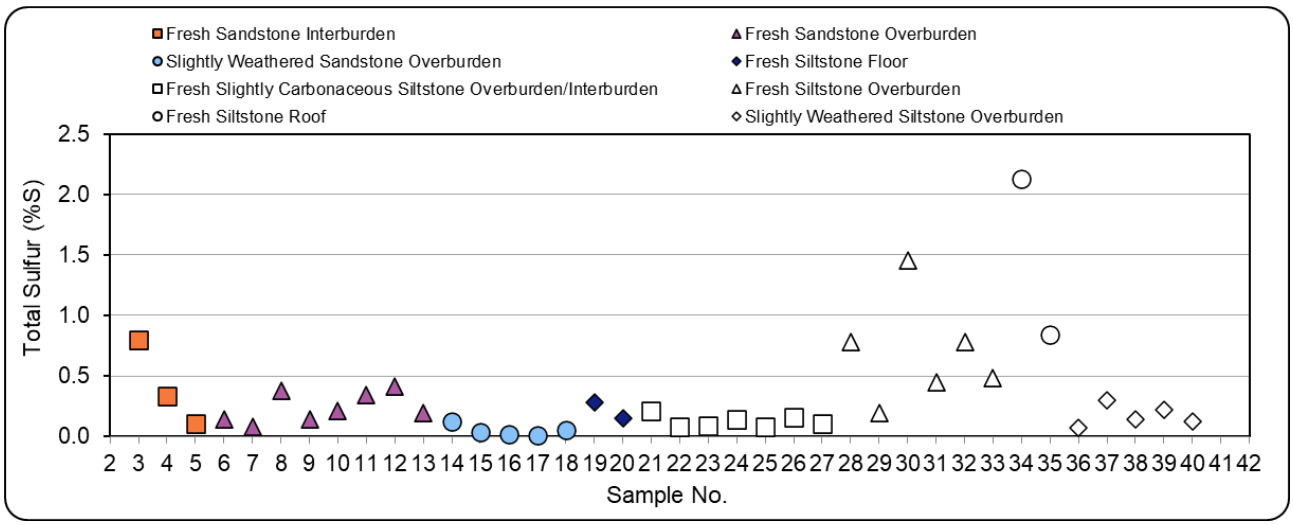


Figure 3-3: Total sulfur values for waste rock samples from Vulcan Coal Mine Matilda Pit

Sulfide Sulfur: Sulfide sulfur concentrations relative to total sulfur concentrations are shown in **Figure 3-4**. Samples with total sulfur concentrations less than 0.1 %S (the median crustal abundance of sulfur (0.07%) rounded to one decimal place (Bowen, 1979; INAP, 2022)) were not analysed for sulfide sulfur and show 0 % sulfide proportions in the figure. Sulfide sulfur results for samples with total sulfur results greater than 0.1 %S range from 0.101 % to 1.790 % sulfide sulfur, with a median value of 0.223% sulfide sulfur.

Figure 3-5 shows the correlation between total sulfur and sulfide sulfur results for waste rock samples with greater than 0.1% total sulfur. There is a strong correlation between total sulfur and sulfide sulfur (R^2 = 0.9946) and linear regression modelling suggests the approximately 85 % of the total sulfur in waste rock samples with total sulfur greater than 0.1 %S is likely to be present as sulfide sulfur.

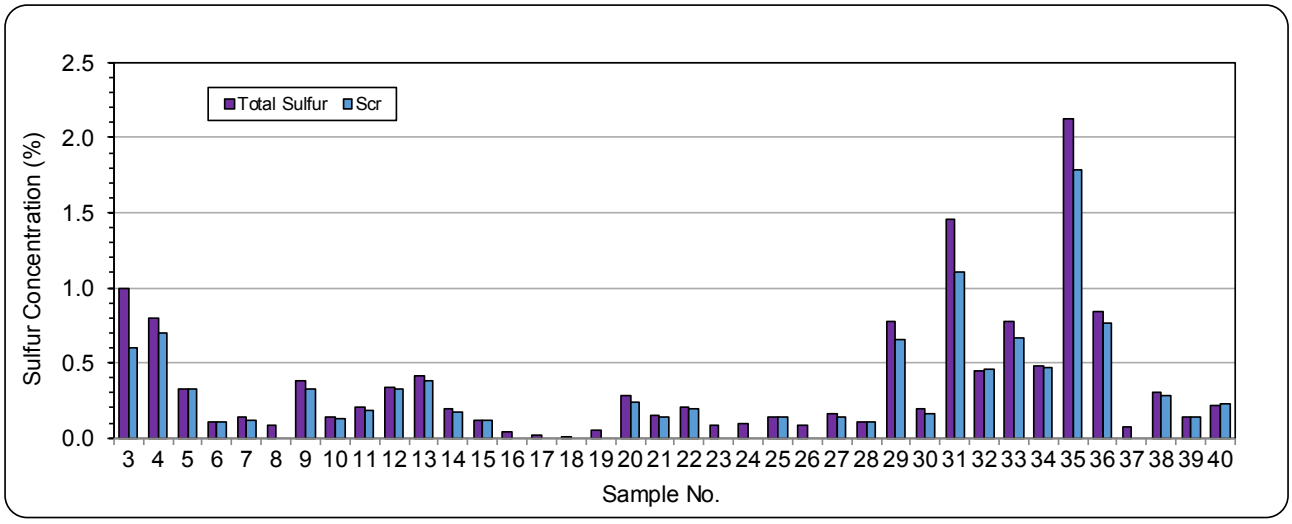


Figure 3-4: Total sulfur, sulfide sulfur, and sulfide proportion values for waste rock samples from Vulcan Coal Mine Matilda Pit

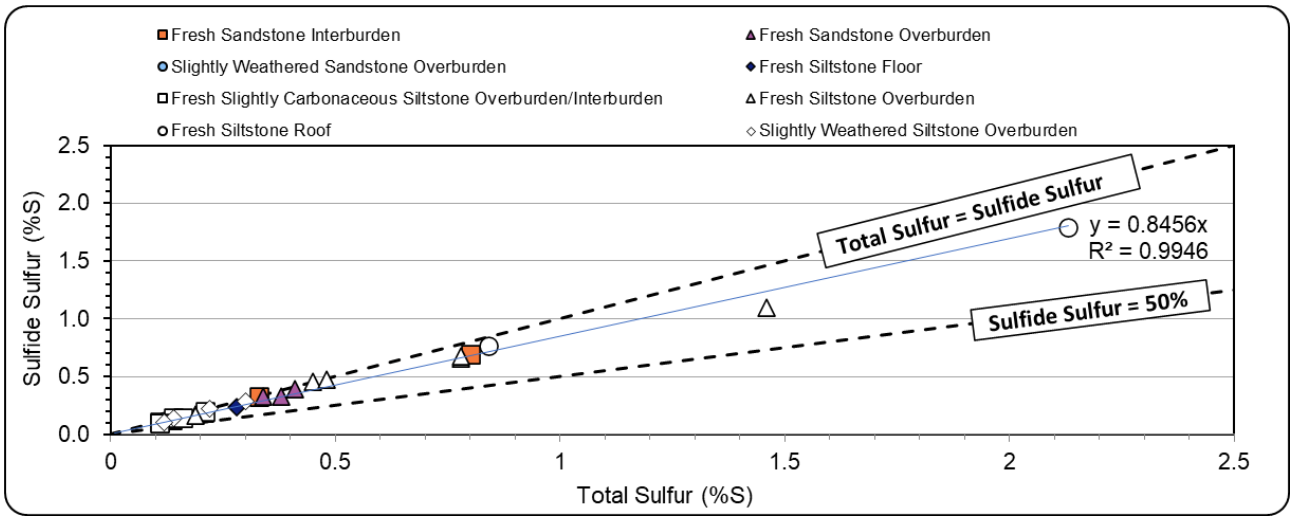


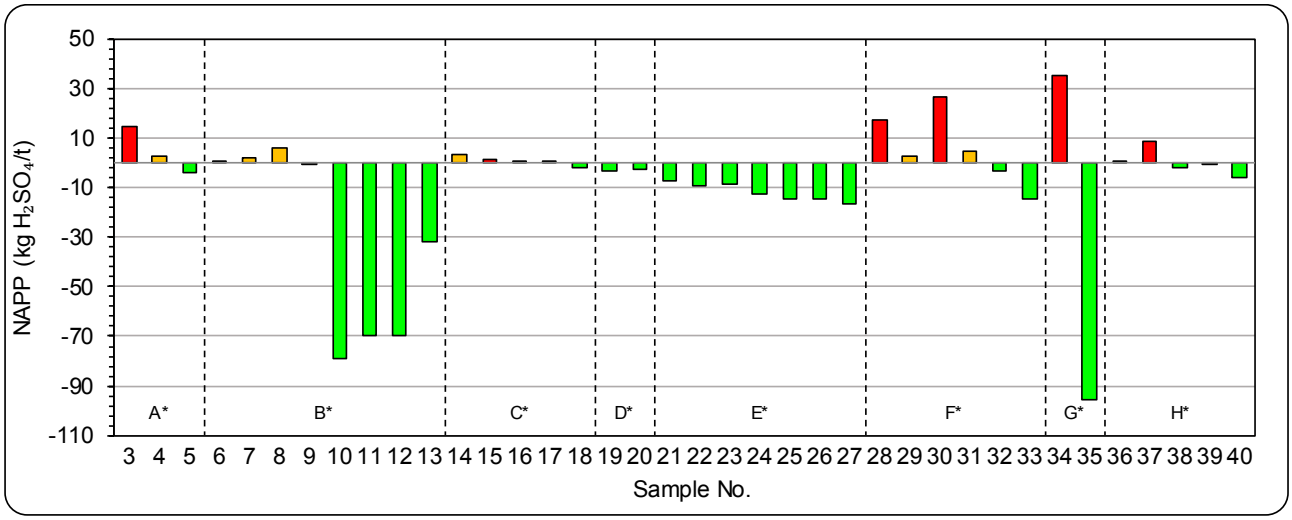
Figure 3-5: Total sulfur vs sulfide sulfur values for waste rock samples from Vulcan Coal Mine Matilda Pit

MPA: Based on the total sulfur content (and sulfide sulfur content, where available), the calculated Maximum Potential Acidity (MPA) that could be generated by the waste rock samples ranges from 0.3 to 54.8 kg H_2SO_4/t. The median MPA for the samples is 4.6 kg H_2SO_4/t.

ANC: The Acid Neutralising Capacity (ANC) values for the waste rock samples range from below the limit of reporting (0.5 kg H_2SO_4/t) to 119.0 kg H_2SO_4/t, with a median value of 4.6 kg H_2SO_4/t.

NAPP: The calculated NAPP values for the waste samples are shown in **Figure 3-6**. The NAPP values range from -95.5 to 35.4 kg H_2SO_4/tonne, with a median value of -1.9 kg H_2SO_4/t. The NAPP results indicate that four samples have a positive NAPP value greater than 10 kg H_2SO_4/t and are classified as Potentially Acid Forming (PAF) and shown in red. The four samples represent one fresh sandstone interburden, two fresh siltstone interburden and one fresh siltstone roof material. Four of the fresh sandstone overburden and

one of the fresh siltstone roof samples have a strongly negative ANC value and represent material that is Non-Acid Forming (NAF) and may have sufficient ANC be considered acid consuming.



* A = Fresh sandstone interburden; B = Fresh sandstone overburden; C = Slightly weathered sandstone overburden; D = Fresh siltstone floor; E = Fresh slightly carbonaceous siltstone overburden/interburden; F = Fresh siltstone overburden; G = Fresh siltstone roof; H = Slightly weathered siltstone overburden

Figure 3-6: NAPP values for waste rock samples from Vulcan Coal Mine Matilda Pit

ANC:MPA ratio: The relationship between the ANC and MPA of waste rock samples is shown in **Figure 3-7**. The ANC:MPA ratio of a sample provides an indication of the risk of acid generation of a sample. Generally, a sample with an ANC:MPA ratio of less than 1 can have an increased risk of acid generation, while a sample with an ANC:MPA ratio of greater than 2 generally has a low to negligible risk of generating acidic drainage.

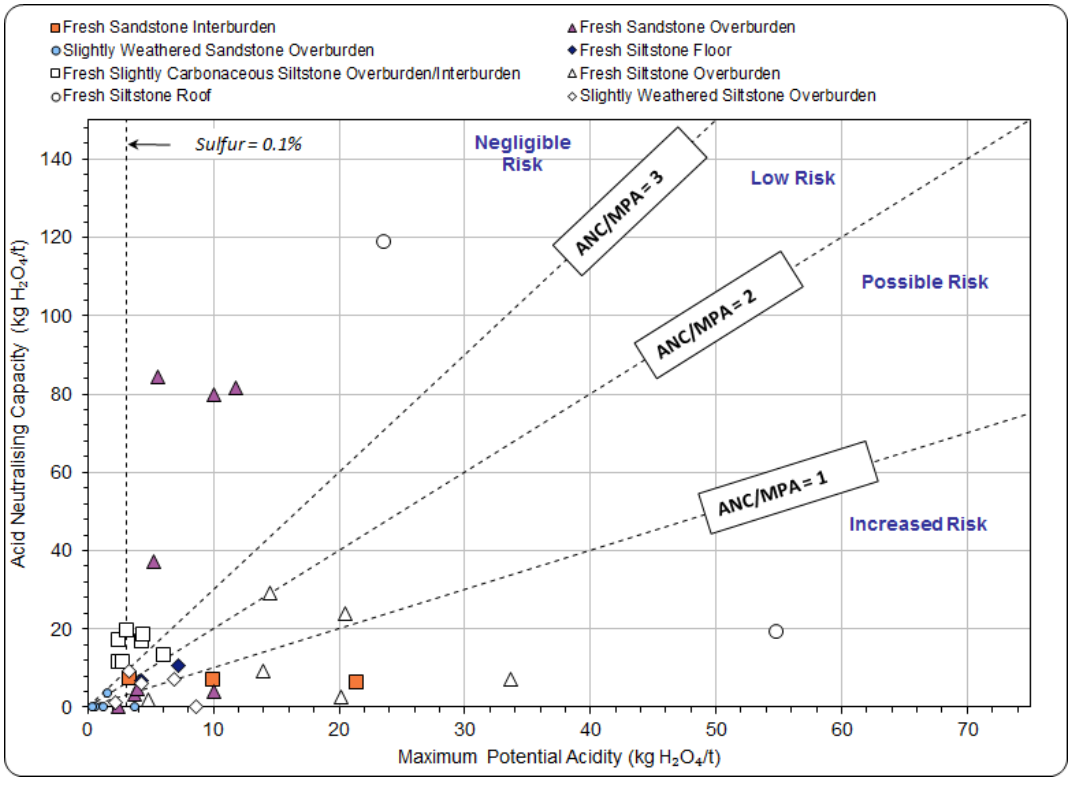


Figure 3-7: MPA vs ANC values for waste rock samples from Vulcan Coal Mine Matilda Pit

Sample Classification: The parameters used to classify the potential for the waste rock (overburden, interburden, roof, and floor) samples to generate AMD and the number of samples which fall into each category are provided in **Table 3-1**. **Figure 3-8** shows the classification of samples by lithology and weathering extent.

A total of 20 of the 38 waste rock samples are classified as NAF or NAF (Barren). A further 12 samples are classified as Uncertain and have a NAPP value that is close to zero and are unlikely to be a source of AMD. Hence, approximately 89 % of the waste rock samples tested are unlikely to be a source of AMD.

Two of the waste rock samples have a NAPP value between 5 and 10 kg H_2SO_4/t and are classified as PAF but have a low capacity to generate AMD (i.e., PAF-LC). Four samples are classified as PAF and have a reduced factor of safety with respect to AMD. The four PAF samples represent one fresh sandstone interburden, two fresh siltstone overburden and one fresh siltstone roof material.

Table 3-2: AMD classification parameters for waste rock samples from Vulcan Coal Mine Matilda Pit

Classification	Total Sulfur (%)	NAPP value (kg H_2SO_4/tonne)	Number of Samples
Non-Acid Forming (Barren)	≤ 0.1	-	9
Non-Acid Forming	> 0.1	≤ -5	11
Uncertain	> 0.1	> -5 to ≤ +5	12
Potentially Acid Forming - Low Capacity	> 0.1	> 5 to ≤ 10	2
Potentially Acid Forming	> 0.1	> 10	4

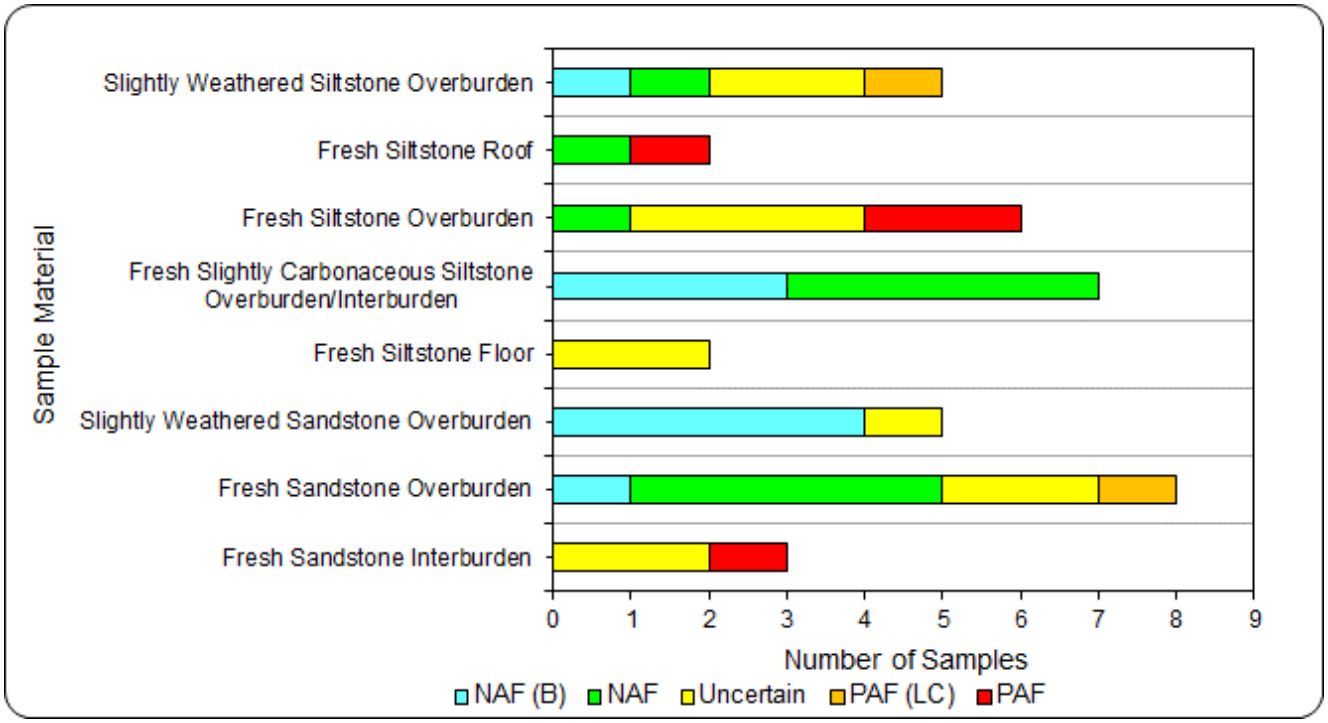


Figure 3-8: AMD classifications for waste rock samples from Vulcan Coal Mine Matilda Pit

3.1.2 Coal rejects

pH: pH results for the coal reject (coarse and fine reject) samples are shown in **Figure 3-9.** The pH results range from pH 3.1 to 6.8, with a median of pH 4.6. Generally, coarse reject samples have a lower pH value than fine rejects. It should be noted that the pH of the deionised water used in the pH tests was 5.7 and therefore all of the coarse reject samples and two of the fine reject samples are likely to add some acidity to initial contact water.

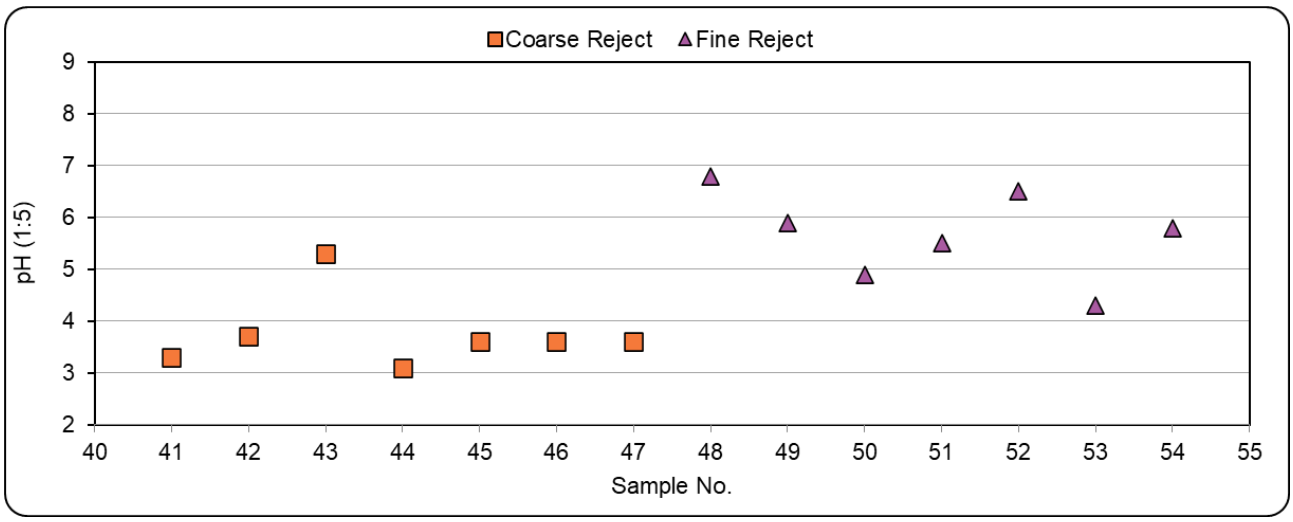


Figure 3-9: pH values for coal reject samples from Vulcan Coal Mine Matilda Pit

EC: EC results for coal reject samples are shown in **Figure 3-10**. The EC results range from 297 to 2,360 µS/cm and have a median value of 963 µS/cm). Coarse reject samples generally have higher EC results than the fine reject samples. It should be noted that the EC of the deionised water used in the EC tests was <1 µS/cm and therefore most coal reject samples add some salts to initial contact water.

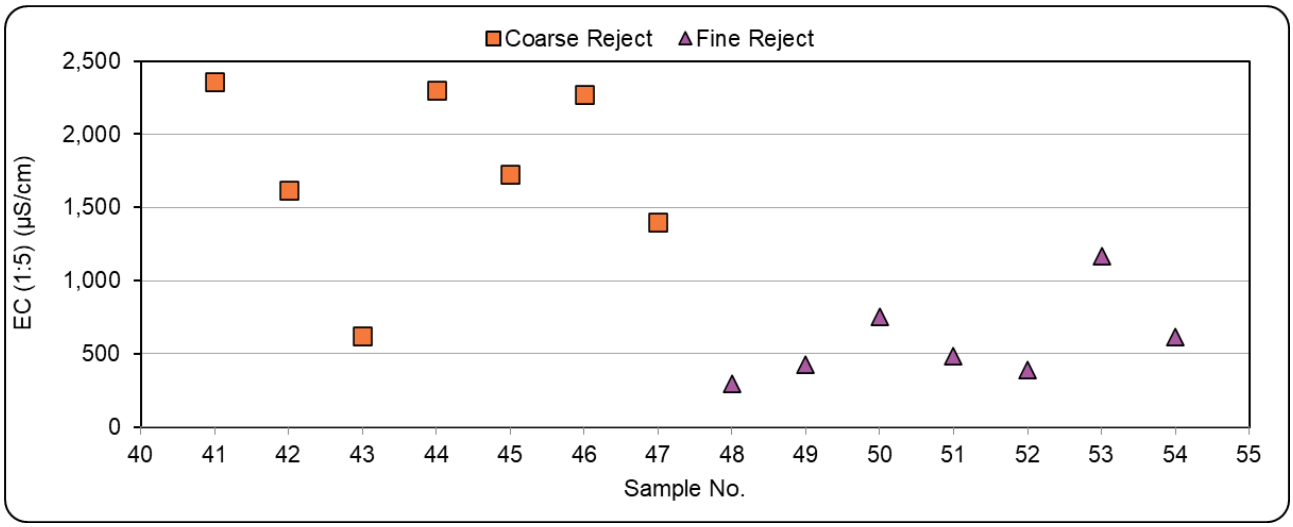


Figure 3-10: EC values for coal reject samples from Vulcan Coal Mine Matilda Pit

Total Sulfur: Total sulfur results for coal reject samples are shown in **Figure 3-11**. The total sulfur values range from 1.04 to 5.16 %S, with an elevated median value of 3.04 %S. Coarse reject samples generally have higher total sulfur results than fine reject samples.

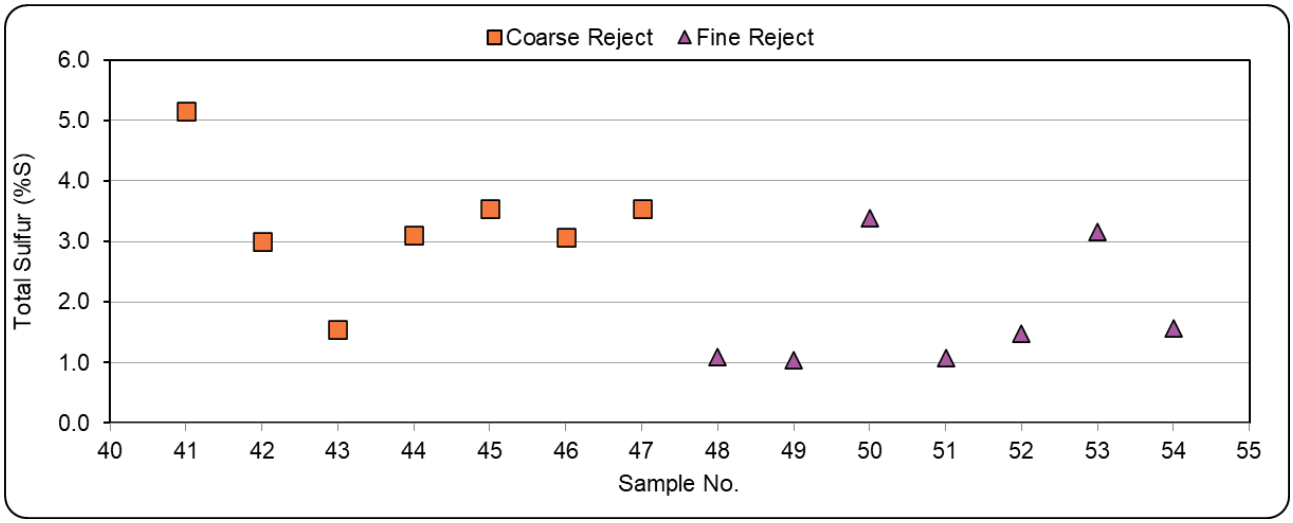


Figure 3-11: Total sulfur values for coal reject samples from Vulcan Coal Mine Matilda Pit

Sulfide Sulfur: Sulfide sulfur concentrations relative to total sulfur concentrations are shown in **Figure 3-12**. Sulfide sulfur results for coal reject samples range from 0.796% to 4.880% sulfide sulfur, with a median of 2.720% sulfide sulfur.

Figure 3-13 shows the correlation between total sulfur and sulfide sulfur results coal reject samples. There is a strong correlation between total sulfur and sulfide sulfur (R^2 = 0.9967) and linear regression modelling suggests the approximately 93 % of the total sulfur in a coal reject sample is likely to be present as sulfide sulfur.

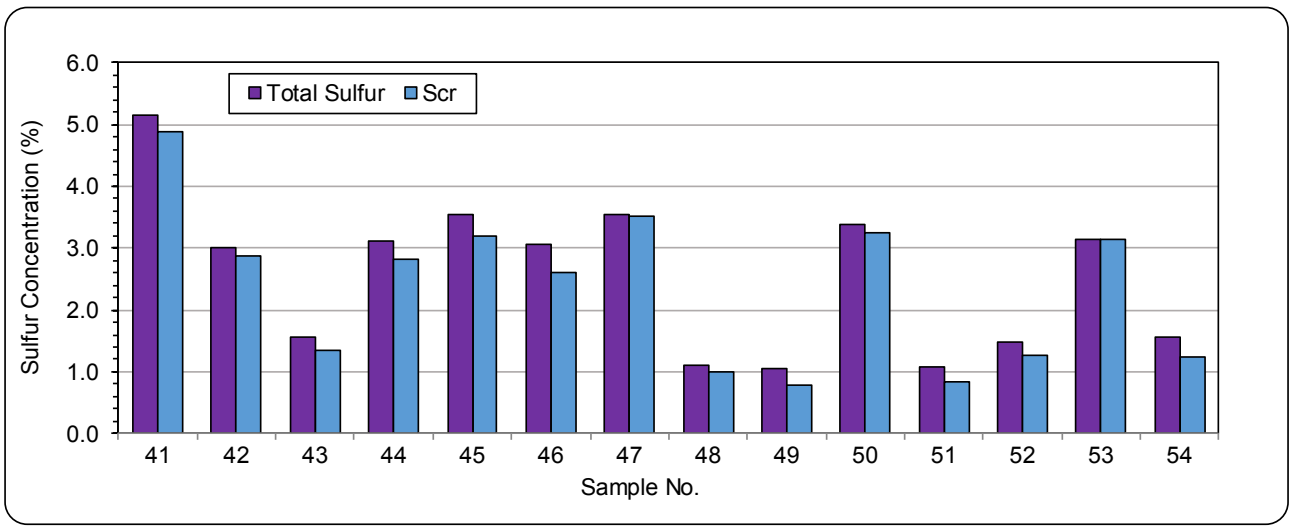


Figure 3-12: Total sulfur and sulfide sulfur values for coal reject samples from Vulcan Coal Mine Matilda Pit

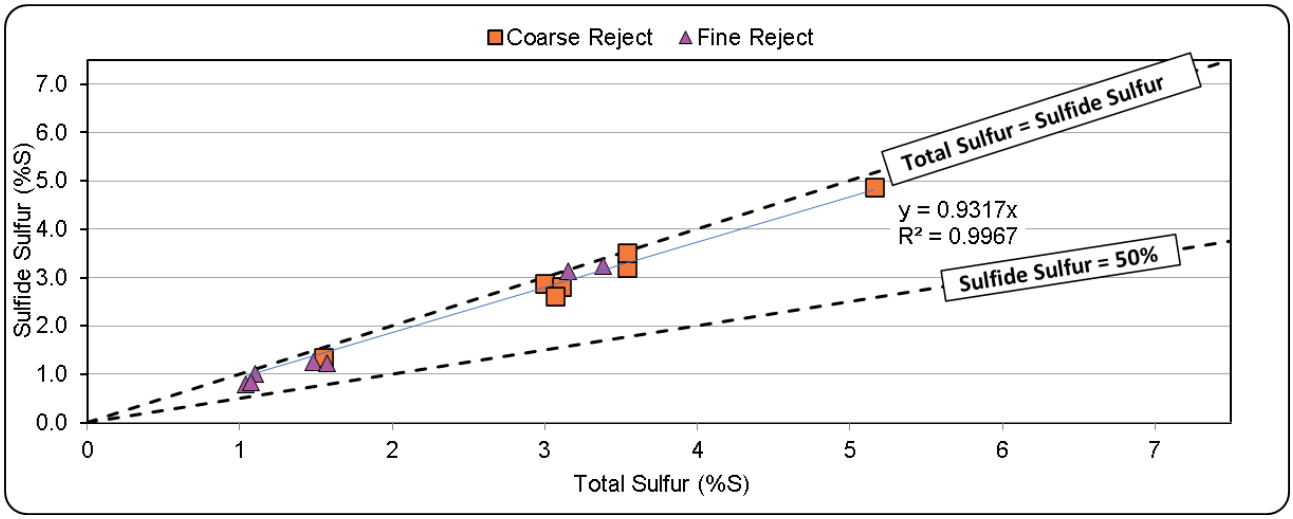


Figure 3-13: Total sulfur vs sulfide sulfur values for coal reject samples from Vulcan Coal Mine Matilda Pit

MPA: Based on the total sulfur content (and sulfide sulfur content, where available), the calculated MPA of the coal reject samples ranges from 24.4 to 149.5 kg H_2SO_4/tonne (median 83.3 kg H_2SO_4/t).

ANC: The ANC of the coal reject samples ranges from 0.3 to 25.3 kg H_2SO_4/t (median 13.5 kg H_2SO_4/t).

NAPP: The calculated NAPP of the coal reject samples is shown in **Figure 3-14**. The NAPP values are all positive and range from 5.3 to 142.8 kg H_2SO_4/tonne (median of 74.4 kg H_2SO_4/t).

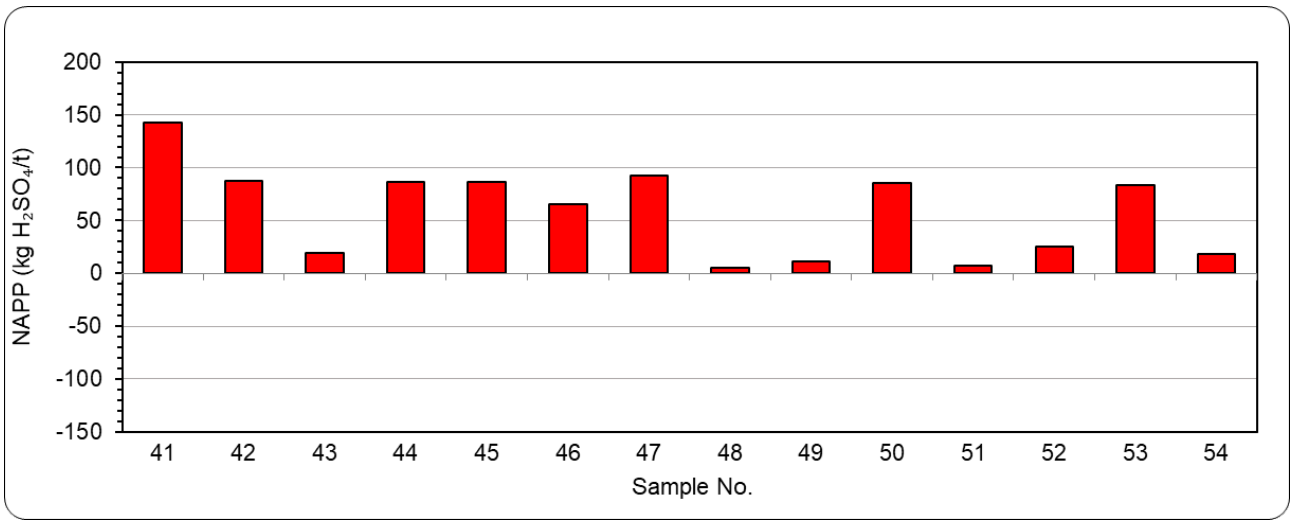


Figure 3-14: NAPP values for coal reject samples from Vulcan Coal Mine Matilda Pit

ANC:MPA ratio: The relationship between the ANC and MPA of coal reject samples is shown in **Figure 3-15**. The ANC:MPA ratio of a sample provides an indication of the risk of acid generation for that sample. Generally, a sample with an ANC:MPA ratio of less than 1 may have an increased risk of acid generation, while a sample with an ANC:MPA ratio of greater than 2 generally has a low to negligible risk of generating acidic drainage.

All the coal reject samples have ANC:MPA ratios of less than 1 indicating the samples are likely to have an increased risk of generating AMD.

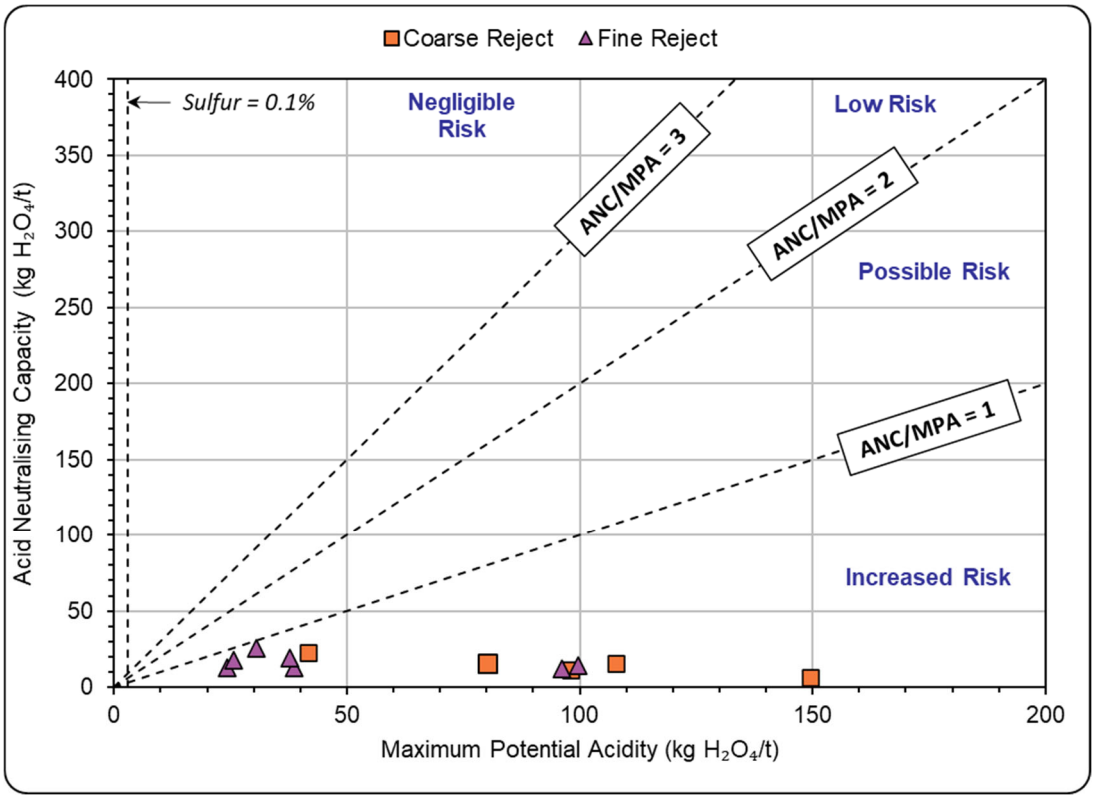


Figure 3-15: MPA vs ANC values for coal reject samples from Vulcan Coal Mine Matilda Pit

Sample Classification: The parameters used to classify the potential of the coal reject samples to generate AMD and the number of samples which fall into each category are shown in **Table 3-3**. **Figure 3-16** shows the classification of samples by reject size (i.e., coarse and fine reject).

All the reject samples are classified as PAF, with two of the fine reject samples classified as PAF-LC. The remainder of the coarse and fine reject samples are classified as PAF.

Table 3-3: AMD classification parameters for coal reject samples from Vulcan Coal Mine Matilda Pit

Classification	Total Sulfur (%)	NAPP value (kg H_2SO_4/tonne)	Number of Samples
Non-Acid Forming (Barren)	≤ 0.1	-	0
Non-Acid Forming	> 0.1	≤ -5	0
Uncertain	> 0.1	> -5 to ≤ +5	0
Potentially Acid Forming - Low Capacity	> 0.1	> 5 to ≤ 10	2
Potentially Acid Forming	> 0.1	> 10	12

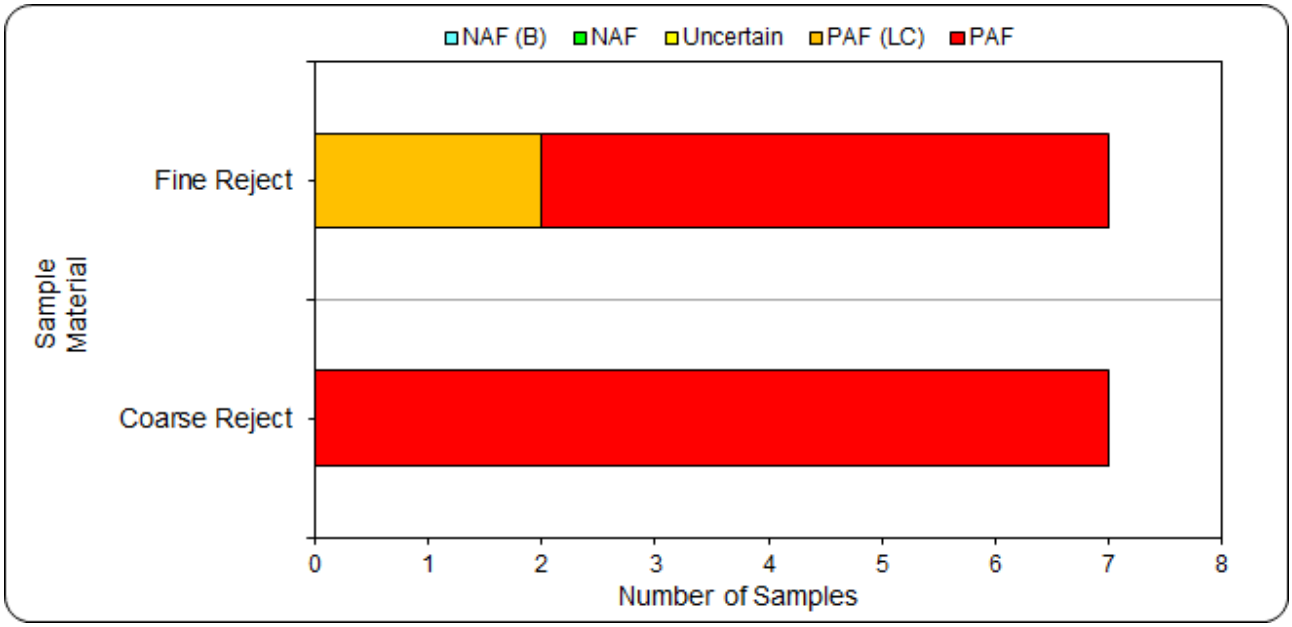


Figure 3-16: AMD classifications for coal reject samples from Vulcan Coal Mine Matilda Pit

3.1.3 Raw coal

pH: The pH results for the two coal samples are shown in **Figure 3-17**. The pH results are moderately alkaline and range from pH 9.1 to 9.2. It should be noted that the pH of the deionised water used in the pH tests was 5.4 and therefore the coal samples are likely to add some alkalinity to initial contact water.

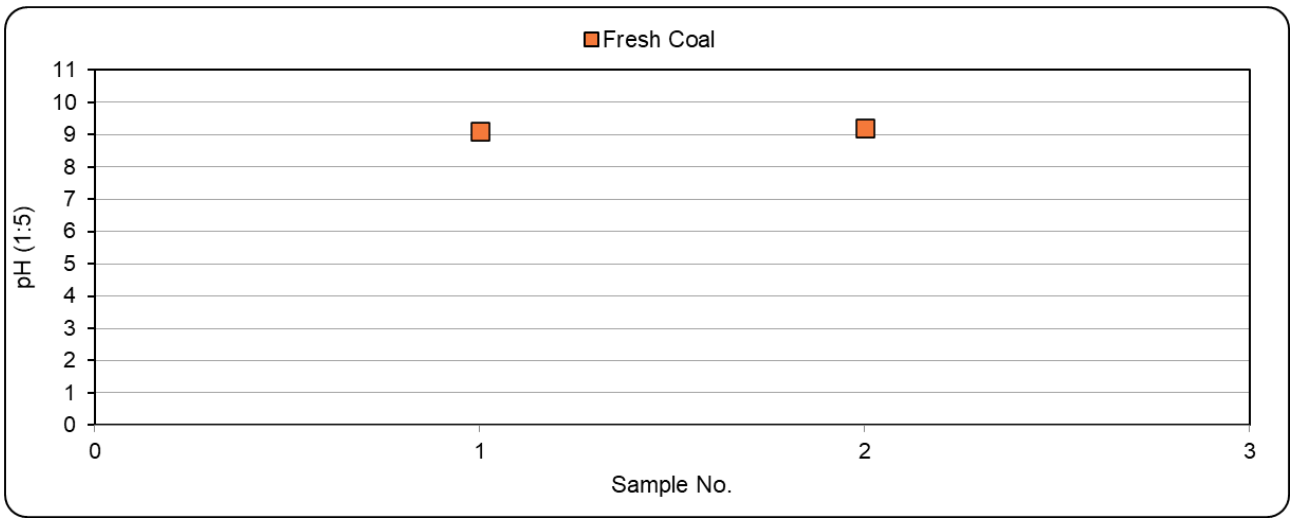


Figure 3-17: pH values for coal samples from Vulcan Coal Mine Matilda Pit

EC: The EC results for the two coal samples are shown in **Figure 3-18**. The EC values are relatively low and range from 120 to 130 µS/cm. It should be noted that the EC of the deionised water used in the EC tests was <1 µS/cm and therefore most waste rock samples add a little salt to initial contact water.

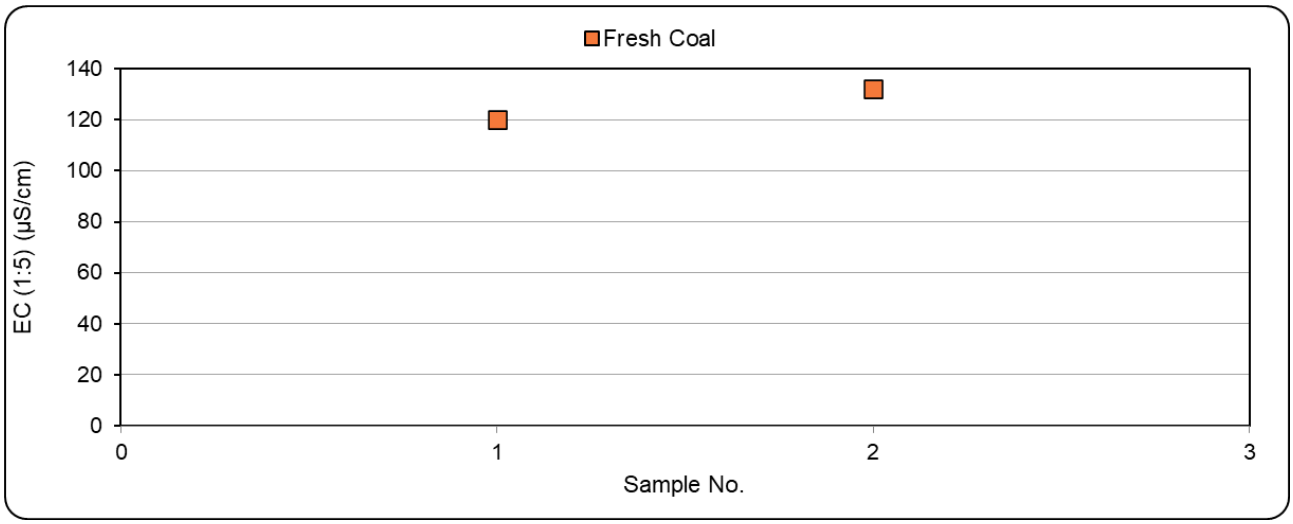


Figure 3-18: EC values for coal samples from Vulcan Coal Mine Matilda Pit

Total sulfur: The total sulfur results for the coal samples are shown in **Figure 3-19**. The total sulfur values range from 1.00 to 1.09 %S.

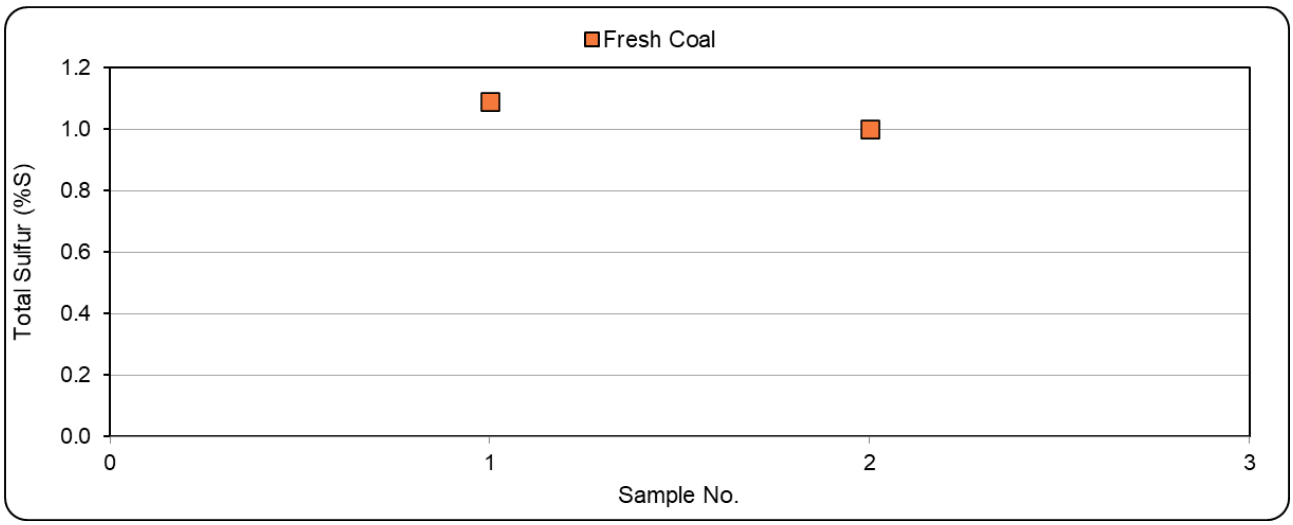


Figure 3-19: Total sulfur values for coal samples from Vulcan Coal Mine Matilda Pit

Sulfide Sulfur: Sulfide sulfur concentrations relative to total sulfur concentrations for the coal samples are shown in **Figure 3-20**. Sulfide sulfur results for coal samples range from 0.605% to 0.732% sulfide sulfur.

Figure 3-21 shows the correlation between total sulfur and sulfide sulfur results for the coal samples. Sulfide sulfur in the coal samples makes up approximately two thirds of the total sulfur in the samples.

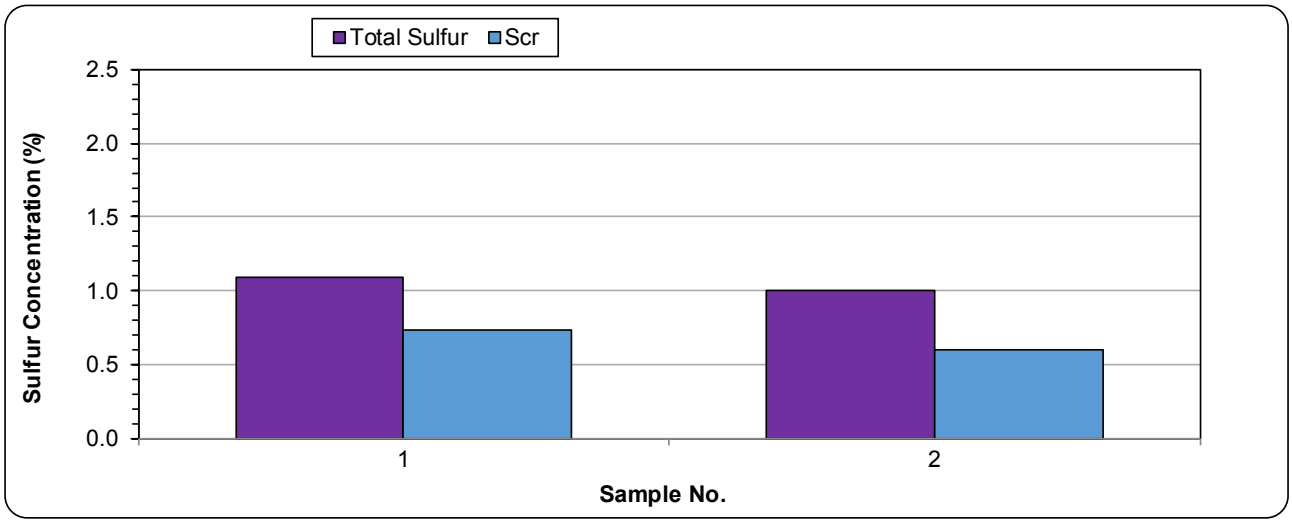


Figure 3-20: Total sulfur and sulfide sulfur values for coal samples from Vulcan Coal Mine Matilda Pit

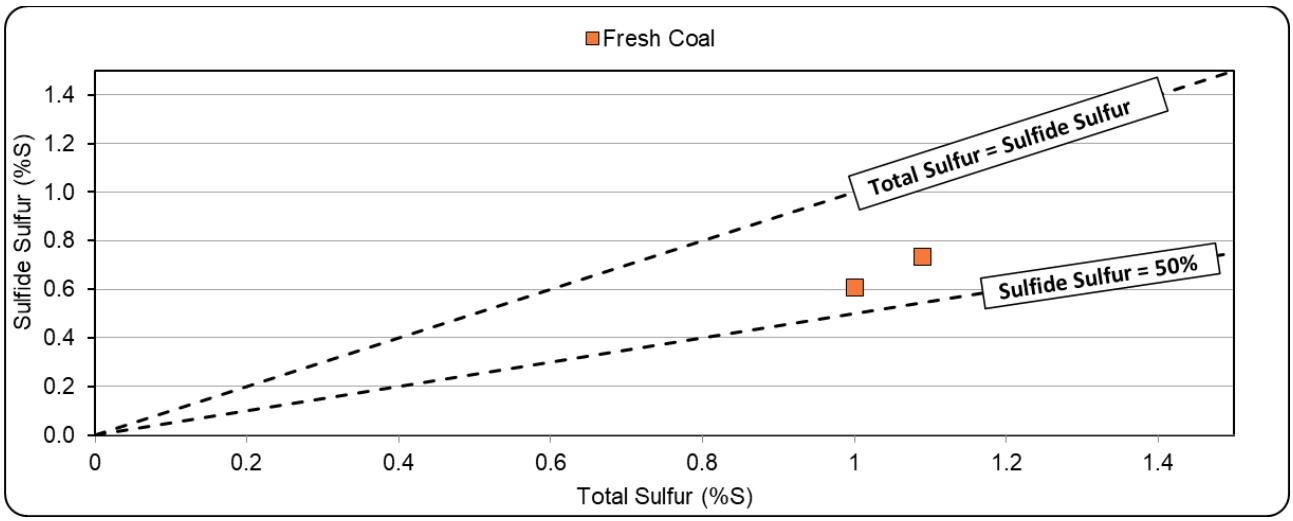


Figure 3-21: Total sulfur vs sulfide sulfur values for coal samples from Vulcan Coal Mine Matilda Pit

MPA: Based on the sulfide sulfur content, the calculated MPA values for the two coal samples range from 18.5 to 22.4 kg H_2SO_4/t.

ANC: The ANC results for the two coal samples range from 13.8 to 72.8 kg H_2SO_4/t.

NAPP: The calculated NAPP values for the coal samples are shown in **Figure 3-22**. The NAPP values range from -54.3 to 8.6 kg H_2SO_4/t.

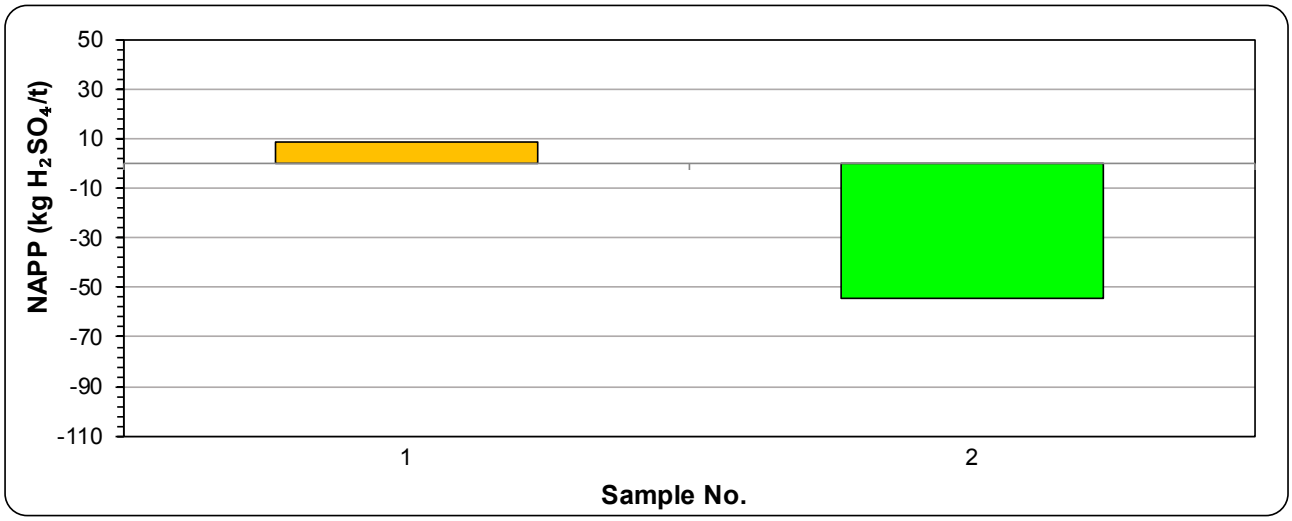


Figure 3-22: NAPP values for coal samples from Vulcan Coal Mine Matilda Pit

ANC:MPA ratio: The relationship between the ANC and MPA values of the two coal samples is shown in **Figure 3-23**. The ANC:MPA ratio of a sample provides an indication of the risk of acid generation for that sample. Generally, a sample with an ANC:MPA ratio of less than 1 is considered to have an increased risk of acid generation, while a sample with an ANC:MPA ratio of greater than 2 generally has a low to negligible risk of generating acidic drainage.

One of the coal samples has an ANC:MPA ratio of less than 1 indicating that material represented by the sample may have an increased risk of generating AMD. The other coal sample has an ANC:MPA ratio of greater than 3 indicating that the sample is likely to have a negligible risk of generating AMD.

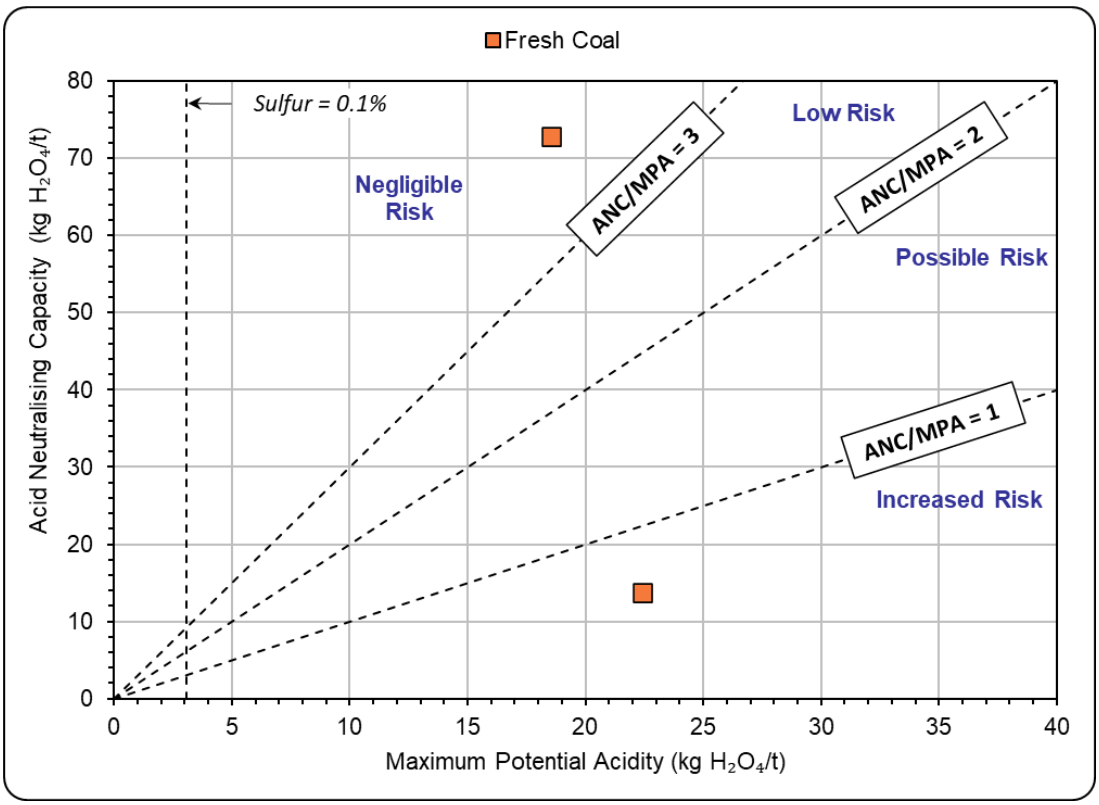


Figure 3-23: MPA vs ANC values for coal samples from Vulcan Coal Mine Matilda Pit

Sample Classification: The parameters used to classify the potential of the coal samples to generate AMD and the number of samples which fall into each category are shown in **Table 3-3**.

One coal sample is classified as NAF, and the other sample is classified as PAF-LC.

Table 3-4: AMD classification parameters for coal samples from Vulcan Coal Mine Matilda Pit

Classification	Total S (%)	NAPP value (kg H_2SO_4/tonne)	Number of Samples
Non-Acid Forming (Barren)	≤ 0.1	-	0
Non-Acid Forming	> 0.1	≤ -5	1
Uncertain	> 0.1	> -5 to ≤ +5	0
Potentially Acid Forming - Low Capacity	> 0.1	> 5 to ≤ 10	1
Potentially Acid Forming	> 0.1	> 10	0

3.2 Multi-element concentration in solids

Multi-element analyses were carried out on 13 mine material samples (eight composite samples of waste rock, four composite samples of coal reject, and one composite sample of coal) as described in **Section 2.2** to identify any metals or metalloids present at concentrations that may be of environmental concern with respect to materials handling, storage, revegetation and water quality.

To provide relevant context, RGS has compared the total metal/metalloid concentrations in samples to National Environmental Protection Council (NEPC) Health-based Investigation Levels (HIL(C)) for soils in public open spaces (NEPC, 2013).

The results from multi-element testing (total metals/metalloids) of the 13 selected composite samples are presented in **Table B2 (Attachment B)**. The results indicate that the sample materials have total metal and metalloid concentrations below the applied NEPC (HIL(C)) guideline for soils.

The results from multi-element testing (total metals/metalloids) of the 13 samples with respect to median crustal abundance in un-mineralised soils are discussed in **Section 3.2.1**.

3.2.1 Geochemical abundance index

Total metal/metalloid concentrations in mining materials can be compared to the median crustal abundance for un-mineralised soils (Bowen, 1979, COA, 2016 and INAP, 2022). The extent of enrichment is reported as the Geochemical Abundance Index (GAI), which relates the actual concentration in a sample with the median crustal abundance on a $\log_{10}$ scale.

The GAI is expressed in integer increments from 0 to 6, where a GAI value of 0 indicates that the element is present at a concentration less than, or similar to, the median crustal abundance; and a GAI value of 6 indicates approximately a 100-fold enrichment above median crustal abundance (see **Table 3-4**).

Table 3-5: Geochemical abundance index values and enrichment factors

GAI	Enrichment Factor	GAI	Enrichment Factor
0	Less than 3-fold enrichment	4	24 – 48-fold enrichment
1	3 – 6-fold enrichment	5	48 – 96-fold enrichment
2	6 – 12-fold enrichment	6	Greater than 96-fold enrichment
3	12 – 24-fold enrichment		

Generally, a GAI value of greater than 3 signifies enrichment that may warrant further examination. This is particularly the case with some environmentally important 'trace' elements, such as arsenic, chromium, cadmium, copper, lead, selenium, and zinc rather than with major rock-forming elements, such as aluminium, calcium, iron, manganese, and sodium.

Elements identified as enriched may not necessarily be a concern for revegetation, drainage water quality or public health, but their significance should still be evaluated. While the GAI provides an indication of metals/metalloids that may be enriched relative to the global median crustal abundance in un-mineralised soils, the following points should also be considered:

- The median crustal abundance varies between different literature sources, thereby affecting the calculated GAI values.
- Samples that are enriched relative to the median crustal abundance, do not necessarily leach metals/metalloids at elevated concentrations. The mobility of metals/metalloids is dependent on mineralogy, adsorption/desorption, and the environment in which it occurs.

Similarly, because an element is not enriched does not mean it will never be a concern, as under some conditions (e.g., low pH) the solubility of common environmentally important elements such as aluminium, copper, cadmium, iron, and zinc increase significantly.

Table B2 (**Attachment B**) provides total metal/metalloid concentrations for the 13 samples of mine materials described in **Section 2.2**. The relative enrichment of metals/metalloids in the samples compared to median crustal abundance (the Geochemical Abundance Index - GAI) is presented in **Table B3** (**Attachment B**).

The GAI results indicate that of the metals/metalloids measured, none of the waste rock, coal reject or coal samples are enriched with most metals/metalloids compared to median crustal abundance in un-mineralised soils (i.e., all samples have a GAI value of less than 3). Whilst the coarse and fine composite coal reject samples which have GAI values for mercury that range from 3.2 and 3.6, a corresponding enrichment in mercury is not observed in roof, floor, or coal samples. The highest mercury concentration of 1.1 mg/kg in the coal reject samples is almost 40 times lower than the health-based NEPM investigation level for residences with garden accessible soil (includes childcare centres, preschools and primary schools) for inorganic mercury (NSW Health, 2022).

The potential solubility of metals/metalloids in the sample materials was investigated further through water extract tests and results are presented in **Section 3.4**.

3.3 Soil characteristics and sodicity

Five of the eight composite waste rock samples were also analysed for soil characteristics and sodicity. The selected composite samples represent materials that could potentially report to the outer surfaces of final landforms and could also be earmarked for use in other site infrastructure and rehabilitation works (i.e., the samples are not classified as PAF and not derived from the roof or floor material of the Matilda Seam). The tests focussed on exchangeable cations and allowed calculation of the effective cation exchange capacity (CEC) and exchangeable sodium percentage values. The test results and calculated values are provided in **Table B2** (**Attachment B**) and are summarised below.

3.3.1 Soil characteristics

The effective CEC results for the five composite waste rock samples are presented in **Table B2** (**Attachment B**). The CEC results range from 2.1 to 6.0 meq/100g and are typically in the very low to low range as described in **Table 4-6** (Hazelton and Murphy, 2007). The slightly weathered samples have calcium:magnesium ratios of less than one. For waste rock materials with a very low to low CEC value and low calcium:magnesium ratio, some fertiliser and gypsum addition may be required to provide a reasonable growth medium for vegetation roots as part of sustainable revegetation and rehabilitation activities.

Table 3-6: Ratings for cation exchange capacity

CEC Rating	CEC (meq/100g)
Very low	<6
Low	6 – 12
Moderate	12 – 25
High	25 – 40
Very high	>40

3.3.2 Sodicity

The exchangeable sodium percentage (ESP) results for the five composite waste rock samples are presented in **Table B2** (**Attachment B**). The ESP value for a sample is the proportion of exchangeable sodium relative to the total effective cation exchange capacity for a sample. Generally, samples with ESP values less than 6 % are considered non-sodic, and greater than 14% are considered strongly sodic and may be susceptible to dispersion and erosion (Isbell, 2002; and Northcote and Skene, 1972). Sodicity can result in surface crusting and low infiltration and hydraulic conductivity within the affected soils (Hazelton and Murphy, 2007).

Exchangeable sodium results for the samples range from 0.2 to 0.6 meq/100g and ESP results for the samples range from 9.3% to 11.7%. These results are expected for waste rock materials found in this part of the Bowen Basin and it is important to note that in materials with low CEC values and moderately sodic ESP results can be caused by relatively low concentrations of exchangeable sodium.

Overall, the results of the ESP tests indicate that most waste rock materials represented by these samples may be moderately sodic; and consequently, may be susceptible to dispersion and erosion. Due to the relatively low exchangeable sodium concentrations and the low CEC values for the samples field trials to assess the tendency of samples to erode may be beneficial in determining appropriate management strategies for these materials. Where required, the addition of gypsum, organic matter and fertilizer to moderately sodic waste rock materials has the potential to reduce the sodicity and reduce the potential for dispersion and erosion.

3.4 Water quality static tests

There are no specific regulatory criteria for metal/metalloid concentrations in leachate from mining waste materials on mine sites in Queensland. As such, RGS has compared the multi-element results in water extracts from the 13 composite samples of mine materials (eight waste rock, four coal reject, and one coal) from the Project, described in **Section 3.2**, with Australian guidelines for livestock drinking water and aquatic freshwater ecosystems (ANZECC & ARMCANZ, 2000; ANZG, 2018) guideline values. These guidelines are provided for context only and are not intended to be interpreted as “maximum permissible levels” for site water storage or discharge.

It should also be recognised that direct comparison of geochemical data with guideline values can be misleading. For this study, guideline values are only provided for broad context and should not be interpreted as arbitrary “maximum” values or “trigger” values. Using sample pulps (ground to passing 75 µm) provides a very high surface area to solution ratio, which encourages mineral reaction and dissolution of the solid phase. Therefore, the results of screening tests on water extract solutions are assumed to represent a ‘worst-case’ scenario for pore water and initial contact water for mining materials.

The results from multi-element testing of water extracts (1:5 solid:water) from the 13 composite samples are presented in **Table B4** (**Attachment B**).

The pH values for the eight waste rock (overburden, interburden, roof, and floor) composite samples range from pH 5.8 to 9.1 and the fresh siltstone floor and fresh slightly carbonaceous siltstone overburden/ interburden composite samples are slightly higher (pH 9.1) than the pH range for 95 % species protection in freshwater aquatic ecosystems (ANZECC & ARMCANZ, 2000; ANZG, 2018). Most waste rock samples are pH to moderately alkaline (pH 7.3 to 9.1) apart from one slightly weathered sandstone overburden sample which has a pH value of 5.8. In most cases it is expected that some alkalinity will be added to initial contact water from these materials as the deionised water used in the tests was pH 5.4.

The pH values for the four coal reject composite samples are acidic to slightly acidic and range from pH 3.4 to 5.3. The coal composite sample has a slightly alkaline pH of 8.8. The pH results for the coarse and fine reject composite samples are below the range of pH 6 to 9 for 95 % species protection in freshwater aquatic ecosystems (ANZECC & ARMCANZ, 2000; ANZG, 2018).

Coal and waste rock composite samples have relatively low EC values compared to the coal rejects composite samples. The coal reject samples have EC values ranging from 533 to 1,790 µS/cm. EC values for the coarse reject samples are 2-3 times higher than the EC values for the fine rejects and only the coarse reject composite samples have EC values which exceeded the 95 % species protection in freshwater aquatic ecosystems trigger value of 1,000 µS/cm (ANZECC & ARMCANZ, 2000; ANZG, 2018)

The calculated net alkalinity values in the water extracts from the waste rock composite samples range from -47 to 6,140 mg $CaCO_3$/L. The slightly weathered sandstone overburden composite sample was the only waste rock sample with a slight excess of acidity relative to alkalinity. All other waste rock samples have more strongly positive net alkalinity values. Alkalinity in the waste rock samples is primarily generated by bicarbonate species rather than carbonates. The coal reject samples all have negative net alkalinity values and the coarse reject samples have lower net alkalinity values compared to the fine reject samples. The coal composite sample has a strongly positive net alkalinity value relative to the other composite samples and again this alkalinity is primarily present as bicarbonate.

The major soluble ions in the waste rock sample water extracts are generally sodium, potassium, and sulfate. In contrast, sulfate, calcium, and magnesium are the primary major ions in the water extracts from the coarse reject samples. The water extracts from the fine reject samples have lower concentrations of major ions relative to the coarse rejects. The major ions with the highest concentrations in the water extracts from the fine reject samples are sulfate and calcium. The major ions in the water extract from the coal sample are primarily sulfate and sodium. The concentrations of calcium, sulfate, and fluoride in all samples are below the applied (ANZECC & ARMCANZ, 2000; ANZG, 2018) water quality guideline criteria (1,000 mg/L calcium, 1,000 mg/L sulfate, and 2 mg/L fluoride) for livestock drinking water.

The concentrations of trace metals/metalloids tested in water extracts from the waste rock and coal samples are typically low and predominantly below the laboratory limit of reporting. Most metal/metalloid concentrations are below the applied water quality guideline criteria. The exception is aluminium in the slightly weathered sandstone overburden water extract, which has a concentration (0.08 mg/L) which is marginally greater than the applied freshwater aquatic ecosystem water quality guideline value (0.055 mg/L) for 95% species protection but is almost two orders of magnitude lower than the applied guideline value (5 mg/L) for livestock drinking water (ANZECC & ARMCANZ, 2000; ANZG, 2018).

Soluble trace metals and metalloid concentrations in water extracts from the coal reject samples are elevated relative to the waste rock and coal composite samples. The concentrations of eight elements in the water extracts from the coarse reject composite samples are greater than the applied guideline values (0.55 mg/L aluminium, 0.024 mg/L arsenic, 0.0002 mg/L cadmium, 0.0014 mg/L copper, 1.9 mg/L manganese, 0.011 mg/L nickel, 0.0034 mg/L lead, and 0.008 mg/L zinc) for 95 % species protection (ANZECC & ARMCANZ, 2000; ANZG, 2018). The water extracts from the fine reject samples have elevated values for four elements; aluminium, copper, nickel, and zinc compared to the applied 95 % aquatic species protection guideline values. All elements tested in the water extracts from both coarse and fine reject samples are below the guideline values for livestock drinking water (ANZECC & ARMCANZ, 2000; ANZG, 2018).

As previously stated, due to the relatively large surface area of the sample materials in contact with the water extracts the results presented above are likely to represent a ‘worst-case’ scenario for pore water and initial contact water for mining materials.

4 Discussion

4.1 AMD potential and management

The geochemical investigations demonstrate that bulk waste rock material located within the weathered zone of the stratigraphic profile at the Matilda Pit (generally less than 15m) typically has low sulfur content, low ANC and is classified as NAF. Fresh waste rock (overburden and interburden) material from deeper in the stratigraphic profile is also likely to be NAF, although PAF materials have been identified for siltstone from 18 to 22 m depth, sandstone at the base of the open pit from 39 to 42 m depth, and for a siltstone roof sample from 32 to 33 m depth. There is also a band of fresh sandstone material from 22 to 29 m depth that has excess ANC and could be considered acid consuming. In terms of material management, it is recommended that fresh waste rock material be backfilled into the open pit and covered with at least 5 m of weathered NAF waste rock material as part of rehabilitation activities. If required, the high ANC acid consuming material could be used as part of the overall management process for pit backfilling.

In contrast, coal reject materials are classified as PAF and ideally should report deep into to the open pit profile as backfill and be progressively covered with NAF waste rock materials. If there is insufficient capacity in the open pit to accommodate coal reject materials and ex-pit disposal is required, encapsulation of coal rejects will be required including a base of NAF waste rock material. Paddock dumping and traffic compaction of coal reject materials during ex-pit placement should be completed prior to covering with NAF waste rock materials. Any surface runoff/seepage from ex-pit coal reject emplacement areas should report to the open pit and/or be captured in the water management system employed under the Water Management Plan.

Most of the coarse reject samples have a pH value between 3 and 4 and are already acidic therefore the high ANC waste rock described above may be a useful source of interim covering/neutralising/alkaline materials during the mining and backfilling process. Traffic compaction of the in- pit coal reject materials will also assist in limiting air entry to the coal rejects to surface diffusion and slow down the overall rate of reaction of the bulk coal reject materials. This outcome will also be favoured using the co-disposal of coarse and fine reject materials whereby fine rejects fill the air gaps in coarse rejects and limit oxygen diffusion into the bulk materials. At the same time the co-disposed coarse rejects provide additional geotechnical stability to the fine rejects. Notwithstanding, as above, the final cover of the backfilled pit should comprise at least 5 m of weathered NAF waste rock material as part of rehabilitation activities

The results from the geochemical assessment of coal samples from the Matilda Seam suggest that some coal has to potential to generate relatively low amounts of AMD. The NAF coal sample has sufficient ANC to neutralise MPA of both samples combined, which suggests that mixed coal from the Matilda Seam in a stockpile may not generate acidic drainage but has the potential to generate neutral mine drainage. Whilst the coal will be stockpiled on site for limited periods of time, it is recommended that surface runoff and seepage from stockpiles be managed appropriately within the site water management system as part of the Water Management Plan.

Previous geochemistry studies at the Vulcan Coal Mine (RGS, 2020) have demonstrated that there is a large volume of NAF waste rock materials with low sulfur content and excess ANC that will be generated from operation of the Vulcan and Jupiter pits, compared to the relatively small Matilda pit. Hence, in the unlikely event that there is a shortfall in NAF waste rock material at the Matilda Pit, NAF waste rock material from the Vulcan and/or Jupiter Pits will be used to implement the PAF material management strategy at Matilda pit.

4.2 Multi-element composition and water quality

4.1.1 Multi-element composition and enrichment

The multi-element results indicate that none of the waste rock, coal reject and coal samples are not significantly enriched with most metals/metalloids compared to applied guideline values and median crustal abundance for un-mineralised soils. The exception is mercury in the coarse and fine reject samples, although the highest mercury concentration of 1.1 mg/kg is almost 40 times lower than the health-based NEPM investigation level for residences with garden accessible soil (includes childcare centres, preschools and primary schools) for inorganic mercury (NSW Health, 2022).

4.1.2 Water quality

The results of static water quality tests demonstrate that coal and waste rock materials will produce neutral to alkaline drainage with low salinity and low concentrations of metals and metalloids relative to the coal reject materials. Drainage from the coal rejects is likely to have a lower pH, higher salinity, and higher concentrations of metals and metalloids in solution.

4.2 Revegetation and rehabilitation

In general, waste rock has a low CEC value and is moderately sodic; and consequently, may be susceptible to dispersion and erosion. Hence, rehabilitation field trials may be beneficial in determining the appropriate management strategies for these materials. Where required, the addition of gypsum, organic matter and fertilizer to waste rock materials has the potential to increase the CEC, reduce the sodicity and reduce the potential for dispersion and erosion.

Additional confirmatory sampling and testing should be completed for bulk waste rock materials when available during the operational phase of the Project to determine the best management option for progressive rehabilitation of these materials during operations and at mine closure. Sampling should focus on collecting representative samples of any waste rock materials planned to be used at the surface of final landforms to supplement any existing subsoil and topsoil salvaged re-used in revegetation and rehabilitation activities. Testing should include typical soil parameters including pH, EC, exchangeable cations, organic matter, total organic carbon, Emerson Aggregate class, particle size distribution, and nutrients (including available potassium, phosphorus, organic carbon, as well as nitrogen and nitrogen species (nitrite, nitrate, and ammonia).

4.3 Management measures

Table 4-1 provides a summary how the waste rock, coal reject and coal materials will be managed through all stages of the mine life including construction, operations, rehabilitation, and decommissioning.

Table 4-1: Material management over mine life

Project Phase	Waste Rock	Coal Rejects	Coal
Construction	Stored at out-of-pit WRD	None produced	None produced
Operations	Stored at out-of-pit WRD and/or backfilled in-pit.	Preferentially co-disposed / backfilled/traffic compacted in-pit and covered with 5 m of NAF waste rock material. Contact water monitored for quality and managed in the mine water management system as part of Water Management Plan	Temporarily stockpiled at ROM. Contact water monitored for quality and managed in the mine water management system as part of Water Management Plan
Rehabilitation	Final landforms rehabilitated/ revegetated	Final landforms rehabilitated/ revegetated	ROM removed and footprint rehabilitated/revegetated
Decommissioning	Final landform performance monitoring moving towards lease relinquishment	Final landform performance monitoring moving towards lease relinquishment	None

5 Conclusions and recommendations

5.1 Conclusions

RGS has completed a geochemical assessment of waste rock (overburden, interburden, roof, and floor materials), coal rejects (coarse and fine fractions), and coal from a proposed pit targeting the Matilda Seam. The main findings of the geochemical assessment are:

- Bulk waste rock material located within the weathered zone of the stratigraphic profile at the Matilda Pit (generally less than 15m) typically has low sulfur content, low ANC and is classified as NAF and is likely to generate low salinity surface runoff/seepage.
- Most of the fresh waste rock (overburden and interburden) material from deeper in the stratigraphic profile is also likely to be NAF, although occasional PAF strata have been identified. A band of high ANC strata has also been identified that may be acid consuming and could be a useful resource if used as part of operational pit backfilling management activities.
- Coal reject materials are likely to be PAF and could generate acidic and brackish leachate with elevated concentrations of major ions (e.g. sulfate) and dissolved metals/metalloids and will require management.
- Coal from the Matilda Pit has variable geochemical characteristics and surface runoff/seepage from these materials will require management.
- Mine materials generated from the Matilda Pit are generally not significantly enriched with most metals/metalloids compared to applied guideline values and median crustal abundance for un-mineralised soils.
- Most metals/metalloids are sparingly soluble at the neutral to alkaline pH of initial leachate expected from bulk waste rock materials. Dissolved metal/metalloid concentrations in surface runoff and leachate from bulk NAF waste rock materials are expected to be low and unlikely to pose a significant risk to the quality of surface and groundwater resources at relevant storage facilities.
- NAF weathered waste rock materials should be amenable to revegetation as part of rehabilitation activities, although, gypsum, fertiliser and organic matter addition may improve material characteristics and outcomes if used as part of rehabilitation activities.

5.2 Recommendations

The main recommendations of the geochemical assessment are:

- Based on the outcomes of the static geochemical characterisation program and in line with the management measures described in **Section 4.3,** it is recommended that coal rejects are preferentially co-disposed and traffic compacted as part of in-pit backfill operations and finally covered with 5 m of NAF waste rock material.
- The potential for reuse of the high ANC (acid consuming) waste rock material as part of the operational pit backfilling management activities should be investigated.
- Contact water from any PAF mine materials should be monitored for quality and managed in the mine water management system as part of Water Management Plan.
- Rehabilitation field trials should be undertaken on waste rock materials from the Matilda Pit to determine the appropriate amelioration measures and management strategies for these materials.

6 References

AMIRA (2002). *ARD Test Handbook: Project 387A Prediction and Kinetic Control of Acid Mine Drainage*. Australian Minerals Industry Research Association, Ian Wark Research Institute and Environmental Geochemistry International Pty Ltd, May 2002.

ANZECC & ARMCANZ (2000). *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Australian and New Zealand Environment Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra, ACT (2000). Now superseded by:

ANZG (2018). *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Australian and New Zealand Environment Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra, ACT (2018). Livestock drinking water (low risk trigger levels).

Bowen, H.J.M. (1979). *Environmental Chemistry of the Elements*. Academic Press, New York.

COA (2016). Leading Practice Sustainable Development Program for the Mining Industry - Managing Acid and Metalliferous Drainage. Commonwealth of Australia, Canberra.

DEHP (2013). Application Requirements for Activities with Impacts to Land Guideline. Queensland Department of Environment and Heritage Protection.

DME (1995). Draft Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland, Technical Guideline – Assessment and Management of Acid Drainage and Saline/Sodic Wastes. Queensland Department of Minerals and Energy (DME).

Hazelton, P. and Murphy, B. (2007). Interpreting soil test results: What do all the numbers mean?. CSIRO publishing.

INAP (2022). *Global Acid Rock Drainage Guide (GARD Guide)*. Document prepared by Golder Associates on behalf of the International Network on Acid Prevention (INAP). June 2009 (http://www.inap.com.au/).

Isbell, RF. (2002). The Australian Soil Classification (revised edition). CSIRO Publishing. Victoria.

NEPC (2013). *National Environmental Protection (Assessment of Site Contamination) Measure (NEPM)*, Amendment of Schedule B1-B7 of 1999 version. National Environmental Protection Council (NEPC).

NSW Health (2022). https://www.health.nsw.gov.au/environment/factsheets/Pages/mercury.aspx.

Northcote, KH. and Skene, JKM. (1972). *Australian Soils with Saline and Sodic properties.* CSIRO Australia, Soil Publication No. 27, Canberra.

RGS (2020). *Geochemical Assessment of Waste Rock and Coal Reject. Vulcan Complex Project*. Prepared on behalf of Mining & Energy Technical Services Pty Ltd for Vitrinite Pty Ltd by RGS Environmental Pty Ltd. 18 June.

7 Attachments

Attachment A: Geochemical Assessment of Mining Materials

ACID GENERATION AND PREDICTION

Acid generation is caused by the exposure of sulfide minerals, most commonly pyrite (FeS_2), to atmospheric oxygen and water. Sulfur assay results are used to calculate the potential acidity that could be generated by the sample typically by determining the sulfidic S content directly. Pyrite reacts under oxidising conditions to generate acid according to the following overall reaction:

$$FeS_2 + 15/4\ O_2 + 7/2\ H_2O \text{ ---> } Fe(OH)_3 + 2\ H_2SO_4$$

According to this reaction, the maximum potential acidity (MPA) of a sample containing 1% S as pyrite would be 30.6 kg H_2SO_4/t. The chemical components of the acid generation process consist of the above sulfide oxidation reaction and acid neutralization, which is mainly provided by inherent carbonates and to a lesser extent silicate minerals. The amount and rate of acid generation is determined by the interaction and overall balance of the acid generation and neutralisation components.

Net Acid Producing Potential

The net acid producing potential (NAPP) is used as an indicator of materials that may be of concern with respect to acid generation. The NAPP calculation represents the balance between the maximum potential acidity (MPA) of a sample, which is derived from the sulfide sulfur content, and the acid neutralising capacity (ANC) of the material, which is determined experimentally. By convention, the NAPP result is expressed in units of kg H_2SO_4/t sample. If the capacity of the solids to neutralise acid (ANC) exceeds their capacity to generate acid (MPA), then the NAPP of the material is negative. Conversely, if the MPA exceeds the ANC, the NAPP of the material is positive. A NAPP assessment involves a series of analytical tests that include:

Determination of pH and EC

pH and EC measured on 1:5 w/w water extract. This gives an indication of the inherent acidity and salinity of the waste material when initially exposed in a waste emplacement area.

Total sulfur content and Maximum Potential Acidity (MPA)

Total sulfur content is determined by the Leco high temperature combustion method. The total sulfur content is then used to calculate the MPA, which assumes that the entire sulfur content is present as reactive pyrite. Direct determination of the pyritic sulfur content can provide a more accurate estimate of the MPA.

Acid neutralising capacity (ANC)

By addition of acid to a known weight of sample, then titration with NaOH to determine the amount of residual acid. The ANC measures the capacity of a sample to react with and neutralise acid. The ANC can be further evaluated by slow acid titration to a set end-point in the Acid Buffering Characteristic Curve (ABCC) test through calculation of the amount of acid consumed and evaluation of the resultant titration curve.

ASSESSMENT OF ELEMENT ENRICHMENT AND SOLUBILITY

In mineralised areas it is common to find a suite of enriched elements that have resulted from natural geological processes. Multi-element scans are carried out to identify any elements that are present in a material (or readily leachable from a material) at concentrations that may be of environmental concern with respect to surface water quality, revegetation and public health. The samples are generally analysed for the following elements:

Major elements: Al, Ca, Fe, K, Mg, Na and S.

Minor elements: As, B, Cd, Co, Cr, Cu, F, Hg, Mn, Mo, Ni, Pb, Sb, Se, and Zn.

The concentration of these elements in samples can be directly compared with relevant state or national environmental and health-based concentration guideline criteria to determine the level of significance. Water

extracts are used to determine the immediate element solubilities under the existing sample pH conditions of the sample. The following tests are normally carried out:

Multi-element composition of solids.

Multi-element composition of solid samples determined using a combination of ICP-mass spectroscopy (ICP-MS), ICP-optical emission spectroscopy (OES), and atomic absorption spectrometry (AAS).

Multi-element composition of water extracts (1:5 sample:deionised water).

Multi-element composition of water extracts from solid samples determined using a combination of ICP-mass spectroscopy (ICP-MS), ICP-optical emission spectroscopy (OES), and atomic absorption spectrometry (AAS).

Under some conditions (*e.g.* low pH) the solubility and mobility of common environmentally important elements can increase significantly. If element mobility under initial pH conditions is deemed likely and/or subsequent low pH conditions may occur, kinetic leach column test work may be completed on representative samples.

Attachment B: Static Geochemical Test Results

Table B1: Acid Base Account Results for Waste Rock and Coal from the Vulcan Coal Mine Matilda Pit Project

Sample No.	Date	RGS Sample ID	ALS Lab ID	Drill Hole ID	Client Sample ID	Sample Lithology	Weathering	Sample Location in Pit	From	To	Interval	pH (1:5)	EC (1:5)	Total S	Scr	ANC[2]	MPA[2]	NAPP[2]	ANC: MPA Ratio	Sample Classification[3]	Composite
1	2022	2022049_016	EB2218704016	VSW263_O	147220	Coal	Fresh	Coal	35.00	36.00	1.00	9.1	120	1.09	0.732	13.8	22.4	8.6	0.6	Potentially Acid Forming - Low Capacity	2022049_C001
2	2022	2022049_036	EB2218704036	VSW264_O	147250	Coal	Fresh	Coal	33.00	34.00	1.00	9.2	132	1.00	0.605	72.8	18.5	-54.3	3.9	Non-Acid Forming	2022049_C001
3	2022	2022049_040	EB2218704040	VSW264_O	147240	Sandstone	Fresh	Interburden	39.00	42.00	3.00	8.5	263	0.80	0.697	6.5	21.3	14.8	0.3	Potentially Acid Forming	2022049_C002
4	2022	2022049_039	EB2218704039	VSW264_O	147239	Sandstone	Fresh	Interburden	36.00	39.00	3.00	8.9	192	0.33	0.324	7.2	9.9	2.7	0.7	Uncertain	2022049_C002
5	2022	2022049_020	EB2218704020	VSW263_O	147219	Sandstone	Fresh	Interburden	40.00	42.00	2.00	9.2	165	0.11	0.106	7.4	3.2	-4.2	2.3	Uncertain	2022049_C002
6	2022	2022049_026	EB2218704026	VSW264_O	147227	Sandstone	Fresh	Overburden	14.00	16.00	2.00	6.5	281	0.14	0.120	3.3	3.7	0.4	0.9	Uncertain	2022049_C003
7	2022	2022049_006	EB2218704006	VSW263_O	147206	Sandstone	Fresh	Overburden	13.00	16.00	3.00	6.7	78	0.08		<0.5	2.5	2.2	0.1	Non-Acid Forming (Barren)	2022049_C003
8	2022	2022049_028	EB2218704028	VSW264_O	147229	Sandstone	Fresh	Overburden	17.00	19.00	2.00	6.8	330	0.38	0.326	4.1	10.0	5.9	0.4	Potentially Acid Forming - Low Capacity	2022049_C003
9	2022	2022049_007	EB2218704007	VSW263_O	147207	Sandstone	Fresh	Overburden	16.00	18.00	2.00	7.0	324	0.14	0.129	4.8	4.0	-0.8	1.2	Uncertain	2022049_C003
10	2022	2022049_010	EB2218704010	VSW263_O	147210	Sandstone	Fresh	Overburden	24.00	27.00	3.00	9.0	271	0.21	0.182	84.5	5.6	-78.9	15.2	Non-Acid Forming	2022049_C003
11	2022	2022049_030	EB2218704030	VSW264_O	147231	Sandstone	Fresh	Overburden	22.00	25.00	3.00	9.0	249	0.34	0.328	79.7	10.0	-69.7	7.9	Non-Acid Forming	2022049_C003
12	2022	2022049_031	EB2218704031	VSW264_O	147232	Sandstone	Fresh	Overburden	25.00	27.00	2.00	9.1	223	0.41	0.386	81.7	11.8	-69.9	6.9	Non-Acid Forming	2022049_C003
13	2022	2022049_011	EB2218704011	VSW263_O	147211	Sandstone	Fresh	Overburden	27.00	29.00	2.00	9.2	224	0.19	0.170	37.2	5.2	-32.0	7.1	Non-Acid Forming	2022049_C003
14	2022	2022049_025	EB2218704025	VSW264_O	147226	Sandstone	Slightly Weathered	Overburden	11.00	14.00	3.00	5.9	120	0.12	0.120	<0.5	3.7	3.4	0.1	Uncertain	2022049_C004
15	2022	2022049_022	EB2218704022	VSW264_O	147223	Sandstone	Slightly Weathered	Overburden	3.00	6.00	3.00	6.0	76	0.04		<0.5	1.2	1.0	0.2	Non-Acid Forming (Barren)	2022049_C004
16	2022	2022049_001	EB2218704001	VSW263_O	147201	Sandstone	Slightly Weathered	Overburden	0.10	3.00	2.90	6.2	31	0.02		<0.5	0.6	0.4	0.4	Non-Acid Forming (Barren)	2022049_C004
17	2022	2022049_021	EB2218704021	VSW264_O	147222	Sandstone	Slightly Weathered	Overburden	0.10	3.00	2.90	6.4	28	0.01		<0.5	0.3	0.1	0.8	Non-Acid Forming (Barren)	2022049_C004
18	2022	2022049_003	EB2218704003	VSW263_O	147203	Sandstone	Slightly Weathered	Overburden	6.00	7.00	1.00	7.6	97	0.05		3.5	1.5	-2.0	2.3	Non-Acid Forming (Barren)	2022049_C004
19	2022	2022049_037	EB2218704037	VSW264_O	147237	Siltstone	Fresh	Floor	34.00	35.00	1.00	9.2	142	0.28	0.236	10.5	7.2	-3.3	1.5	Uncertain	2022049_C005
20	2022	2022049_017	EB2218704017	VSW263_O	147216	Siltstone	Fresh	Floor	36.00	37.00	1.00	9.3	177	0.15	0.140	6.7	4.3	-2.4	1.6	Uncertain	2022049_C005
21	2022	2022049_038	EB2218704038	VSW264_O	147238	Siltstone	Fresh	Interburden	35.00	36.00	1.00	9.1	161	0.21	0.196	13.6	6.0	-7.6	2.3	Non-Acid Forming	2022049_C006
22	2022	2022049_018	EB2218704018	VSW263_O	147217	Siltstone	Fresh	Interburden	37.00	38.00	1.00	9.3	153	0.08		11.7	2.5	-9.3	4.8	Non-Acid Forming (Barren)	2022049_C006
23	2022	2022049_019	EB2218704019	VSW263_O	147218	Siltstone	Fresh	Interburden	38.00	40.00	2.00	9.3	173	0.09		11.7	2.8	-8.9	4.2	Non-Acid Forming (Barren)	2022049_C006
24	2022	2022049_014	EB2218704014	VSW263_O	147214	Siltstone	Fresh	Overburden	33.00	34.00	1.00	9.2	197	0.14	0.140	16.9	4.3	-12.6	3.9	Non-Acid Forming	2022049_C006
25	2022	2022049_033	EB2218704033	VSW264_O	147234	Siltstone	Fresh	Overburden	30.00	31.00	1.00	9.2	178	0.08		17.3	2.5	-14.9	7.1	Non-Acid Forming (Barren)	2022049_C006
26	2022	2022049_034	EB2218704034	VSW264_O	147235	Siltstone	Fresh	Overburden	31.00	32.00	1.00	9.2	178	0.16	0.143	18.8	4.4	-14.4	4.3	Non-Acid Forming	2022049_C006
27	2022	2022049_013	EB2218704013	VSW263_O	147213	Siltstone	Fresh	Overburden	32.00	33.00	1.00	9.4	194	0.11	0.101	19.9	3.1	-16.8	6.4	Non-Acid Forming	2022049_C006
28	2022	2022049_008	EB2218704008	VSW263_O	147208	Siltstone	Fresh	Overburden	18.00	21.00	3.00	5.5	441	0.78	0.657	2.6	20.1	17.5	0.1	Potentially Acid Forming	2022049_C007
29	2022	2022049_027	EB2218704027	VSW264_O	147228	Siltstone	Fresh	Overburden	16.00	17.00	1.00	6.5	320	0.19	0.158	1.9	4.8	2.9	0.4	Uncertain	2022049_C007
30	2022	2022049_029	EB2218704029	VSW264_O	147230	Siltstone	Fresh	Overburden	19.00	22.00	3.00	7.2	416	1.46	1.100	7.3	33.7	26.4	0.2	Potentially Acid Forming	2022049_C007
31	2022	2022049_009	EB2218704009	VSW263_O	147209	Siltstone	Fresh	Overburden	21.00	24.00	3.00	7.9	285	0.45	0.454	9.2	13.9	4.7	0.7	Uncertain	2022049_C007
32	2022	2022049_012	EB2218704012	VSW263_O	147212	Siltstone	Fresh	Overburden	29.00	32.00	3.00	8.7	344	0.78	0.670	23.8	20.5	-3.3	1.2	Uncertain	2022049_C007
33	2022	2022049_032	EB2218704032	VSW264_O	147233	Siltstone	Fresh	Overburden	27.00	30.00	3.00	9.1	210	0.48	0.472	29.3	14.5	-14.8	2.0	Non-Acid Forming	2022049_C007
34	2022	2022049_035	EB2218704035	VSW264_O	147236	Siltstone	Fresh	Roof	32.00	33.00	1.00	8.9	206	2.13	1.790	19.4	54.8	35.4	0.4	Potentially Acid Forming	2022049_C008
35	2022	2022049_015	EB2218704015	VSW263_O	147215	Siltstone	Fresh	Roof	34.00	35.00	1.00	9.3	171	0.84	0.767	119.0	23.5	-95.5	5.1	Non-Acid Forming	2022049_C008
36	2022	2022049_002	EB2218704002	VSW263_O	147202	Siltstone	Slightly Weathered	Overburden	3.00	6.00	3.00	6.2	80	0.07		1.3	2.1	0.8	0.6	Non-Acid Forming (Barren)	2022049_C009
37	2022	2022049_024	EB2218704024	VSW264_O	147225	Siltstone	Slightly Weathered	Overburden	9.00	11.00	2.00	7.1	190	0.30	0.282	<0.5	8.6	8.4	0.0	Potentially Acid Forming - Low Capacity	2022049_C009
38	2022	2022049_023	EB2218704023	VSW264_O	147224	Siltstone	Slightly Weathered	Overburden	6.00	9.00	3.00	7.4	117	0.14	0.139	6.0	4.3	-1.7	1.4	Uncertain	2022049_C009
39	2022	2022049_005	EB2218704005	VSW263_O	147205	Siltstone	Slightly Weathered	Overburden	10.00	13.00	3.00	7.6	136	0.22	0.223	7.0	6.8	-0.2	1.0	Uncertain	2022049_C009
40	2022	2022049_004	EB2218704004	VSW263_O	147204	Siltstone	Slightly Weathered	Overburden	7.00	10.00	3.00	7.9	89	0.12	0.106	9.4	3.2	-6.2	2.9	Non-Acid Forming	2022049_C009
41	44776	2022049_041	EB2222926001	VSW205_C	179695-180303	Coarse Reject	Fresh	Coarse Reject				3.3	2,360	5.16	4.880	6.7	149.5	142.8	0.0	Potentially Acid Forming	2022049_C010
42	44776	2022049_043	EB2222926003	VSW206_C	180306-180311	Coarse Reject	Fresh	Coarse Reject				3.7	1,620	3.00	2.870	<0.5	87.9	87.6	0.0	Potentially Acid Forming	2022049_C010
43	44776	2022049_045	EB2222926005	VSW225_C	164433-164440	Coarse Reject	Fresh	Coarse Reject				5.3	619	1.55	1.360	22.8	41.7	18.9	0.5	Potentially Acid Forming	2022049_C010
44	44776	2022049_047	EB2222926007	VSW226_C	164355-164360	Coarse Reject	Fresh	Coarse Reject				3.1	2,300	3.11	2.820	<0.5	86.4	86.1	0.0	Potentially Acid Forming	2022049_C011
45	44776	2022049_049	EB2222926009	VSW227_C3	164387-164391	Coarse Reject	Fresh	Coarse Reject				3.6	1,730	3.54	3.200	11.1	98.0	86.9	0.1	Potentially Acid Forming	2022049_C011
46	44776	2022049_051	EB2222926011	VSW228_C	164380-164384	Coarse Reject	Fresh	Coarse Reject				3.6	2,270	3.07	2.620	15.2	80.2	65.0	0.2	Potentially Acid Forming	2022049_C011
47	44776	2022049_053	EB2222926013	VSW229_C	145103-145108	Coarse Reject	Fresh	Coarse Reject				3.6	1,400	3.54	3.520	15.8	107.8	92.0	0.1	Potentially Acid Forming	2022049_C011
48	44776	2022049_046	EB2222926006	VSW225_C	164433-164440	Fine Reject	Fresh	Fine Reject				6.8	297	1.10	1.000	25.3	30.6	5.3	0.8	Potentially Acid Forming - Low Capacity	2022049_C012
49	44776	2022049_048	EB2222926008	VSW226_C	164355-164360	Fine Reject	Fresh	Fine Reject				5.9	427	1.04	0.796	12.8	24.4	11.6	0.5	Potentially Acid Forming	2022049_C012
50	44776	2022049_054	EB2222926014	VSW229_C	145103-145108	Fine Reject	Fresh	Fine Reject				4.9	755	3.38	3.250	13.9	99.5	85.6	0.1	Potentially Acid Forming	2022049_C012
51	44776	2022049_042	EB2222926002	VSW205_C	179695-180303	Fine Reject	Fresh	Fine Reject				5.5	484	1.07	0.841	18.1	25.8	7.7	0.7	Potentially Acid Forming - Low Capacity	2022049_C013
52	44776	2022049_044	EB2222926004	VSW206_C	180306-180311	Fine Reject	Fresh	Fine Reject				6.5	387	1.48	1.260	13.0	38.6	25.6	0.3	Potentially Acid Forming	2022049_C013
53	44776	2022049_050	EB2222926010	VSW227_C3	164387-164391	Fine Reject	Fresh	Fine Reject				4.3	1,170	3.15	3.140	12.4	96.2	83.8	0.1	Potentially Acid Forming	2022049_C013
54	44776	2022049_052	EB2222926012	VSW228_C	164380-164384	Fine Reject	Fresh	Fine Reject				5.8	616	1.57	1.230	19.2	37.7	18.5	0.5	Potentially Acid Forming	2022049_C013

Notes:

1. Current pH, EC, Alkalinity and Acidity provided for 1:5 sample:water extracts
2. Scr = Chromium Reducible Sulfur; MPA = Maximum Potential Acidity; ANC = Acid Neutralising Capacity; NAPP = Net Acid Producing Potential; NAG = Net Acid Generation.
3. Sample classification criteria detail provided in report text.

* Where total sulfur or ANC results are less than the laboratory LoR a value of half of the LoR is used .

Table B2: Multi-Element and Exchangeable Cation Results for Waste Rock and Coal from the Vulcan Coal Mine Matilda Pit Project

	RGS Sample Number →		2022049_C001	2022049_C002	2022049_C003	2022049_C004	2022049_C005
	Sampling Date →		01/08/2022	01/08/2022	01/08/2022	01/08/2022	01/08/2022
	ALS Laboratory ID →		EB2222546001	EB2222546002	EB2222546003	EB2222546004	EB2222546005
Parameters	**Limit of Reporting**	NEPC[1] Health-Based Investigation Level (HILs)-C	Fresh Coal	Fresh Sandstone Interburden	Fresh Sandstone Overburden	Slightly Weathered Sandstone Overburden	Fresh Siltstone Floor
pH	0.1	-	8.8	8.7	8.7	5.8	9.1
Electrical Conductivity	1	-	164	215	310	60	175
Major Cations		-	All units mg/kg				
Calcium (Ca)	50	-	45,000	2,210	13,700	190	2,230
Magnesium (Mg)	50	-	1,780	1,110	2,840	440	1,480
Potassium (K)	50	-	1,170	1,220	1,490	1,170	1,350
Sodium (Na)	50	-	230	180	250	60	200
Aluminium (Al)	50	-	1,550	1,410	1,930	1,830	1,310
Iron (Fe)	50	-	28,500	15,500	21,800	9,980	13,100
Minor and Trace Elements		-	All units mg/kg				
Arsenic (As)	0.1	300	9.0	3.9	5.4	4.6	6.1
Boron (B)	50	20,000	<50	<50	<50	<50	<50
Barium (Ba)	0.1	-	119.0	52.4	61.8	30.2	23.5
Beryllium (Be)	0.1	90	0.7	0.4	0.6	0.3	0.5
Cadmium (Cd)	0.1	90	0.1	<0.1	<0.1	<0.1	<0.1
Cobalt (Co)	0.1	300	6.6	4.5	7.0	3.5	8.0
Chromium (Cr) *	0.1	300	0.7	2.0	3.1	2.6	1.9
Copper (Cu)	0.1	17,000	29.6	6.4	8.2	5.1	20.0
Mercury (Hg)	0.1	80	0.1	<0.1	<0.1	<0.1	<0.1
Manganese (Mn)	0.1	19,000	525.0	177.0	334.0	98.2	143.0
Molybdenum (Mo)	0.1	-	1.1	0.5	0.6	0.5	0.8
Nickel (Ni)	0.1	1,200	4.3	7.8	10.6	5.3	13.8
Lead (Pb)	0.1	600	11.1	16.2	14.3	10.8	20.6
Antimony (Sb)	0.1	-	0.3	0.2	0.2	0.2	0.2
Selenium (Se)	1	700	1	<1	<1	<1	<1
Thorium (Th)	0.1	-	2.3	1.4	2.1	1.2	2.2
Uranium (U)	0.1	-	0.5	0.3	0.4	0.2	0.4
Vanadium (V)	1	-	8	3	10	3	3
Zinc (Zn)	0.5	30,000	64.2	33.9	46.5	28.4	66.1
Exchangeable Cations		-	All units meq/100g (except Exchangable Sodium Percentage (%))				
Exchangeable Calcium	0.2	-	----	1.1	1.7	0.5	----
Exchangeable Potassium	0.2	-	----	0.2	0.4	0.2	----
Exchangeable Magnesium	0.2	-	----	0.8	1.8	1.0	----
Exchangeable Sodium	0.2	-	----	<0.2	0.5	0.2	----
Cation Exchange Capacity	0.2	-	----	2.1	4.3	2.1	----
Exchangeable Sodium Percent	0.2	-	----	<0.2	11.0	9.3	----
Calcium/Magnesium Ratio	0.2	-	----	1.4	1.0	0.5	----
Magnesium/Potassium Ratio	0.2	-	----	3.5	4.3	4.1	----

Notes:
< indicates less than the laboratory limit of reporting. Shaded cells exceed applied guideline limit.
* Guideline level for Cr(VI) = 300 mg/kg.
1. NEPC (2013). National Environmental Protection Council (NEPC). National Environmental Protection (Assessment of Site Contamination) Measure (NEPM), Amendment of Schedule B1-B7 of 1999 version. Guideline on Investigation Levels for Soil and Groundwater. Health-Based Investigation Level - HIL(C); public open spaces - recreational use.

Table B2: Multi-Element and Exchangeable Cation Results for Waste Rock and Coal from the Vulcan Coal Mine Matilda Pit Project

	RGS Sample Number →		2022049_C006	2022049_C007	2022049_C008	2022049_C009	2022049_C10
	Sampling Date →		01/08/2022	01/08/2022	01/08/2022	01/08/2022	17/08/2022
	ALS Laboratory ID →		EB2222546006	EB2222546007	EB2222546008	EB2222546009	EB2224164001
Parameters	**Limit of Reporting**	NEPC[1] Health-Based Investigation Level (HILs)-C	Fresh Slightly Carbonaceous Siltstone Overburden/Interburden	Fresh Siltstone Overburden	Fresh Siltstone Roof	Slightly Weathered Siltstone Overburden	Coarse Rejects
pH	0.1	-	9.1	8.4	8.9	7.3	4.0
Electrical Conductivity	1	-	195	363	230	135	1,390
Major Cations		-	All units mg/kg				
Calcium (Ca)	50	-	4,620	3,860	34,400	610	3,890
Magnesium (Mg)	50	-	3,040	3,040	4,900	1,580	1,920
Potassium (K)	50	-	1,530	1,770	1,360	1,600	1,080
Sodium (Na)	50	-	320	270	310	160	330
Aluminium (Al)	50	-	1,760	2,060	1,710	1,620	1,450
Iron (Fe)	50	-	30,600	33,700	38,900	25,900	49,400
Minor and Trace Elements		-	All units mg/kg				
Arsenic (As)	0.1	300	6.0	8.1	10.5	7.1	26.8
Boron (B)	50	20,000	<50	<50	<50	<50	<50
Barium (Ba)	0.1	-	25.8	28.6	178.0	48.2	38.4
Beryllium (Be)	0.1	90	0.6	0.6	0.7	0.9	1.8
Cadmium (Cd)	0.1	90	<0.1	<0.1	<0.1	0.1	0.1
Cobalt (Co)	0.1	300	7.8	8.2	5.5	9.6	10.4
Chromium (Cr) *	0.1	300	2.8	3.3	2.8	3.0	0.5
Copper (Cu)	0.1	17,000	16.8	13.8	19.4	17.3	76.8
Mercury (Hg)	0.1	80	<0.1	0.2	0.1	<0.1	1.1
Manganese (Mn)	0.1	19,000	369.0	402.0	625.0	329.0	745.0
Molybdenum (Mo)	0.1	-	0.6	0.6	1.7	0.7	1.0
Nickel (Ni)	0.1	1,200	11.8	16.1	7.5	15.5	7.8
Lead (Pb)	0.1	600	17.8	19.6	13.6	20.5	12.1
Antimony (Sb)	0.1	-	0.2	0.2	0.2	0.3	0.6
Selenium (Se)	1	700	<1	<1	<1	<1	2
Thorium (Th)	0.1	-	2.0	1.9	3.9	2.2	1.9
Uranium (U)	0.1	-	0.4	0.3	0.5	0.4	0.4
Vanadium (V)	1	-	10	9	12	7	5
Zinc (Zn)	0.5	30,000	60.2	59.5	44.9	82.4	64.3
Exchangeable Cations		-	All units meq/100g (except Exchangable Sodium Percentage (%))				
Exchangeable Calcium	0.2	-	1.8	----	----	1.0	----
Exchangeable Potassium	0.2	-	0.4	----	----	0.6	----
Exchangeable Magnesium	0.2	-	1.4	----	----	3.7	----
Exchangeable Sodium	0.2	-	0.5	----	----	0.6	----
Cation Exchange Capacity	0.2	-	4.1	----	----	6.0	----
Exchangeable Sodium Percent	0.2	-	11.7	----	----	10.0	----
Calcium/Magnesium Ratio	0.2	-	1.3	----	----	0.3	----
Magnesium/Potassium Ratio	0.2	-	3.4	----	----	6.6	----

Notes:
< indicates less than the laboratory limit of reporting. Shaded cells exceed applied guideline limit.
* Guideline level for Cr(VI) = 300 mg/kg.
1. NEPC (2013). National Environmental Protection Council (NEPC). National Environmental Protection (Assessment of Site Contamination) Measure (NEPM), Amendment of Schedule B1-B7 of 1999 version. Guideline on Investigation Levels for Soil and Groundwater. Health-Based Investigation Level - HIL(C); public open spaces - recreational use.

Table B2: Multi-Element and Exchangeable Cation Results for Waste Rock and Coal from the Vulcan Coal Mine Matilda Pit Project

	RGS Sample Number →		2022049_C11	2022049_C12	2022049_C13
	Sampling Date →		17/08/2022	17/08/2022	17/08/2022
	ALS Laboratory ID →		EB2224164002	EB2224164003	EB2224164004
Parameters	**Limit of Reporting**	NEPC[1] Health-Based Investigation Level (HILs)-C	Coarse Rejects	Fine Rejects	Fine Rejects
pH	0.1	-	3.4	5.3	5.1
Electrical Conductivity	1	-	1,790	533	652
Major Cations		-	All units mg/kg		
Calcium (Ca)	50	-	6,020	3,990	3,410
Magnesium (Mg)	50	-	1,910	1,710	1,480
Potassium (K)	50	-	1,180	1,310	1,220
Sodium (Na)	50	-	350	300	410
Aluminium (Al)	50	-	2,180	1,970	2,120
Iron (Fe)	50	-	38,900	45,300	34,200
Minor and Trace Elements		-	All units mg/kg		
Arsenic (As)	0.1	300	18.4	21.1	15.1
Boron (B)	50	20,000	<50	<50	<50
Barium (Ba)	0.1	-	39.7	63.1	61.5
Beryllium (Be)	0.1	90	0.9	1.1	0.9
Cadmium (Cd)	0.1	90	0.1	0.2	0.2
Cobalt (Co)	0.1	300	4.7	12.7	5.6
Chromium (Cr) *	0.1	300	0.2	1.3	0.7
Copper (Cu)	0.1	17,000	62.2	38.3	50.7
Mercury (Hg)	0.1	80	0.8	0.9	0.9
Manganese (Mn)	0.1	19,000	365.0	382.0	295.0
Molybdenum (Mo)	0.1	-	1.1	1.4	0.9
Nickel (Ni)	0.1	1,200	3.1	11.6	4.9
Lead (Pb)	0.1	600	10.9	13.7	17.3
Antimony (Sb)	0.1	-	0.7	0.4	0.5
Selenium (Se)	1	700	2	2	2
Thorium (Th)	0.1	-	2.1	1.9	1.7
Uranium (U)	0.1	-	0.7	0.4	0.4
Vanadium (V)	1	-	4	4	4
Zinc (Zn)	0.5	30,000	59.0	138.0	121.0
Exchangeable Cations		-	All units meq/100g (except Exchangable Sodium Percentage (%))		
Exchangeable Calcium	0.2	-	----	----	----
Exchangeable Potassium	0.2	-	----	----	----
Exchangeable Magnesium	0.2	-	----	----	----
Exchangeable Sodium	0.2	-	----	----	----
Cation Exchange Capacity	0.2	-	----	----	----
Exchangeable Sodium Percent	0.2	-	----	----	----
Calcium/Magnesium Ratio	0.2	-	----	----	----
Magnesium/Potassium Ratio	0.2	-	----	----	----

Notes:
< indicates less than the laboratory limit of reporting. Shaded cells exceed applied guideline limit.
* Guideline level for Cr(VI) = 300 mg/kg.
1. NEPC (2013). National Environmental Protection Council (NEPC). National Environmental Protection (Assessment of Site Contamination) Measure (NEPM), Amendment of Schedule B1-B7 of 1999 version. Guideline on Investigation Levels for Soil and Groundwater. Health-Based Investigation Level - HIL(C); public open spaces - recreational use.

Table B3: Geochemical Abundance Index (GAI) Results for Waste Rock and Coal from the Vulcan Coal Mine Matilda Pit Project

		RGS Sample Number →	2022049_C001	2022049_C002	2022049_C003	2022049_C004	2022049_C005
		Sampling Date →	01/08/2022	01/08/2022	01/08/2022	01/08/2022	01/08/2022
		ALS Laboratory ID →	EB2222546001	EB2222546002	EB2222546003	EB2222546004	EB2222546005
Parameters	**Limit of Reporting**	Median Crustal Abundance[1,2,3]	Fresh Coal	Fresh Sandstone Interburden	Fresh Sandstone Overburden	Slightly Weathered Sandstone Overburden	Fresh Siltstone Floor
Major Cations	(All units in mg/kg)		Geochemical Abundance Index				
Calcium (Ca)	50	15,000	1.0	0.0	0.0	0.0	0.0
Magnesium (Mg)	50	5,000	0.0	0.0	0.0	0.0	0.0
Potassium (K)	50	14,000	0.0	0.0	0.0	0.0	0.0
Sodium (Na)	50	5,000	0.0	0.0	0.0	0.0	0.0
Aluminium (Al)	50	71,000	0.0	0.0	0.0	0.0	0.0
Iron (Fe)	50	40,000	0.0	0.0	0.0	0.0	0.0
Minor and Trace Elements	(All units in mg/kg)		Geochemical Abundance Index				
Arsenic (As)	0.1	6	0.0	0.0	0.0	0.0	0.0
Boron (B)	50	20	0.0	0.0	0.0	0.0	0.0
Barium (Ba)	0.1	500	0.0	0.0	0.0	0.0	0.0
Beryllium (Be)	0.1	0.3	0.6	0.0	0.4	0.0	0.2
Cadmium (Cd)	0.1	0.35	0.0	0.0	0.0	0.0	0.0
Cobalt (Co)	0.1	8	0.0	0.0	0.0	0.0	0.0
Chromium (Cr)	0.1	70	0.0	0.0	0.0	0.0	0.0
Copper (Cu)	0.1	30	0.0	0.0	0.0	0.0	0.0
Mercury (Hg)	0.1	0.06	0.2	0.0	0.0	0.0	0.0
Manganese (Mn)	0.1	1000	0.0	0.0	0.0	0.0	0.0
Molybdenum (Mo)	0.1	1.2	0.0	0.0	0.0	0.0	0.0
Nickel (Ni)	0.1	50	0.0	0.0	0.0	0.0	0.0
Lead (Pb)	0.1	35	0.0	0.0	0.0	0.0	0.0
Antimony (Sb)	0.1	1	0.0	0.0	0.0	0.0	0.0
Selenium (Se)	1	0.4	0.7	0.0	0.0	0.0	0.0
Thorium (Th)	0.1	9	0.0	0.0	0.0	0.0	0.0
Uranium (U)	0.1	2	0.0	0.0	0.0	0.0	0.0
Vanadium (V)	1	90	0.0	0.0	0.0	0.0	0.0
Zinc (Zn)	0.5	90	0.0	0.0	0.0	0.0	0.0

Notes: GAI's greater than or equal to 3 are highlighted.

1. Median Crustal Abundance values sourced from the "GARD Guide", Chapter 5 (INAP, 2009).

2. When no GARD Guide value is available for particular element, then values are taken from Bowen (1979) Environmental Chemistry of the Elements, p 60-61.

3. If no guide value from GARD or Bowen H.J.M. (1979) exists, up to date, curated data is provided by CRC Handbook of Chemistry and Physics (2000).

Table B3: Geochemical Abundance Index (GAI) Results for Waste Rock and Coal from the Vulcan Coal Mine Matilda Pit Project

		RGS Sample Number →	2022049_C006	2022049_C007	2022049_C008	2022049_C009	2022049_C10
		Sampling Date →	01/08/2022	01/08/2022	01/08/2022	01/08/2022	17/08/2022
		ALS Laboratory ID →	EB2222546006	EB2222546007	EB2222546008	EB2222546009	EB2224164001
Parameters	**Limit of Reporting**	Median Crustal Abundance[1,2,3]	Fresh Slightly Carbonaceous Siltstone Overburden/Interburden	Fresh Siltstone Overburden	Fresh Siltstone Roof	Slightly Weathered Siltstone Overburden	Coarse Rejects
Major Cations	(All units in mg/kg)		Geochemical Abundance Index				
Calcium (Ca)	50	15,000	0.0	0.0	0.6	0.0	0.0
Magnesium (Mg)	50	5,000	0.0	0.0	0.0	0.0	0.0
Potassium (K)	50	14,000	0.0	0.0	0.0	0.0	0.0
Sodium (Na)	50	5,000	0.0	0.0	0.0	0.0	0.0
Aluminium (Al)	50	71,000	0.0	0.0	0.0	0.0	0.0
Iron (Fe)	50	40,000	0.0	0.0	0.0	0.0	0.0
Minor and Trace Elements	(All units in mg/kg)		Geochemical Abundance Index				
Arsenic (As)	0.1	6	0.0	0.0	0.2	0.0	1.6
Boron (B)	50	20	0.0	0.0	0.0	0.0	0.0
Barium (Ba)	0.1	500	0.0	0.0	0.0	0.0	0.0
Beryllium (Be)	0.1	0.3	0.4	0.4	0.6	1.0	2.0
Cadmium (Cd)	0.1	0.35	0.0	0.0	0.0	0.0	0.0
Cobalt (Co)	0.1	8	0.0	0.0	0.0	0.0	0.0
Chromium (Cr)	0.1	70	0.0	0.0	0.0	0.0	0.0
Copper (Cu)	0.1	30	0.0	0.0	0.0	0.0	0.8
Mercury (Hg)	0.1	0.06	0.0	1.2	0.2	0.0	3.6
Manganese (Mn)	0.1	1000	0.0	0.0	0.0	0.0	0.0
Molybdenum (Mo)	0.1	1.2	0.0	0.0	0.0	0.0	0.0
Nickel (Ni)	0.1	50	0.0	0.0	0.0	0.0	0.0
Lead (Pb)	0.1	35	0.0	0.0	0.0	0.0	0.0
Antimony (Sb)	0.1	1	0.0	0.0	0.0	0.0	0.0
Selenium (Se)	1	0.4	0.0	0.0	0.0	0.0	1.7
Thorium (Th)	0.1	9	0.0	0.0	0.0	0.0	0.0
Uranium (U)	0.1	2	0.0	0.0	0.0	0.0	0.0
Vanadium (V)	1	90	0.0	0.0	0.0	0.0	0.0
Zinc (Zn)	0.5	90	0.0	0.0	0.0	0.0	0.0

Notes: GAI's greater than or equal to 3 are highlighted.

1. Median Crustal Abundance values sourced from the "GARD Guide", Chapter 5 (INAP, 2009).

2. When no GARD Guide value is available for particular element, then values are taken from Bowen (1979) Environmental Chemistry of the Elements, p 60-61.

3. If no guide value from GARD or Bowen H.J.M. (1979) exists, up to date, curated data is provided by CRC Handbook of Chemistry and Physics (2000).

Table B3: Geochemical Abundance Index (GAI) Results for Waste Rock and Coal from the Vulcan Coal Mine Matilda Pit Project

	RGS Sample Number →		2022049_C11	2022049_C12	2022049_C13
	Sampling Date →		17/08/2022	17/08/2022	17/08/2022
	ALS Laboratory ID →		EB2224164002	EB2224164003	EB2224164004
Parameters	**Limit of Reporting**	Median Crustal Abundance[1,2,3]	Coarse Rejects	Fine Rejects	Fine Rejects
Major Cations	(All units in mg/kg)		Geochemical Abundance Index		
Calcium (Ca)	50	15,000	0.0	0.0	0.0
Magnesium (Mg)	50	5,000	0.0	0.0	0.0
Potassium (K)	50	14,000	0.0	0.0	0.0
Sodium (Na)	50	5,000	0.0	0.0	0.0
Aluminium (Al)	50	71,000	0.0	0.0	0.0
Iron (Fe)	50	40,000	0.0	0.0	0.0
Minor and Trace Elements	(All units in mg/kg)		Geochemical Abundance Index		
Arsenic (As)	0.1	6	1.0	1.2	0.7
Boron (B)	50	20	0.0	0.0	0.0
Barium (Ba)	0.1	500	0.0	0.0	0.0
Beryllium (Be)	0.1	0.3	1.0	1.3	1.0
Cadmium (Cd)	0.1	0.35	0.0	0.0	0.0
Cobalt (Co)	0.1	8	0.0	0.1	0.0
Chromium (Cr)	0.1	70	0.0	0.0	0.0
Copper (Cu)	0.1	30	0.5	0.0	0.2
Mercury (Hg)	0.1	0.06	3.2	3.3	3.3
Manganese (Mn)	0.1	1000	0.0	0.0	0.0
Molybdenum (Mo)	0.1	1.2	0.0	0.0	0.0
Nickel (Ni)	0.1	50	0.0	0.0	0.0
Lead (Pb)	0.1	35	0.0	0.0	0.0
Antimony (Sb)	0.1	1	0.0	0.0	0.0
Selenium (Se)	1	0.4	1.7	1.7	1.7
Thorium (Th)	0.1	9	0.0	0.0	0.0
Uranium (U)	0.1	2	0.0	0.0	0.0
Vanadium (V)	1	90	0.0	0.0	0.0
Zinc (Zn)	0.5	90	0.0	0.0	0.0

Notes: GAI's greater than or equal to 3 are highlighted.

1. Median Crustal Abundance values sourced from the "GARD Guide", Chapter 5 (INAP, 2009).

2. When no GARD Guide value is available for particular element, then values are taken from Bowen (1979) Environmental Chemistry of the Elements, p 60-61.

3. If no guide value from GARD or Bowen H.J.M. (1979) exists, up to date, curated data is provided by CRC Handbook of Chemistry and Physics (2000).

Table B4: Multi-Element Test Results for Water Extracts from Waste Rock and Coal from the Vulcan Coal Mine Matilda Pit Project

		RGS Sample Number →	2022049_C001	2022049_C002	2022049_C003	2022049_C004	2022049_C005
		Sample Date →	01/08/2022	01/08/2022	01/08/2022	01/08/2022	01/08/2022
		ALS Laboratory ID →	EB2222546001	EB2222546002	EB2222546003	EB2222546004	EB2222546005
Parameters	**Limit of Reporting**	Aquatic Ecosystems (freshwater)[1]	Livestock Drinking Water[2]	Fresh Coal	Fresh Sandstone Interburden	Fresh Sandstone Overburden	Slightly Weathered Sandstone Overburden	Fresh Siltstone Floor
pH	0.1 pH unit	6 to 9	-	8.8	8.7	8.7	5.8	9.1
Electrical Conductivity	1 µS/cm	<1,000#	3,580^	164	215	310	60	175
Carbonate Alkalinity (mg CaCO /L)	1 mg/L	-	-	180	<0.2	<0.2	<0.2	180
Bicarbonate Alkalinity (mg CaCO /L)	1 mg/L	-	-	5,760	990	3,520	108	540
Total Alkalinity (mg CaCO /L)	1 mg/L	-	-	5,940	990	3,520	108	720
Acidity (mg CaCO /L)	1 mg/L	-	-	<0.2	5	<0.2	155	<0.2
Net Alkalinity (mg CaCO /L)	1 mg/L	-	-	5,940	985	3,520	-47	720
Major Ions				All units mg/L				
Calcium (Ca)	2	-	1,000	8	10	12	<2	4
Magnesium (Mg)	2	-	-	4	4	8	<2	<2
Potassium (K)	2	-	-	8	20	24	12	16
Sodium (Na)	2	-	-	24	24	34	6	26
Chloride (Cl)	2	-	-	4	12	8	2	6
Fluoride (F)	0.2	-	2	1.2	0.2	0.6	<0.2	0.6
Sulfate (SO)	2	-	1,000	40	58	72	18	40
Silica (Si)	0.2	-	-	3.0	4.4	4.8	13.8	5.2
Reactive Phosphorus (P)	0.02	-	-	<0.02	<0.02	<0.02	<0.02	<0.02
Trace Metals/Metalloids				All units mg/L				
Aluminium (Al)	0.02	0.055	5	<0.02	0.02	0.02	0.08	0.04
Arsenic (As)	0.002	0.024 **	0.5	<0.002	0.002	0.002	<0.002	0.018
Boron (B)	0.2	0.37	5	<0.2	<0.2	<0.2	<0.2	<0.2
Barium (Ba)	0.002	-	-	0.036	0.028	0.012	<0.002	0.004
Beryllium (Be)	0.002	-	-	<0.002	<0.002	<0.002	<0.002	<0.002
Cadmium (Cd)	0.002	0.0002	0.01	<0.002	<0.002	<0.002	<0.002	<0.002
Cobalt (Co)	0.002	-	1	<0.002	<0.002	<0.002	<0.002	<0.002
Chromium (Cr)	0.002	0.001 (hex)*	1 (total)	<0.002	<0.002	<0.002	<0.002	<0.002
Copper (Cu)	0.002	0.0014	1	<0.002	<0.002	<0.002	<0.002	<0.002
Iron (Fe)	0.2	-	-	<0.2	<0.2	<0.2	<0.2	<0.2
Mercury (Hg)	0.0001	0.0006	0.002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Manganese (Mn)	0.002	1.9	-	<0.002	0.004	0.008	0.004	<0.002
Molybdenum (Mo)	0.002	-	0.15	0.010	0.018	0.022	<0.002	0.056
Nickel (Ni)	0.002	0.011	1	<0.002	<0.002	<0.002	<0.002	<0.002
Lead (Pb)	0.002	0.0034	0.1	<0.002	<0.002	<0.002	<0.002	<0.002
Antimony (Sb)	0.002	-	-	<0.002	0.006	0.004	<0.002	0.008
Selenium (Se)	0.02	0.011	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Thorium (Th)	0.002	-	-	<0.002	<0.002	<0.002	<0.002	<0.002
Uranium (U)	0.002	-	-	<0.002	<0.002	<0.002	<0.002	<0.002
Vanadium (V)	0.02	-	-	<0.02	<0.02	<0.02	<0.02	<0.02
Zinc (Zn)	0.01	0.008	20	<0.01	<0.01	<0.01	<0.01	<0.01

Notes: < indicates concentration less than the detection limit. Shaded cells exceed applied guideline values. * Cr (VI) = hexavalent. ** 0.013 mg/L for pentavalent Arsenic (V).

for still water bodies only, moving rivers at low flow rates should not exceed 2,200µS/cm. ^ calculated based on total dissolved solids (TDS) conversion rate of 0.67% of EC.

TDS is an approximate measure of inorganic dissolved salts and should not exceed 2,400mg/L for livestock drinking water. pH and EC of composites are median pH and EC values of individual samples reported in Table C2.

1. ANZG (2018). Trigger values for freshwater aquatic ecosystems (95% species protection level)

2. ANZG (2018). Recommended guideline limits for Livestock Drinking Water.

Table B4: Multi-Element Test Results for Water Extracts from Waste Rock and Coal from the Vulcan Coal Mine Matilda Pit Project

		RGS Sample Number →	2022049_C006	2022049_C007	2022049_C008	2022049_C009	2022049_C10
		Sample Date →	01/08/2022	01/08/2022	01/08/2022	01/08/2022	17/08/2022
		ALS Laboratory ID →	EB2222546006	EB2222546007	EB2222546008	EB2222546009	EB2224164001
Parameters	**Limit of Reporting**	Aquatic Ecosystems (freshwater)[1]	Livestock Drinking Water[2]	Fresh Slightly Carbonaceous Siltstone Overburden/Interburden	Fresh Siltstone Overburden	Fresh Siltstone Roof	Slightly Weathered Siltstone Overburden	Coarse Rejects
pH	0.1 pH unit	6 to 9	-	9.1	8.4	8.9	7.3	4.0
Electrical Conductivity	1 µS/cm	<1,000#	3,580^	195	363	230	135	1,390
Carbonate Alkalinity (mg $CaCO_3$ /L)	1 mg/L	-	-	<0.2	<0.2	18	<0.2	<0.2
Bicarbonate Alkalinity (mg $CaCO_3$ /L)	1 mg/L	-	-	1,008	738	6,120	306	18
Total Alkalinity (mg $CaCO_3$ /L)	1 mg/L	-	-	1,008	738	6,140	306	18
Acidity (mg $CaCO_3$ /L)	1 mg/L	-	-	<0.2	8	<0.2	74	416
Net Alkalinity (mg $CaCO_3$ /L)	1 mg/L	-	-	1,008	730	6,140	232	-398
Major Ions				All units mg/L				
Calcium (Ca)	2	-	1,000	2	16	8	<2	88
Magnesium (Mg)	2	-	-	<2	8	4	<2	60
Potassium (K)	2	-	-	14	30	12	16	16
Sodium (Na)	2	-	-	34	36	36	18	38
Chloride (Cl)	2	-	-	6	8	8	2	4
Fluoride (F)[4]	0.2	-	2	0.4	0.4	1.0	0.6	0.6
Sulfate (SO_4^{2-})	2	-	1,000	32	116	52	44	784
Silica (Si)	0.2	-	-	5.4	5.0	4.6	8.2	4.2
Reactive Phosphorus (P)	0.02	-	-	<0.02	<0.02	<0.02	<0.02	<0.02
Trace Metals/Metalloids				All units mg/L				
Aluminium (Al)	0.02	0.055	5	0.04	<0.02	0.02	<0.02	1.50
Arsenic (As)	0.002	0.024 **	0.5	0.014	<0.002	0.004	<0.002	0.016
Boron (B)	0.2	0.37	5	<0.2	<0.2	<0.2	<0.2	<0.2
Barium (Ba)	0.002	-	-	<0.002	0.006	0.064	0.004	0.052
Beryllium (Be)	0.002	-	-	<0.002	<0.002	<0.002	<0.002	0.020
Cadmium (Cd)	0.002	0.0002	0.01	<0.002	<0.002	<0.002	<0.002	<0.002
Cobalt (Co)	0.002	-	1	<0.002	<0.002	<0.002	<0.002	0.260
Chromium (Cr)	0.002	0.001 (hex)*	1 (total)	<0.002	<0.002	<0.002	<0.002	<0.002
Copper (Cu)	0.002	0.0014	1	<0.002	<0.002	<0.002	<0.002	0.266
Iron (Fe)	0.2	-	-	<0.2	<0.2	<0.2	<0.2	193.6
Mercury (Hg)	0.0001	0.0006	0.002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Manganese (Mn)	0.002	1.9	-	<0.002	0.014	0.002	0.044	3.540
Molybdenum (Mo)	0.002	-	0.15	0.058	0.022	0.038	0.002	0.004
Nickel (Ni)	0.002	0.011	1	<0.002	<0.002	<0.002	0.002	0.222
Lead (Pb)	0.002	0.0034	0.1	<0.002	<0.002	<0.002	<0.002	0.004
Antimony (Sb)	0.002	-	-	0.010	0.004	0.004	<0.002	<0.002
Selenium (Se)	0.02	0.011	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Thorium (Th)	0.002	-	-	<0.002	<0.002	<0.002	<0.002	<0.002
Uranium (U)	0.002	-	-	<0.002	<0.002	<0.002	<0.002	<0.002
Vanadium (V)	0.02	-	-	<0.02	<0.02	<0.02	<0.02	<0.02
Zinc (Zn)	0.01	0.008	20	<0.01	<0.01	<0.01	<0.01	0.51

Notes: < indicates concentration less than the detection limit. Shaded cells exceed applied guideline values. * Cr (VI) = hexavalent. ** 0.013 mg/L for pentavalent Arsenic (V).

for still water bodies only, moving rivers at low flow rates should not exceed 2,200µS/cm. ^ calculated based on total dissolved solids (TDS) conversion rate of 0.67% of EC.

TDS is an approximate measure of inorganic dissolved salts and should not exceed 2,400mg/L for livestock drinking water. pH and EC of composites are median pH and EC values of individual samples reported in Table C2.

1. ANZG (2018). Trigger values for freshwater aquatic ecosystems (95% species protection level)

2. ANZG (2018). Recommended guideline limits for Livestock Drinking Water.

Table B4: Multi-Element Test Results for Water Extracts from Waste Rock and Coal from the Vulcan Coal Mine Matilda Pit Project

		RGS Sample Number →		2022049_C11	2022049_C12	2022049_C13
		Sample Date →		17/08/2022	17/08/2022	17/08/2022
		ALS Laboratory ID →		EB2224164002	EB2224164003	EB2224164004
Parameters	**Limit of Reporting**	Aquatic Ecosystems (freshwater)[1]	Livestock Drinking Water[2]	Coarse Rejects	Fine Rejects	Fine Rejects
pH	0.1 pH unit	6 to 9	-	3.4	5.3	5.1
Electrical Conductivity	1 µS/cm	<1,000#	3,580^	1,790	533	652
Carbonate Alkalinity (mg $CaCO_3$ /L)	1 mg/L	-	-	<0.2	<0.2	<0.2
Bicarbonate Alkalinity (mg $CaCO_3$ /L)	1 mg/L	-	-	<0.2	12	21
Total Alkalinity (mg $CaCO_3$ /L)	1 mg/L	-	-	<0.2	12	21
Acidity (mg $CaCO_3$ /L)	1 mg/L	-	-	742	58	74
Net Alkalinity (mg $CaCO_3$ /L)	1 mg/L	-	-	-742	-46	-54
Major Ions				All units mg/L		
Calcium (Ca)	2	-	1,000	116	38	52
Magnesium (Mg)	2	-	-	60	20	30
Potassium (K)	2	-	-	20	10	10
Sodium (Na)	2	-	-	38	30	32
Chloride (Cl)	2	-	-	4	22	20
Fluoride (F)[4]	0.2	-	2	0.6	<0.2	<0.2
Sulfate (SO_4^{2-})	2	-	1,000	946	216	310
Silica (Si)	0.2	-	-	6.8	7.0	6.0
Reactive Phosphorus (P)	0.02	-	-	<0.02	<0.02	<0.02
Trace Metals/Metalloids				All units mg/L		
Aluminium (Al)	0.02	0.055	5	2.72	0.04	0.08
Arsenic (As)	0.002	0.024 **	0.5	0.026	<0.002	<0.002
Boron (B)	0.2	0.37	5	<0.2	<0.2	<0.2
Barium (Ba)	0.002	-	-	0.048	0.048	0.048
Beryllium (Be)	0.002	-	-	0.024	<0.002	<0.002
Cadmium (Cd)	0.002	0.0002	0.01	0.002	<0.002	<0.002
Cobalt (Co)	0.002	-	1	0.244	0.058	0.036
Chromium (Cr)	0.002	0.001 (hex)*	1 (total)	<0.002	<0.002	<0.002
Copper (Cu)	0.002	0.0014	1	0.444	0.026	0.040
Iron (Fe)	0.2	-	-	256.0	3.4	12.6
Mercury (Hg)	0.0001	0.0006	0.002	<0.0001	<0.0001	<0.0001
Manganese (Mn)	0.002	1.9	-	1.196	0.286	0.378
Molybdenum (Mo)	0.002	-	0.15	<0.002	<0.002	<0.002
Nickel (Ni)	0.002	0.011	1	0.228	0.048	0.030
Lead (Pb)	0.002	0.0034	0.1	0.016	<0.002	<0.002
Antimony (Sb)	0.002	-	-	0.004	<0.002	<0.002
Selenium (Se)	0.02	0.011	0.02	<0.02	<0.02	<0.02
Thorium (Th)	0.002	-	-	<0.002	<0.002	<0.002
Uranium (U)	0.002	-	-	0.004	<0.002	<0.002
Vanadium (V)	0.02	-	-	<0.02	<0.02	<0.02
Zinc (Zn)	0.01	0.008	20	0.44	0.52	0.67

Notes: < indicates concentration less than the detection limit. Shaded cells exceed applied guideline values. * Cr (VI) = hexavalent. ** 0.013 mg/L for pentavalent Arsenic (V).

for still water bodies only, moving rivers at low flow rates should not exceed 2,200µS/cm. ^ calculated based on total dissolved solids (TDS) conversion rate of 0.67% of EC.

TDS is an approximate measure of inorganic dissolved salts and should not exceed 2,400mg/L for livestock drinking water. pH and EC of composites are median pH and EC values of individual samples reported in Table C2.

1. ANZG (2018). Trigger values for freshwater aquatic ecosystems (95% species protection level)

2. ANZG (2018). Recommended guideline limits for Livestock Drinking Water.

Attachment C: ALS Laboratory Results

(Certificates of Analysis)

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB2218704**	Page	: 1 of 12
Client	: **RGS ENVIRONMENTAL CONSULTANTS PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: PETER LONG	Contact	: Customer Services EB
Address	: 3/30 LENSWORTH STREET COOPERS PLAINS 4107	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: 07 3344 1222	Telephone	: +61-7-3243 7222
Project	: 2022049 Vulcan Coal Mine Matilda Pit	Date Samples Received	: 27-Jun-2022 10:40
Order number	: ----	Date Analysis Commenced	: 01-Jul-2022
C-O-C number	: ----	Issue Date	: 08-Jul-2022 11:21
Sampler	: PRIYA RAJENDRAN		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 41		
No. of samples analysed	: 41		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ben Felgendrejeris	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contract for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- ASS: EA013 (ANC) Fizz Rating: 0- None; 1- Slight; 2- Moderate; 3- Strong; 4- Very Strong; 5- Lime.

Analytical Results

Sub-Matrix: **COAL**
(Matrix: **SOIL**)

			Sample ID	2022049_016 147220 VSW263_O Coal	2022049_036 147250 VSW264_O Coal	----	----	----
			Sampling date / time	22-Jun-2022 00:00	22-Jun-2022 00:00	----	----	----
Compound	CAS Number	LOR	Unit	EB2218704-016	EB2218704-036	--------	--------	--------
				Result	Result	----	----	----
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	**9.1**	**9.2**	**----**	**----**	**----**
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	**19.6**	**-42.2**	**----**	**----**	**----**
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	**120**	**132**	**----**	**----**	**----**
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	**13.8**	**72.8**	**----**	**----**	**----**
ANC as CaCO3	----	0.1	% CaCO3	**1.4**	**7.4**	**----**	**----**	**----**
Fizz Rating	----	0	Fizz Unit	**1**	**2**	**----**	**----**	**----**
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	**1.09**	**1.00**	**----**	**----**	**----**

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	Sample ID	2022049_001 147201 VSW263_O Sandstone	2022049_002 147202 VSW263_O Siltstone	2022049_003 147203 VSW263_O Sandstone	2022049_004 147204 VSW263_O Siltstone	2022049_005 147205 VSW263_O Siltstone
				Sampling date / time	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00
					EB2218704-001	EB2218704-002	EB2218704-003	EB2218704-004	EB2218704-005
					Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit		**6.2**	**6.2**	**7.6**	**7.9**	**7.6**
EA009: Net Acid Production Potential									
Net Acid Production Potential	----	0.5	kg H2SO4/t		**0.6**	**0.8**	**-2.0**	**-5.7**	**-0.3**
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm		**31**	**80**	**97**	**89**	**136**
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		<0.5	**1.3**	**3.5**	**9.4**	**7.0**
ANC as CaCO3	----	0.1	% CaCO3		<0.1	**0.1**	**0.4**	**1.0**	**0.7**
Fizz Rating	----	0	Fizz Unit		**0**	**0**	**0**	**1**	**0**
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		**0.02**	**0.07**	**0.05**	**0.12**	**0.22**

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	Sample ID	2022049_006 147206 VSW263_O Sandstone	2022049_007 147207 VSW263_O Sandstone	2022049_008 147208 VSW263_O Siltstone	2022049_009 147209 VSW263_O Siltstone	2022049_010 147210 VSW263_O Sandstone
				Sampling date / time	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00
					EB2218704-006	EB2218704-007	EB2218704-008	EB2218704-009	EB2218704-010
					Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit		**6.7**	**7.0**	**5.5**	**7.9**	**9.0**
EA009: Net Acid Production Potential									
Net Acid Production Potential	----	0.5	kg H2SO4/t		**2.4**	**-0.5**	**21.3**	**4.6**	**-78.1**
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm		**78**	**324**	**441**	**285**	**271**
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		<0.5	**4.8**	**2.6**	**9.2**	**84.5**
ANC as CaCO3	----	0.1	% CaCO3		<0.1	**0.5**	**0.3**	**0.9**	**8.6**
Fizz Rating	----	0	Fizz Unit		**0**	**0**	**0**	**1**	**2**
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		**0.08**	**0.14**	**0.78**	**0.45**	**0.21**

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	Sample ID	2022049_011 147211 VSW263_O Sandstone	2022049_012 147212 VSW263_O Siltstone	2022049_013 147213 VSW263_O Siltstone	2022049_014 147214 VSW263_O Siltstone	2022049_015 147215 VSW263_O Siltstone
				Sampling date / time	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00
					EB2218704-011	EB2218704-012	EB2218704-013	EB2218704-014	EB2218704-015
					Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit		**9.2**	**8.7**	**9.4**	**9.2**	**9.3**
EA009: Net Acid Production Potential									
Net Acid Production Potential	----	0.5	kg H2SO4/t		**-31.4**	<0.5	**-16.5**	**-12.6**	**-93.3**
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm		**224**	**344**	**194**	**197**	**171**
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		**37.2**	**23.8**	**19.9**	**16.9**	**119**
ANC as CaCO3	----	0.1	% CaCO3		**3.8**	**2.4**	**2.0**	**1.7**	**12.1**
Fizz Rating	----	0	Fizz Unit		**2**	**1**	**1**	**1**	**2**
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		**0.19**	**0.78**	**0.11**	**0.14**	**0.84**

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	Sample ID	2022049_017 147216 VSW263_O Siltstone	2022049_018 147217 VSW263_O Siltstone	2022049_019 147218 VSW263_O Siltstone	2022049_020 147219 VSW263_O Sandstone	2022049_021 147222 VSW263_O Sandstone
				Sampling date / time	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00
					EB2218704-017	EB2218704-018	EB2218704-019	EB2218704-020	EB2218704-021
					Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit		**9.3**	**9.3**	**9.3**	**9.2**	**6.4**
EA009: Net Acid Production Potential									
Net Acid Production Potential	----	0.5	kg H2SO4/t		**-2.1**	**-9.2**	**-8.9**	**-4.0**	<0.5
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm		**177**	**153**	**173**	**165**	**28**
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		**6.7**	**11.7**	**11.7**	**7.4**	<0.5
ANC as CaCO3	----	0.1	% CaCO3		**0.7**	**1.2**	**1.2**	**0.8**	<0.1
Fizz Rating	----	0	Fizz Unit		**1**	**1**	**1**	**1**	**0**
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		**0.15**	**0.08**	**0.09**	**0.11**	**0.01**

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	Sample ID	2022049_022 147223 VSW264_O Sandstone	2022049_023 147224 VSW264_O Siltstone	2022049_024 147225 VSW264_O Siltstone	2022049_025 147226 VSW264_O Sandstone	2022049_026 147227 VSW264_O Sandstone
				Sampling date / time	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00
					EB2218704-022	EB2218704-023	EB2218704-024	EB2218704-025	EB2218704-026
					Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit		**6.0**	**7.4**	**7.1**	**5.9**	**6.5**
EA009: Net Acid Production Potential									
Net Acid Production Potential	----	0.5	kg H2SO4/t		**1.2**	**-1.7**	**9.2**	**3.7**	**1.0**
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm		**76**	**117**	**190**	**120**	**281**
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		<0.5	**6.0**	<0.5	<0.5	**3.3**
ANC as CaCO3	----	0.1	% CaCO3		<0.1	**0.6**	<0.1	<0.1	**0.3**
Fizz Rating	----	0	Fizz Unit		**0**	**1**	**0**	**0**	**0**
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		**0.04**	**0.14**	**0.30**	**0.12**	**0.14**

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	Sample ID	2022049_027 147228 VSW264_O Siltstone	2022049_028 147229 VSW264_O Sandstone	2022049_029 147230 VSW264_O Siltstone	2022049_030 147231 VSW264_O Sandstone	2022049_031 147232 VSW264_O Sandstone
				Sampling date / time	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00
					EB2218704-027	EB2218704-028	EB2218704-029	EB2218704-030	EB2218704-031
					Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit		**6.5**	**6.8**	**7.2**	**9.0**	**9.1**
EA009: Net Acid Production Potential									
Net Acid Production Potential	----	0.5	kg H2SO4/t		**3.9**	**7.5**	**37.4**	**-69.3**	**-69.2**
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm		**320**	**330**	**416**	**249**	**223**
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		**1.9**	**4.1**	**7.3**	**79.7**	**81.7**
ANC as CaCO3	----	0.1	% CaCO3		**0.2**	**0.4**	**0.7**	**8.1**	**8.3**
Fizz Rating	----	0	Fizz Unit		**0**	**0**	**0**	**2**	**2**
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		**0.19**	**0.38**	**1.46**	**0.34**	**0.41**

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	Sample ID	2022049_032 147233 VSW264_O Siltstone	2022049_033 147234 VSW264_O Siltstone	2022049_034 147235 VSW264_O Siltstone	2022049_035 147236 VSW264_O Siltstone	2022049_037 147237 VSW264_O Siltstone
				Sampling date / time	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00
					EB2218704-032	EB2218704-033	EB2218704-034	EB2218704-035	EB2218704-037
					Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit		**9.1**	**9.2**	**9.2**	**8.9**	**9.2**
EA009: Net Acid Production Potential									
Net Acid Production Potential	----	0.5	kg H2SO4/t		**-14.6**	**-14.8**	**-13.9**	**45.8**	**-1.9**
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm		**210**	**178**	**178**	**206**	**142**
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		**29.3**	**17.3**	**18.8**	**19.4**	**10.5**
ANC as CaCO3	----	0.1	% CaCO3		**3.0**	**1.8**	**1.9**	**2.0**	**1.1**
Fizz Rating	----	0	Fizz Unit		**1**	**1**	**1**	**1**	**1**
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		**0.48**	**0.08**	**0.16**	**2.13**	**0.28**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2022049_038 147238 VSW264_O Siltstone	2022049_039 147239 VSW264_O Sandstone	2022049_040 147240 VSW264_O Sandstone	----	----
			Sampling date / time	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	----	----
Compound	CAS Number	LOR	Unit	EB2218704-038	EB2218704-039	EB2218704-040	--------	--------
				Result	Result	Result	----	----
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	**9.1**	**8.9**	**8.5**	**----**	**----**
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	**-7.2**	**2.9**	**18.0**	**----**	**----**
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	**161**	**192**	**263**	**----**	**----**
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	**13.6**	**7.2**	**6.5**	**----**	**----**
ANC as CaCO3	----	0.1	% CaCO3	**1.4**	**0.7**	**0.7**	**----**	**----**
Fizz Rating	----	0	Fizz Unit	**1**	**0**	**1**	**----**	**----**
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	**0.21**	**0.33**	**0.80**	**----**	**----**

Analytical Results

Sub-Matrix: **WATER** (Matrix: **SOIL**)				Sample ID	**DI water for PH and EC**	**----**	**----**	**----**	**----**
				Sampling date / time	22-Jun-2022 00:00	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*		**EB2218704-041**	**--------**	**--------**	**--------**	**--------**
					Result	----	----	----	----
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit		**5.4**	**----**	**----**	**----**	**----**
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm		<1	**----**	**----**	**----**	**----**

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB2220042**	Page	: 1 of 9
Client	: **RGS ENVIRONMENTAL CONSULTANTS PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: PETER LONG	Contact	: Customer Services EB
Address	: 3/30 LENSWORTH STREET COOPERS PLAINS 4108	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: 07 3344 1222	Telephone	: +61-7-3243 7222
Project	: 2022049 Vulcan Coal Mine Matilda Pit	Date Samples Received	: 08-Jul-2022 13:55
Order number	: ----	Date Analysis Commenced	: 18-Jul-2022
C-O-C number	: ----	Issue Date	: 19-Jul-2022 11:18
Sampler	: PRIYA RAJENDRAN		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 31		
No. of samples analysed	: 31		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ben Felgendrejeris	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contract for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2022049_004 147204 VSW263_O Siltstone	2022049_005 147205 VSW263_O Siltstone	2022049_007 147207 VSW263_O Sandstone	2022049_008 147208 VSW263_O Siltstone	2022049_009 147209 VSW263_O Siltstone
			Sampling date / time	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00
Compound	CAS Number	LOR	Unit	EB2220042-001	EB2220042-002	EB2220042-003	EB2220042-004	EB2220042-005
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	**0.106**	**0.223**	**0.129**	**0.657**	**0.454**

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

				Sample ID	2022049_010 147210 VSW263_O Sandstone	2022049_011 147211 VSW263_O Sandstone	2022049_012 147212 VSW263_O Siltstone	2022049_013 147213 VSW263_O Siltstone	2022049_014 147214 VSW263_O Siltstone
				Sampling date / time	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00
Compound	CAS Number	LOR	Unit		EB2220042-006	EB2220042-007	EB2220042-008	EB2220042-009	EB2220042-010
					Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur									
Chromium Reducible Sulphur	----	0.005	%		**0.182**	**0.170**	**0.670**	**0.101**	**0.140**

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	Sample ID	2022049_015 147215 VSW263_O Siltstone	2022049_016 147220 VSW263_O Coal	2022049_017 147216 VSW263_O Siltstone	2022049_020 147219 VSW263_O Sandstone	2022049_023 147224 VSW264_O Siltstone
				Sampling date / time	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00
				EB2220042-011	EB2220042-012	EB2220042-013	EB2220042-014	EB2220042-015	
				Result	Result	Result	Result	Result	
EA026 : Chromium Reducible Sulfur									
Chromium Reducible Sulphur	----	0.005	%	**0.767**	**0.732**	**0.140**	**0.106**	**0.139**	

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2022049_024 147225 VSW264_O Siltstone	2022049_025 147226 VSW264_O Sandstone	2022049_026 147227 VSW264_O Sandstone	2022049_027 147228 VSW264_O Siltstone	2022049_028 147229 VSW264_O Sandstone
			Sampling date / time	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00
Compound	CAS Number	LOR	Unit	EB2220042-016	EB2220042-017	EB2220042-018	EB2220042-019	EB2220042-020
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	**0.282**	**0.120**	**0.120**	**0.158**	**0.326**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2022049_029 147230 VSW264_O Siltstone	2022049_030 147231 VSW264_O Sandstone	2022049_031 147232 VSW264_O Sandstone	2022049_032 147233 VSW264_O Siltstone	2022049_034 147235 VSW264_O Siltstone
			Sampling date / time	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00
Compound	CAS Number	LOR	Unit	EB2220042-021	EB2220042-022	EB2220042-023	EB2220042-024	EB2220042-025
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	**1.10**	**0.328**	**0.386**	**0.472**	**0.143**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2022049_035 147236 VSW264_O Siltstone	2022049_036 147250 VSW264_O Coal	2022049_037 147237 VSW264_O Siltstone	2022049_038 147238 VSW264_O Siltstone	2022049_039 147239 VSW264_O Sandstone
			Sampling date / time	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00
Compound	CAS Number	LOR	Unit	EB2220042-026	EB2220042-027	EB2220042-028	EB2220042-029	EB2220042-030
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	**1.79**	**0.605**	**0.236**	**0.196**	**0.324**

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			Sample ID	**2022049_040 147240 VSW264_O Sandstone**	**----**	**----**	**----**	**----**
			Sampling date / time	22-Jun-2022 00:00	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EB2220042-031**	**--------**	**--------**	**--------**	**--------**
				Result	----	----	----	----
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	**0.697**	**----**	**----**	**----**	**----**

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB2222926**	Page	: 1 of 5
Client	: **RGS ENVIRONMENTAL CONSULTANTS PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: PETER LONG	Contact	: Customer Services EB
Address	: 3/30 LENSWORTH STREET COOPERS PLAINS 4108	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: 07 3344 1222	Telephone	: +61-7-3243 7222
Project	: 2022049 Vulcan Coal Mine Matilda Pit	Date Samples Received	: 04-Aug-2022 14:57
Order number	: ----	Date Analysis Commenced	: 08-Aug-2022
C-O-C number	: ----	Issue Date	: 15-Aug-2022 11:34
Sampler	: ----		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 15		
No. of samples analysed	: 15		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ben Felgendrejeris	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contract for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- ASS: EA013 (ANC) Fizz Rating: 0- None; 1- Slight; 2- Moderate; 3- Strong; 4- Very Strong; 5- Lime.

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	Sample ID	2022049_41 179695-180303 Coarse Reject VSW205_C Coarse Reject	2022049_42 179695-180303 Fine Reject VSW205_C Fine Reject	2022049_43 180306-180311 Coarse Reject VSW206_C Coarse Reject	2022049_44 180306-180311 Fine Reject VSW206_C Fine Reject	2022049_45 164433-164440 Coarse Reject VSW225_C Coarse Reject
				Sampling date / time	03-Aug-2022 00:00	03-Aug-2022 00:00	03-Aug-2022 00:00	03-Aug-2022 00:00	03-Aug-2022 00:00
					EB2222926-001	EB2222926-002	EB2222926-003	EB2222926-004	EB2222926-005
					Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit		**3.3**	**5.5**	**3.7**	**6.5**	**5.3**
EA009: Net Acid Production Potential									
Net Acid Production Potential	----	0.5	kg H2SO4/t		**151**	**14.6**	**91.8**	**32.3**	**24.6**
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm		**2360**	**484**	**1620**	**387**	**619**
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		**6.7**	**18.1**	<0.5	**13.0**	**22.8**
ANC as CaCO3	----	0.1	% CaCO3		**0.7**	**1.8**	<0.1	**1.3**	**2.3**
Fizz Rating	----	0	Fizz Unit		**1**	**1**	**0**	**1**	**1**
EA026 : Chromium Reducible Sulfur									
Chromium Reducible Sulphur	----	0.005	%		**4.88**	**0.841**	**2.87**	**1.26**	**1.36**
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		**5.16**	**1.07**	**3.00**	**1.48**	**1.55**

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	Sample ID	2022049_46 164433-164440 Fine Reject VSW225_C Fine Reject	2022049_47 164355-164360 Coarse Reject VSW226_C Coarse Reject	2022049_48 164355-164360 Fine Reject VSW226_C Fine Reject	2022049_49 164387-164391 Coarse Reject VSW227_C3 Coarse Reject	2022049_50 164387-164391 Fine Reject VSW227_C3 Fine Reject
				Sampling date / time	03-Aug-2022 00:00	03-Aug-2022 00:00	03-Aug-2022 00:00	03-Aug-2022 00:00	03-Aug-2022 00:00
					EB2222926-006	EB2222926-007	EB2222926-008	EB2222926-009	EB2222926-010
					Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit		**6.8**	**3.1**	**5.9**	**3.6**	**4.3**
EA009: Net Acid Production Potential									
Net Acid Production Potential	----	0.5	kg H2SO4/t		**8.4**	**95.2**	**19.0**	**97.2**	**84.0**
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm		**297**	**2300**	**427**	**1730**	**1170**
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		**25.3**	<0.5	**12.8**	**11.1**	**12.4**
ANC as CaCO3	----	0.1	% CaCO3		**2.6**	<0.1	**1.3**	**1.1**	**1.3**
Fizz Rating	----	0	Fizz Unit		**1**	**0**	**1**	**1**	**1**
EA026 : Chromium Reducible Sulfur									
Chromium Reducible Sulphur	----	0.005	%		**1.00**	**2.82**	**0.796**	**3.20**	**3.14**
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		**1.10**	**3.11**	**1.04**	**3.54**	**3.15**

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	Sample ID	2022049_51 164380-164384 Coarse Reject VSW228_C Coarse Reject	2022049_52 164380-164384 Fine Reject VSW228_C Fine Reject	2022049_53 145103-145108 Coarse Reject VSW229_C Coarse Reject	2022049_54 145103-145108 Fine Reject VSW229_C Fine Reject	pH and EC of DI water
				Sampling date / time	03-Aug-2022 00:00	03-Aug-2022 00:00	03-Aug-2022 00:00	03-Aug-2022 00:00	03-Aug-2022 00:00
					EB2222926-011	EB2222926-012	EB2222926-013	EB2222926-014	EB2222926-015
					Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit		**3.6**	**5.8**	**3.6**	**4.9**	**5.7**
EA009: Net Acid Production Potential									
Net Acid Production Potential	----	0.5	kg H2SO4/t		**78.7**	**28.8**	**92.5**	**89.5**	**----**
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm		**2270**	**616**	**1400**	**755**	<1
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		**15.2**	**19.2**	**15.8**	**13.9**	**----**
ANC as CaCO3	----	0.1	% CaCO3		**1.6**	**2.0**	**1.6**	**1.4**	**----**
Fizz Rating	----	0	Fizz Unit		**1**	**1**	**1**	**1**	**----**
EA026 : Chromium Reducible Sulfur									
Chromium Reducible Sulphur	----	0.005	%		**2.62**	**1.23**	**3.52**	**3.25**	**----**
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		**3.07**	**1.57**	**3.54**	**3.38**	**----**

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB2222546**	Page	: 1 of 8
Client	: **RGS ENVIRONMENTAL CONSULTANTS PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: PETER LONG	Contact	: Customer Services EB
Address	: 3/30 LENSWORTH STREET COOPERS PLAINS 4108	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: 07 3344 1222	Telephone	: +61-7-3243 7222
Project	: 2022049 Vulcan Coal Mine Matilda Pit	Date Samples Received	: 02-Aug-2022 12:57
Order number	: ----	Date Analysis Commenced	: 04-Aug-2022
C-O-C number	: ----	Issue Date	: 11-Aug-2022 15:45
Sampler	: ASITHA JAJASINGHE		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 9		
No. of samples analysed	: 9		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Kim McCabe	Senior Inorganic Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Layla Hafner	Acid Sulphate Soils - Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contract for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- ED037 (Alkalinity): NATA accreditation does not cover the performance of this service.
- ED038 (Acidity): NATA accreditation does not cover the performance of this service.
- ALS is not NATA accredited for the analysis of Exchangeable Aluminium and Exchange Acidity in soils when performed under ALS Method ED005.
- ALS is not NATA accredited for the analysis of Exchangeable Cations on Alkaline Soils when performed under ALS Method ED006.
- EG005T-Total Metals by ICP-AES: Sample EB2222681-002 shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- ED007 and ED008: When Exchangeable Al is reported from these methods, it should be noted that Rayment & Lyons (2011) suggests Exchange Acidity by 1M KCl - Method 15G1 (ED005) is a more suitable method for the determination of exchange acidity (H+ + Al3+).

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Sample ID	2022049_C001	2022049_C002	2022049_C003	2022049_C004	2022049_C005
			Sampling date / time	01-Aug-2022 00:00	01-Aug-2022 00:00	01-Aug-2022 00:00	01-Aug-2022 00:00	01-Aug-2022 00:00
Compound	CAS Number	LOR	Unit	EB2222546-001	EB2222546-002	EB2222546-003	EB2222546-004	EB2222546-005
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.8	8.7	8.7	5.8	9.1
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	164	215	310	60	175
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	----	<1.0	<1.0	<1.0	----
ED005: Exchange Acidity								
ø Exchange Acidity	----	0.1	meq/100g	----	----	----	1.3	----
ø Exchangeable Aluminium	----	0.1	meq/100g	----	----	----	0.7	----
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	----	1.1	1.7	----	----
ø Exchangeable Magnesium	----	0.2	meq/100g	----	0.8	1.8	----	----
ø Exchangeable Potassium	----	0.2	meq/100g	----	0.2	0.4	----	----
ø Exchangeable Sodium	----	0.2	meq/100g	----	<0.2	0.5	----	----
ø Cation Exchange Capacity	----	0.2	meq/100g	----	2.1	4.3	----	----
ø Exchangeable Sodium Percent	----	0.2	%	----	<0.2	11.0	----	----
ø Calcium/Magnesium Ratio	----	0.2	-	----	1.4	1.0	----	----
ø Magnesium/Potassium Ratio	----	0.2	-	----	3.5	4.3	----	----
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	----	----	----	0.5	----
Exchangeable Magnesium	----	0.1	meq/100g	----	----	----	1.0	----
Exchangeable Potassium	----	0.1	meq/100g	----	----	----	0.2	----
Exchangeable Sodium	----	0.1	meq/100g	----	----	----	0.2	----
Cation Exchange Capacity	----	0.1	meq/100g	----	----	----	2.1	----
Exchangeable Sodium Percent	----	0.1	%	----	----	----	9.3	----
Calcium/Magnesium Ratio	----	0.1	-	----	----	----	0.5	----
Magnesium/Potassium Ratio	----	0.1	-	----	----	----	4.1	----
ED037: Alkalinity								
ø Total Alkalinity as CaCO3	----	1	mg/kg	29700	4950	17600	540	3600
ø Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	28800	4950	17600	540	2700
ø Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	900	<5	<5	<5	900
ED038A: Acidity								
Acidity	----	1	mg/kg	<5	24	<5	776	<5
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	200	290	360	90	200

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Sample ID	2022049_C001	2022049_C002	2022049_C003	2022049_C004	2022049_C005
			Sampling date / time	01-Aug-2022 00:00	01-Aug-2022 00:00	01-Aug-2022 00:00	01-Aug-2022 00:00	01-Aug-2022 00:00
Compound	CAS Number	LOR	Unit	EB2222546-001	EB2222546-002	EB2222546-003	EB2222546-004	EB2222546-005
				Result	Result	Result	Result	Result
ED040S : Soluble Sulfate by ICPAES - Continued								
Silica	7631-86-9	1	mg/kg	15	22	24	69	26
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	20	60	40	10	30
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	40	50	60	<10	20
Magnesium	7439-95-4	10	mg/kg	20	20	40	<10	<10
Sodium	7440-23-5	10	mg/kg	120	120	170	30	130
Potassium	7440-09-7	10	mg/kg	40	100	120	60	80
ED093T: Total Major Cations								
Sodium	7440-23-5	50	mg/kg	230	180	250	60	200
Potassium	7440-09-7	50	mg/kg	1170	1220	1490	1170	1350
Calcium	7440-70-2	50	mg/kg	45000	2210	13700	190	2230
Magnesium	7439-95-4	50	mg/kg	1780	1110	2840	440	1480
EG005(ED093)S : Soluble Metals by ICPAES								
Boron	7440-42-8	1	mg/kg	<1	<1	<1	<1	<1
Iron	7439-89-6	1	mg/kg	<1	<1	<1	<1	<1
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	1550	1410	1930	1830	1310
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Iron	7439-89-6	50	mg/kg	28500	15500	21800	9980	13100
EG020S: Soluble Metals by ICPMS								
Arsenic	7440-38-2	0.01	mg/kg	<0.01	0.01	0.01	<0.01	0.09
Selenium	7782-49-2	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Barium	7440-39-3	0.01	mg/kg	0.18	0.14	0.06	<0.01	0.02
Beryllium	7440-41-7	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium	7440-43-9	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Cobalt	7440-48-4	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Chromium	7440-47-3	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Thorium	7440-29-1	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Copper	7440-50-8	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Manganese	7439-96-5	0.01	mg/kg	<0.01	0.02	0.04	0.02	<0.01
Molybdenum	7439-98-7	0.01	mg/kg	0.05	0.09	0.11	<0.01	0.28
Nickel	7440-02-0	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Lead	7439-92-1	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)				Sample ID	2022049_C001	2022049_C002	2022049_C003	2022049_C004	2022049_C005
				Sampling date / time	01-Aug-2022 00:00	01-Aug-2022 00:00	01-Aug-2022 00:00	01-Aug-2022 00:00	01-Aug-2022 00:00
Compound	CAS Number	LOR	Unit		EB2222546-001	EB2222546-002	EB2222546-003	EB2222546-004	EB2222546-005
					Result	Result	Result	Result	Result
EG020S: Soluble Metals by ICPMS - Continued									
Antimony	7440-36-0	0.01	mg/kg		<0.01	**0.03**	**0.02**	<0.01	**0.04**
Uranium	7440-61-1	0.01	mg/kg		<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	7440-66-6	0.05	mg/kg		<0.05	<0.05	<0.05	<0.05	<0.05
Vanadium	7440-62-2	0.1	mg/kg		<0.1	<0.1	<0.1	<0.1	<0.1
Aluminium	7429-90-5	0.1	mg/kg		<0.1	**0.1**	**0.1**	**0.4**	**0.2**
EG020T: Total Metals by ICP-MS									
Arsenic	7440-38-2	0.1	mg/kg		**9.0**	**3.9**	**5.4**	**4.6**	**6.1**
Selenium	7782-49-2	1	mg/kg		**1**	<1	<1	<1	<1
Barium	7440-39-3	0.1	mg/kg		**119**	**52.4**	**61.8**	**30.2**	**23.5**
Beryllium	7440-41-7	0.1	mg/kg		**0.7**	**0.4**	**0.6**	**0.3**	**0.5**
Cadmium	7440-43-9	0.1	mg/kg		**0.1**	<0.1	<0.1	<0.1	<0.1
Cobalt	7440-48-4	0.1	mg/kg		**6.6**	**4.5**	**7.0**	**3.5**	**8.0**
Chromium	7440-47-3	0.1	mg/kg		**0.7**	**2.0**	**3.1**	**2.6**	**1.9**
Copper	7440-50-8	0.1	mg/kg		**29.6**	**6.4**	**8.2**	**5.1**	**20.0**
Thorium	7440-29-1	0.1	mg/kg		**2.3**	**1.4**	**2.1**	**1.2**	**2.2**
Manganese	7439-96-5	0.1	mg/kg		**525**	**177**	**334**	**98.2**	**143**
Molybdenum	7439-98-7	0.1	mg/kg		**1.1**	**0.5**	**0.6**	**0.5**	**0.8**
Nickel	7440-02-0	0.1	mg/kg		**4.3**	**7.8**	**10.6**	**5.3**	**13.8**
Lead	7439-92-1	0.1	mg/kg		**11.1**	**16.2**	**14.3**	**10.8**	**20.6**
Antimony	7440-36-0	0.1	mg/kg		**0.3**	**0.2**	**0.2**	**0.2**	**0.2**
Uranium	7440-61-1	0.1	mg/kg		**0.5**	**0.3**	**0.4**	**0.2**	**0.4**
Zinc	7440-66-6	0.5	mg/kg		**64.2**	**33.9**	**46.5**	**28.4**	**66.1**
Vanadium	7440-62-2	1	mg/kg		**8**	**3**	**10**	**3**	**3**
EG035S: Soluble Mercury by FIMS									
Mercury	7439-97-6	0.0005	mg/kg		<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
EG035T: Total Recoverable Mercury by FIMS									
Mercury	7439-97-6	0.1	mg/kg		**0.1**	<0.1	<0.1	<0.1	<0.1
EK040S: Fluoride Soluble									
Fluoride	16984-48-8	1	mg/kg		**6**	**1**	**3**	<1	**3**
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.1	mg/kg		<0.1	<0.1	<0.1	<0.1	<0.1

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Sample ID	2022049_C006	2022049_C007	2022049_C008	2022049_C009	----
			Sampling date / time	01-Aug-2022 00:00	01-Aug-2022 00:00	01-Aug-2022 00:00	01-Aug-2022 00:00	----
Compound	CAS Number	LOR	Unit	EB2222546-006	EB2222546-007	EB2222546-008	EB2222546-009	--------
				Result	Result	Result	Result	----
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	9.1	8.4	8.9	7.3	----
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	195	363	230	135	----
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	<1.0	----	----	<1.0	----
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	1.8	----	----	----	----
ø Exchangeable Magnesium	----	0.2	meq/100g	1.4	----	----	----	----
ø Exchangeable Potassium	----	0.2	meq/100g	0.4	----	----	----	----
ø Exchangeable Sodium	----	0.2	meq/100g	0.5	----	----	----	----
ø Cation Exchange Capacity	----	0.2	meq/100g	4.1	----	----	----	----
ø Exchangeable Sodium Percent	----	0.2	%	11.7	----	----	----	----
ø Calcium/Magnesium Ratio	----	0.2	-	1.3	----	----	----	----
ø Magnesium/Potassium Ratio	----	0.2	-	3.4	----	----	----	----
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	----	----	----	1.0	----
Exchangeable Magnesium	----	0.1	meq/100g	----	----	----	3.7	----
Exchangeable Potassium	----	0.1	meq/100g	----	----	----	0.6	----
Exchangeable Sodium	----	0.1	meq/100g	----	----	----	0.6	----
Cation Exchange Capacity	----	0.1	meq/100g	----	----	----	6.0	----
Exchangeable Sodium Percent	----	0.1	%	----	----	----	10.0	----
Calcium/Magnesium Ratio	----	0.1	-	----	----	----	0.3	----
Magnesium/Potassium Ratio	----	0.1	-	----	----	----	6.6	----
ED037: Alkalinity								
ø Total Alkalinity as CaCO3	----	1	mg/kg	5040	3690	30700	1530	----
ø Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	5040	3690	30600	1530	----
ø Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	<5	<5	90	<5	----
ED038A: Acidity								
Acidity	----	1	mg/kg	<5	41	<5	368	----
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	160	580	260	220	----
Silica	7631-86-9	1	mg/kg	27	25	23	41	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	30	40	40	10	----

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Sample ID	2022049_C006	2022049_C007	2022049_C008	2022049_C009	----
			Sampling date / time	01-Aug-2022 00:00	01-Aug-2022 00:00	01-Aug-2022 00:00	01-Aug-2022 00:00	----
Compound	CAS Number	LOR	Unit	EB2222546-006	EB2222546-007	EB2222546-008	EB2222546-009	--------
				Result	Result	Result	Result	----
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	**10**	**80**	**40**	<10	----
Magnesium	7439-95-4	10	mg/kg	<10	**40**	**20**	<10	----
Sodium	7440-23-5	10	mg/kg	**170**	**180**	**180**	**90**	----
Potassium	7440-09-7	10	mg/kg	**70**	**150**	**60**	**80**	----
ED093T: Total Major Cations								
Sodium	7440-23-5	50	mg/kg	**320**	**270**	**310**	**160**	----
Potassium	7440-09-7	50	mg/kg	**1530**	**1770**	**1360**	**1600**	----
Calcium	7440-70-2	50	mg/kg	**4620**	**3860**	**34400**	**610**	----
Magnesium	7439-95-4	50	mg/kg	**3040**	**3040**	**4900**	**1580**	----
EG005(ED093)S : Soluble Metals by ICPAES								
Boron	7440-42-8	1	mg/kg	<1	<1	<1	<1	----
Iron	7439-89-6	1	mg/kg	<1	<1	<1	<1	----
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**1760**	**2060**	**1710**	**1620**	----
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	----
Iron	7439-89-6	50	mg/kg	**30600**	**33700**	**38900**	**25900**	----
EG020S: Soluble Metals by ICPMS								
Arsenic	7440-38-2	0.01	mg/kg	**0.07**	<0.01	**0.02**	<0.01	----
Selenium	7782-49-2	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	----
Barium	7440-39-3	0.01	mg/kg	<0.01	**0.03**	**0.32**	**0.02**	----
Beryllium	7440-41-7	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	----
Cadmium	7440-43-9	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	----
Cobalt	7440-48-4	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	----
Chromium	7440-47-3	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	----
Thorium	7440-29-1	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	----
Copper	7440-50-8	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	----
Manganese	7439-96-5	0.01	mg/kg	<0.01	**0.07**	**0.01**	**0.22**	----
Molybdenum	7439-98-7	0.01	mg/kg	**0.29**	**0.11**	**0.19**	**0.01**	----
Nickel	7440-02-0	0.01	mg/kg	<0.01	<0.01	<0.01	**0.01**	----
Lead	7439-92-1	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	----
Antimony	7440-36-0	0.01	mg/kg	**0.05**	**0.02**	**0.02**	<0.01	----
Uranium	7440-61-1	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	----
Zinc	7440-66-6	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	----
Vanadium	7440-62-2	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	----

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Sample ID	2022049_C006	2022049_C007	2022049_C008	2022049_C009	----
			Sampling date / time	01-Aug-2022 00:00	01-Aug-2022 00:00	01-Aug-2022 00:00	01-Aug-2022 00:00	----
Compound	CAS Number	LOR	Unit	EB2222546-006	EB2222546-007	EB2222546-008	EB2222546-009	--------
				Result	Result	Result	Result	----
EG020S: Soluble Metals by ICPMS - Continued								
Aluminium	7429-90-5	0.1	mg/kg	**0.2**	<0.1	**0.1**	<0.1	----
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.1	mg/kg	**6.0**	**8.1**	**10.5**	**7.1**	----
Selenium	7782-49-2	1	mg/kg	<1	<1	<1	<1	----
Barium	7440-39-3	0.1	mg/kg	**25.8**	**28.6**	**178**	**48.2**	----
Beryllium	7440-41-7	0.1	mg/kg	**0.6**	**0.6**	**0.7**	**0.9**	----
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	**0.1**	----
Cobalt	7440-48-4	0.1	mg/kg	**7.8**	**8.2**	**5.5**	**9.6**	----
Chromium	7440-47-3	0.1	mg/kg	**2.8**	**3.3**	**2.8**	**3.0**	----
Copper	7440-50-8	0.1	mg/kg	**16.8**	**13.8**	**19.4**	**17.3**	----
Thorium	7440-29-1	0.1	mg/kg	**2.0**	**1.9**	**3.9**	**2.2**	----
Manganese	7439-96-5	0.1	mg/kg	**369**	**402**	**625**	**329**	----
Molybdenum	7439-98-7	0.1	mg/kg	**0.6**	**0.6**	**1.7**	**0.7**	----
Nickel	7440-02-0	0.1	mg/kg	**11.8**	**16.1**	**7.5**	**15.5**	----
Lead	7439-92-1	0.1	mg/kg	**17.8**	**19.6**	**13.6**	**20.5**	----
Antimony	7440-36-0	0.1	mg/kg	**0.2**	**0.2**	**0.2**	**0.3**	----
Uranium	7440-61-1	0.1	mg/kg	**0.4**	**0.3**	**0.5**	**0.4**	----
Zinc	7440-66-6	0.5	mg/kg	**60.2**	**59.5**	**44.9**	**82.4**	----
Vanadium	7440-62-2	1	mg/kg	**10**	**9**	**12**	**7**	----
EG035S: Soluble Mercury by FIMS								
Mercury	7439-97-6	0.0005	mg/kg	<0.0005	<0.0005	<0.0005	<0.0005	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	**0.2**	**0.1**	<0.1	----
EK040S: Fluoride Soluble								
Fluoride	16984-48-8	1	mg/kg	**2**	**2**	**5**	**3**	----
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	14265-44-2	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	----

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB2224164**	Page	: 1 of 5
Client	: **RGS ENVIRONMENTAL CONSULTANTS PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: PETER LONG	Contact	: Customer Services EB
Address	: 3/30 LENSWORTH STREET COOPERS PLAINS 4108	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: 07 3344 1222	Telephone	: +61-7-3243 7222
Project	: 2022049 Vulcan Coal Mine Matilda Pit	Date Samples Received	: 17-Aug-2022 16:00
Order number	: ----	Date Analysis Commenced	: 19-Aug-2022
C-O-C number	: ----	Issue Date	: 25-Aug-2022 10:10
Sampler	: ASITHA JAJASINGHE		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 4		
No. of samples analysed	: 4		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Layla Hafner	Acid Sulphate Soils - Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Layla Hafner	Acid Sulphate Soils - Chemist	Brisbane Inorganics, Stafford, QLD

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contract for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EG020-S (Soluble Metals by ICP-MS): Sample 2022049_C10 (EB2224164-001) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- ED037 (Alkalinity): NATA accreditation does not cover the performance of this service.
- ED038 (Acidity): NATA accreditation does not cover the performance of this service.
- EG005T (Total Metals by ICP-AES): EB2224045-009 shows poor duplicate results due to sample heterogeneity. This has been confirmed by visual inspection.
- EG005T (Total Metals by ICP-AES): 2022049_C13 (EB2224164-004) shows poor matrix spike recovery due to sample heterogeneity. This has been confirmed by visual inspection.
- EG005S (Soluble Metals by ICP-AES): 2022049_C10 (EB2224164-001) shows poor duplicate results due to sample heterogeneity. This has been confirmed by visual inspection.

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2022049_C10 Coarse Rejects	2022049_C11 Coarse Rejects	2022049_C12 Fine Rejects	2022049_C13 Fine Rejects	----
			Sampling date / time	17-Aug-2022 00:00	17-Aug-2022 00:00	17-Aug-2022 00:00	17-Aug-2022 00:00	----
Compound	CAS Number	LOR	Unit	EB2224164-001	EB2224164-002	EB2224164-003	EB2224164-004	--------
				Result	Result	Result	Result	----
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	4.0	3.4	5.3	5.1	----
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	1390	1790	533	652	----
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	2.1	1.2	2.6	2.4	----
ED037: Alkalinity								
ø Total Alkalinity as CaCO3	----	1	mg/kg	90	<5	61	104	----
ø Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	90	<5	61	104	----
ø Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	<5	<5	<5	<5	----
ED038A: Acidity								
Acidity	----	1	mg/kg	2080	3710	289	372	----
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	3920	4730	1080	1550	----
Silica	7631-86-9	1	mg/kg	21	34	35	30	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	20	20	110	100	----
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	440	580	190	260	----
Magnesium	7439-95-4	10	mg/kg	300	300	100	150	----
Sodium	7440-23-5	10	mg/kg	190	190	150	160	----
Potassium	7440-09-7	10	mg/kg	80	100	50	50	----
ED093T: Total Major Cations								
Sodium	7440-23-5	50	mg/kg	330	350	300	410	----
Potassium	7440-09-7	50	mg/kg	1080	1180	1310	1220	----
Calcium	7440-70-2	50	mg/kg	3890	6020	3990	3410	----
Magnesium	7439-95-4	50	mg/kg	1920	1910	1710	1480	----
EG005(ED093)S : Soluble Metals by ICPAES								
Boron	7440-42-8	1	mg/kg	<1	<1	<1	<1	----
Iron	7439-89-6	1	mg/kg	968	1280	17	63	----
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	1450	2180	1970	2120	----
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	----
Iron	7439-89-6	50	mg/kg	49400	38900	45300	34200	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Sample ID	2022049_C10 Coarse Rejects	2022049_C11 Coarse Rejects	2022049_C12 Fine Rejects	2022049_C13 Fine Rejects	----
				Sampling date / time	17-Aug-2022 00:00	17-Aug-2022 00:00	17-Aug-2022 00:00	17-Aug-2022 00:00	----
Compound	CAS Number	LOR	Unit		EB2224164-001	EB2224164-002	EB2224164-003	EB2224164-004	--------
					Result	Result	Result	Result	----
EG020S: Soluble Metals by ICPMS									
Arsenic	7440-38-2	0.01	mg/kg		**0.08**	**0.13**	<0.01	<0.01	----
Selenium	7782-49-2	0.1	mg/kg		<0.1	<0.1	<0.1	<0.1	----
Barium	7440-39-3	0.01	mg/kg		**0.26**	**0.24**	**0.24**	**0.24**	----
Beryllium	7440-41-7	0.01	mg/kg		**0.10**	**0.12**	<0.01	<0.01	----
Cadmium	7440-43-9	0.01	mg/kg		<0.01	**0.01**	<0.01	<0.01	----
Cobalt	7440-48-4	0.01	mg/kg		**1.30**	**1.22**	**0.29**	**0.18**	----
Chromium	7440-47-3	0.01	mg/kg		<0.01	<0.01	<0.01	<0.01	----
Thorium	7440-29-1	0.01	mg/kg		<0.01	<0.01	<0.01	<0.01	----
Copper	7440-50-8	0.01	mg/kg		**1.33**	**2.22**	**0.13**	**0.20**	----
Manganese	7439-96-5	0.01	mg/kg		**17.7**	**5.98**	**1.43**	**1.89**	----
Molybdenum	7439-98-7	0.01	mg/kg		**0.02**	<0.01	<0.01	<0.01	----
Nickel	7440-02-0	0.01	mg/kg		**1.11**	**1.14**	**0.24**	**0.15**	----
Lead	7439-92-1	0.01	mg/kg		**0.02**	**0.08**	<0.01	<0.01	----
Antimony	7440-36-0	0.01	mg/kg		<0.01	**0.02**	<0.01	<0.01	----
Uranium	7440-61-1	0.01	mg/kg		<0.01	**0.02**	<0.01	<0.01	----
Zinc	7440-66-6	0.05	mg/kg		**2.56**	**2.18**	**2.61**	**3.33**	----
Vanadium	7440-62-2	0.1	mg/kg		<0.1	<0.1	<0.1	<0.1	----
Aluminium	7429-90-5	0.1	mg/kg		**7.5**	**13.6**	**0.2**	**0.4**	----
EG020T: Total Metals by ICP-MS									
Arsenic	7440-38-2	0.1	mg/kg		**26.8**	**18.4**	**21.1**	**15.1**	----
Selenium	7782-49-2	1	mg/kg		**2**	**2**	**2**	**2**	----
Barium	7440-39-3	0.1	mg/kg		**38.4**	**39.7**	**63.1**	**61.5**	----
Beryllium	7440-41-7	0.1	mg/kg		**1.8**	**0.9**	**1.1**	**0.9**	----
Cadmium	7440-43-9	0.1	mg/kg		**0.1**	**0.1**	**0.2**	**0.2**	----
Cobalt	7440-48-4	0.1	mg/kg		**10.4**	**4.7**	**12.7**	**5.6**	----
Chromium	7440-47-3	0.1	mg/kg		**0.5**	**0.2**	**1.3**	**0.7**	----
Copper	7440-50-8	0.1	mg/kg		**76.8**	**62.2**	**38.3**	**50.7**	----
Thorium	7440-29-1	0.1	mg/kg		**1.9**	**2.1**	**1.9**	**1.7**	----
Manganese	7439-96-5	0.1	mg/kg		**745**	**365**	**382**	**295**	----
Molybdenum	7439-98-7	0.1	mg/kg		**1.0**	**1.1**	**1.4**	**0.9**	----
Nickel	7440-02-0	0.1	mg/kg		**7.8**	**3.1**	**11.6**	**4.9**	----
Lead	7439-92-1	0.1	mg/kg		**12.1**	**10.9**	**13.7**	**17.3**	----
Antimony	7440-36-0	0.1	mg/kg		**0.6**	**0.7**	**0.4**	**0.5**	----
Uranium	7440-61-1	0.1	mg/kg		**0.4**	**0.7**	**0.4**	**0.4**	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Sample ID	2022049_C10 Coarse Rejects	2022049_C11 Coarse Rejects	2022049_C12 Fine Rejects	2022049_C13 Fine Rejects	----
				Sampling date / time	17-Aug-2022 00:00	17-Aug-2022 00:00	17-Aug-2022 00:00	17-Aug-2022 00:00	----
Compound	CAS Number	LOR	Unit		EB2224164-001	EB2224164-002	EB2224164-003	EB2224164-004	--------
					Result	Result	Result	Result	----
EG020T: Total Metals by ICP-MS - Continued									
Zinc	7440-66-6	0.5	mg/kg		**64.3**	**59.0**	**138**	**121**	**----**
Vanadium	7440-62-2	1	mg/kg		**5**	**4**	**4**	**4**	**----**
EG035S: Soluble Mercury by FIMS									
Mercury	7439-97-6	0.0005	mg/kg		<0.0005	<0.0005	<0.0005	<0.0005	**----**
EG035T: Total Recoverable Mercury by FIMS									
Mercury	7439-97-6	0.1	mg/kg		**1.1**	**0.8**	**0.9**	**0.9**	**----**
EK040S: Fluoride Soluble									
Fluoride	16984-48-8	1	mg/kg		**3**	**3**	<1	<1	**----**
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.1	mg/kg		<0.1	<0.1	<0.1	<0.1	**----**



MINE WASTE AND
WATER MANAGEMENT

Appendix J- Geochemical Assessment- June 2020

TECHNICAL REPORT

VI010_VCM Matilda Pit Geochemistry Assessment_ September 2022

Vulcan Coal Mine

Prepared for: Mining & Energy Technical Services on behalf of Vitrinite Pty Ltd

MINE WASTE AND WATER MANAGEMENT

© RGS Environmental Consultants Pty Ltd. .....3/30 Lensworth Street, Coopers Plains QLD 4108…….....www.rgsenv.com

TECHNICAL REPORT

VI010_VCM Matilda Pit Geochemistry Assessment_ September 2022

Vulcan Coal Mine

Prepared for: **Mining & Energy Technical Services on behalf of Vitrinite Pty Ltd**

DOCUMENT CONTROL	
Document Number	**01**
Project Number	**2022049**
File Location	**Z:\004_Projects\Projects 2022\2022049 (Vulcan Matilda Pit Geochem)\Reporting\01_2022049_Vulcan Matilda Pit Geochemistry Assessment_Rev 01_30092022.docx**

DOCUMENT DISTRIBUTION			
Document Name	**Revision**	**Distributed to**	**Date distributed**
01_2022049__VI010_VCM Matilda Pit Geochemistry Assessment_ September 2022_Rev 01_30092022	**Rev 01**	**Mining & Energy Technical Services on behalf of Vitrinite Pty Ltd**	**30.09.2022**

Limitations and disclaimer:

This report documents the work undertaken by RGS Environmental Consultants Pty Ltd (RGS).

This report should be read in full. While the findings presented in this report are based on information that RGS considers reliable unless stated otherwise, the accuracy and completeness of source information cannot be guaranteed, although RGS has taken reasonable steps to verify the accuracy of such source data. RGS has made no independent verification of this information beyond the agreed scope of works and RGS assumes no responsibility for any inaccuracies or omissions outside of RGS's direct control. Furthermore, the information compiled in this report addresses the specific needs of the Client, so may not address the needs of third parties using this report for their own purposes. Thus, RGS and their employees accept no liability for any losses or damage for any action taken or not taken on the basis of any part of the contents of this report. Those acting on information provided in this report do so entirely at their own risk.

This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

Table of Contents

1 Introduction 7
1.1 Background 7
1.2 Geology and stratigraphy 7
1.3 Objective 8
1.4 Scope of works 8
2 Methodology 11
2.1 Sample selection and preparation 11
2.1.1 Waste rock (overburden, interburden, roof, and floor material) 11
2.1.2 Coal rejects 13
2.1.3 Raw coal 13
2.1.4 Sample preparation 13
2.2 Geochemical test program 15
3 Geochemical characterisation results 16
3.1 Acid Base Account 16
3.1.1 Waste rock 16
3.1.2 Coal rejects 21
3.1.3 Raw coal 25
3.2 Multi-element concentration in solids 29
3.2.1 Geochemical abundance index 29
3.3 Soil characteristics and sodicity 30
3.3.1 Soil characteristics 30
3.3.2 Sodicity 31
3.4 Water quality static tests 31
4 Discussion 33
4.1 AMD potential and management 33
4.2 Multi-element composition and water quality 33
4.1.1 Multi-element composition and enrichment 33
4.1.2 Water quality 34
4.2 Revegetation and rehabilitation 34
4.3 Management measures 34
5 Conclusions and recommendations 35
5.1 Conclusions 35
5.2 Recommendations 35
6 References 36
7 Attachments A-1
Attachment A: Geochemical Assessment of Mining Materials A-1
Attachment B: Static Geochemical Test Results B-1
Attachment C: ALS Laboratory Results C-1

List of Figures

Figure 1-1: Project location 9
Figure 1-2: Indicative stratigraphic column for the Project area 10
Figure 2-1: Drillholes sampled for waste rock and coal geochemistry 12
Figure 2-2: Drillholes sampled for coal reject geochemistry 14
Figure 3-1: pH values for waste rock samples from Vulcan Coal Mine Matilda Pit 16
Figure 3-2: EC values for waste rock samples from Vulcan Coal Mine Matilda Pit 16
Figure 3-3: Total sulfur values for waste rock samples from Vulcan Coal Mine Matilda Pit 17
Figure 3-4: Total sulfur, sulfide sulfur, and sulfide proportion values for waste rock samples from Vulcan Coal Mine Matilda Pit 18
Figure 3-5: Total sulfur vs sulfide sulfur values for waste rock samples from Vulcan Coal Mine Matilda Pit . 18
Figure 3-6: NAPP values for waste rock samples from Vulcan Coal Mine Matilda Pit 19
Figure 3-7: MPA vs ANC values for waste rock samples from Vulcan Coal Mine Matilda Pit 19
Figure 3-8: AMD classifications for waste rock samples from Vulcan Coal Mine Matilda Pit 20
Figure 3-9: pH values for coal reject samples from Vulcan Coal Mine Matilda Pit 21
Figure 3-10: EC values for coal reject samples from Vulcan Coal Mine Matilda Pit 21
Figure 3-11: Total sulfur values for coal reject samples from Vulcan Coal Mine Matilda Pit 22
Figure 3-12: Total sulfur and sulfide sulfur values for coal reject samples from Vulcan Coal Mine Matilda Pit 22
Figure 3-13: Total sulfur vs sulfide sulfur values for coal reject samples from Vulcan Coal Mine Matilda Pit 23
Figure 3-14: NAPP values for coal reject samples from Vulcan Coal Mine Matilda Pit 23
Figure 3-15: MPA vs ANC values for coal reject samples from Vulcan Coal Mine Matilda Pit 24
Figure 3-16: AMD classifications for coal reject samples from Vulcan Coal Mine Matilda Pit 25
Figure 3-17: pH values for coal samples from Vulcan Coal Mine Matilda Pit 25
Figure 3-18: EC values for coal samples from Vulcan Coal Mine Matilda Pit 26
Figure 3-19: Total sulfur values for coal samples from Vulcan Coal Mine Matilda Pit 26
Figure 3-20: Total sulfur and sulfide sulfur values for coal samples from Vulcan Coal Mine Matilda Pit 27
Figure 3-21: Total sulfur vs sulfide sulfur values for coal samples from Vulcan Coal Mine Matilda Pit 27
Figure 3-22: NAPP values for coal samples from Vulcan Coal Mine Matilda Pit 28
Figure 3-23: MPA vs ANC values for coal samples from Vulcan Coal Mine Matilda Pit 28

List of Tables

Table 2-1: Waste rock samples by material type 11
Table 3-1: Salinity and pH criteria for assessment of waste rock samples 17
Table 3-1: AMD classification parameters for waste rock samples from Vulcan Coal Mine Matilda Pit 20
Table 3-2: AMD classification parameters for coal reject samples from Vulcan Coal Mine Matilda Pit 24

Table 3-3: AMD classification parameters for coal samples from Vulcan Coal Mine Matilda Pit 29
Table 3-4: Geochemical abundance index values and enrichment factors 29
Table 3-5: Ratings for cation exchange capacity 31
Table 4-1: Material management over mine life 34

Glossary of terms and acronyms

Acidity	A measure of hydrogen ion (H+) concentration and certain dissolved metals in a solution when titrated to a set pH value; generally expressed as mg/L $CaCO_3$ equivalent.
ABA	Acid Base Account. Evaluation of the balance between acid generation and acid neutralisation processes. Determines the maximum potential acidity (MPA) and the inherent acid neutralising capacity (ANC), as defined below.
ALS	Australian Laboratory Services.
AMD	Acid and metalliferous drainage from mine waste materials characterised by low pH, elevated metal concentrations, high sulfate concentrations and high salinity.
ANC	Acid Neutralising Capacity expressed as kg H_2SO_4 per tonne of sample. A measure of a sample's maximum potential ability to neutralise acid.
ANC:MPA	The ratio of the acid neutralising capacity to the maximum potential acidity of a sample. Used to assess the risk of a sample generating acid conditions.
AS	Australian Standards
CEC	Cation exchange capacity provides a measure of the mass of exchangeable cations (Ca, Mg, Na and K) in a sample.
Dispersive	Dispersive soil and rock materials are structurally unstable and disperse into basic particles such as sand, silt and clay in water. When a dispersive soil is wet, the basic structure has a tendency to collapse, whereas when it is dry it is prone to surface sealing and crusting.
EC	Electrical Conductivity, expressed as µS/cm.
ESP	Exchangeable sodium percentage provides a measure of the sodicity of a material and propensity to erode.
FIMS	Flow Injection Mercury System.
GAI	Geochemical Abundance Index
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
ICP-AES	Inductively Coupled Plasma Atomic Emission Spectrometry.
INAP	International Network on Acid Prevention
Interburden	The material found in between ore layers and considered to be of low economic value (i.e., a type of waste material).
MPA	Maximum Potential Acidity. Calculated by multiplying the total sulfur or sulfide-sulfur (CRS) content of a sample by 30.6 (stoichiometric factor) and expressed as kg H_2SO_4 per tonne.
NAF	Non-Acid Forming. Geochemical classification criterion for a sample that will not generate acid conditions.
NAF - Barren	Non-acid forming and barren of sulfur (i.e. less than or equal to 0.1% sulfur).
NAPP	Net Acid Producing Potential, expressed as kg H_2SO_4 per tonne. Calculated by subtracting the ANC from the MPA.
Overburden	The waste rock material found overlying the first ore horizon within the stratigraphic profile.
PAF	Potentially Acid Forming. Geochemical classification criterion for a sample that has the potential to generate acid conditions.

PC Titrator	Potentiometric Compact Titrator. PC Titrators are specially designed for routine applications and simple operation, allowing basic titration analysis from a single device.
pH	A measure of hydrogen ion (H^+) concentration.
Sodic	Sodic soil and rock materials are characterized by a disproportionately high concentration of sodium (Na) in their cation exchange complex and are innately unstable, exhibiting poor physical and chemical properties, which impede water infiltration, water availability, and ultimately plant growth.
Static test	Procedure for characterising the geochemical nature of a sample at a single point in time. Static tests may include measurements of mineral and chemical composition of a sample and the Acid Base Account.
w:v	Weight to volume ratio.

1 Introduction

RGS Environmental Consultants Pty Ltd (RGS) was commissioned by Mining & Energy Technical Services Pty Ltd (METServe) to conduct a geochemical assessment of waste rock (overburden, interburden, roof, and floor), coal rejects (coarse and fine fractions), and coal for the Matilda Pit (the Project) at the Vulcan Coal Mine on behalf of Vitrinite Pty Ltd (Vitrinite). This technical report details the methods, results, and outcomes of the geochemical assessment. Based on the outcomes of the geochemical assessment, this report also contains recommendations for environmental management measures for waste rock, coal, and coal reject materials with respect to stockpiling, emplacement, and rehabilitation.

1.1 Background

The Project is located north of Dysart and approximately 33 km south-east of Moranbah in Queensland's Bowen Basin (**Figure 1-1**). The Project lies to the immediate west of several established mining operations, including BHP's Peak Downs and Saraji mines.

The Project currently has approval under Environmental Authority (EA) EA0002912 to operate for four years and to extract approximately six million tonnes of run of mine (ROM) coal. The project is targeting the Alex and multiple Dysart Lower coal seams through a primary open-cut pit developed using truck and shovel mining. The Project is currently approved to transport ROM coal off-site for toll washing by third parties. An initial out-of-pit waste dump will be established followed by in-pit waste emplacements as the open-cut pit is developed. Ancillary infrastructure, such as a ROM pad, mine infrastructure area, offices, roads, and surface water management infrastructure have been established on site.

Vitrinite is proposing an amendment to the approved EA to establish a Coal Handling and Preparation Plant (CHPP), Train Load-out facility, a dedicated rail loop, and an additional smaller open cut pit at the Project. Minor amendments to existing infrastructure layouts are also proposed, e.g., product stockpiles, updated water management infrastructure, and access roads. The proposed additional open cut pit, referred to as the Matilda Pit, will be located inside the rail loop and be developed concurrently with the main pit of the Project. The development of the Matilda Pit is not expected to have a significant impact on the pre-approved production rate or life of the Project.

The Matilda Pit is intended to have a maximum depth of 40 m and targets the Matilda Coal Seam which underlies the Alex and multiple Dysart Lower coal seams mined in the pit to the east. Waste materials excavated from the Matilda Pit will be placed in the previously approved waste rock dump final landforms. With the establishment of the CHPP at the Project coal will be processed through three circuits to produce a primary and secondary product (metallurgical and thermal). Coarse, fine and dry tailings will be trucked for placement within active waste rock dumps (primarily within the in-pit dump). Product coal will be conveyed and stacked on the product coal stockpiles.

In a previous geochemical assessment of waste rock and tailings for the main pit at the Project RGS found that waste rock and coal reject materials generally had low sulfide content and excess acid neutralising capacity (ANC) and so bulk materials posed a low risk of generating acidic or metalliferous drainage (AMD) (RGS, 2020). Total sulfur concentration results for coal quality samples taken from the Matilda Coal Seam indicate higher total sulfur concentrations relative to similar materials likely to be generated from the main pit.

1.2 Geology and stratigraphy

The Project will target the Alex and multiple Dysart Lower coal seams within the Permian-aged Moranbah Coal Measures. A surficial Tertiary waste rock (overburden) sequence is present in the Project area, consisting of unconsolidated soils and sands. Underlying this is Permian-aged waste rock (overburden), which is comprised of sandstone and siltstone.

The Permian waste rock (interburden) materials in the Project area generally comprise sandstone, siltstone, claystone, and coal that were deposited in a fluvial flood plain environment within the Bowen Basin. Significant mesa hills formed by highly resistant sandstones have provided target coal seams throughout the centre of the Project area. The typical stratigraphic profile encountered at the Project is provided in **Figure 1-2**.

The Alex seam is generally quite shallow and occurs just below the base of weathering in the stratigraphic profile. The Dysart Lower Seam comprises several plys with the waste rock (interburden/parting) in between

generally consisting of fine-grained sedimentary units such as siltstone, mudstone, and claystone, with the occasional carbonaceous or coaly unit.

The May Seam (consisting of carbonaceous claystone and considered uneconomic) and Matilda Seam (consisting of interbedded coal and siltstone and the target seam of the proposed Matilda Pit) underlie the Dysart seam.

1.3 Objective

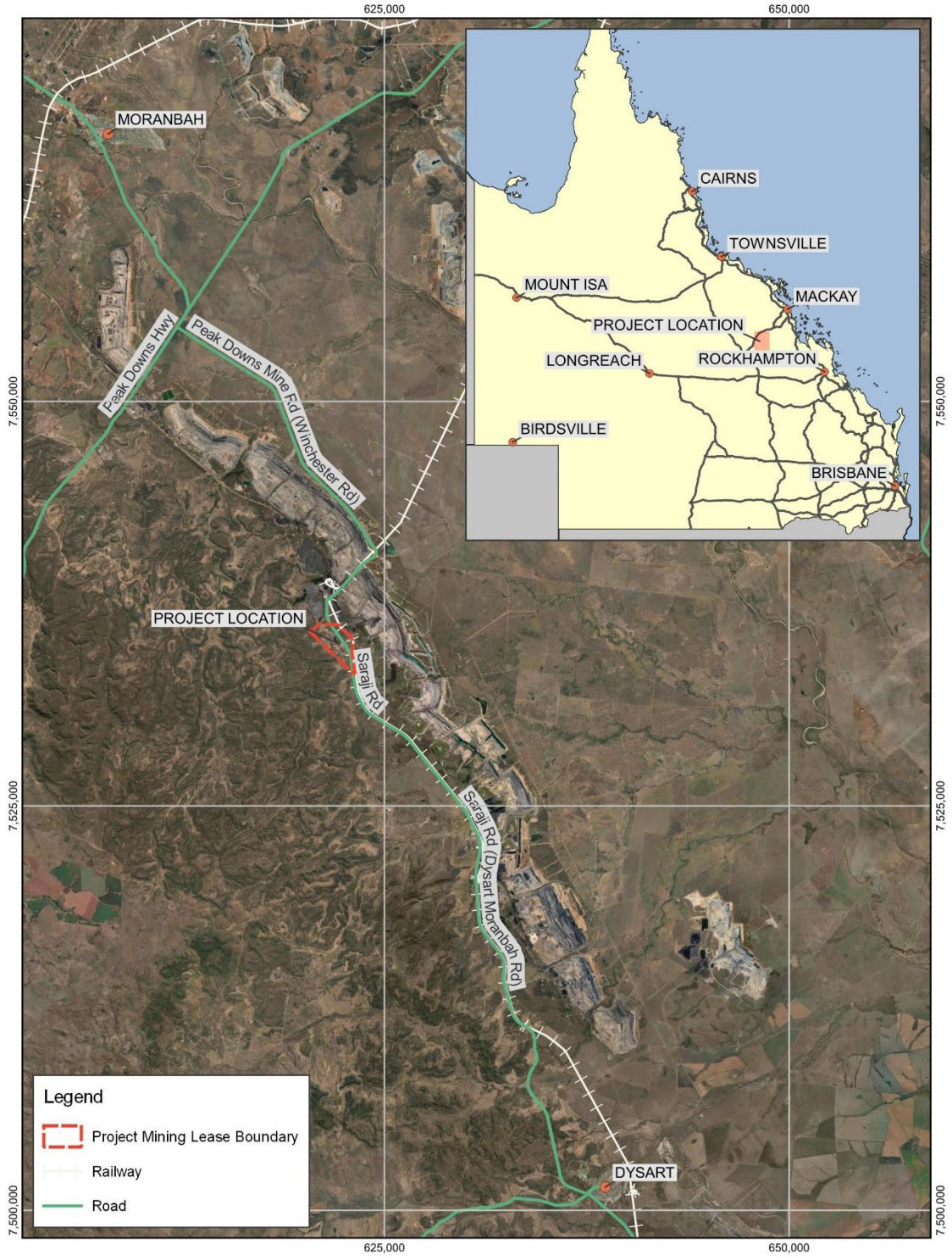
The relatively elevated total sulfur concentrations in the Matilda Coal Seam coal quality samples suggests that the findings of the previous geochemical assessment undertaken on coal and coal reject materials in the pit to the east may not be applicable to the coal and coal reject materials that will be generated from the Matilda Pit. It is on this basis that RGS was requested to undertake a geochemical assessment of waste rock, coal, and coal reject likely to be generated from the proposed Matilda Pit.

The objective of the assessment was therefore to complete a static geochemical assessment of representative samples of waste rock (overburden, interburden, roof, and floor) coal, and coal rejects (coarse and fine fractions) for the proposed Matilda Pit.

1.4 Scope of works

To achieve the above objective, RGS undertook the following scope of work:

- Design of a static geochemical assessment program, including sampling for, and testing of, representative overburden, interburden, roof, floor, coal reject, and coal materials within the Matilda Pit boundary;
- Develop environmental management measures related to waste rock, coal, and coal reject materials with respect to stockpiling and/or emplacement and rehabilitation; and
- Prepare this Geochemical Assessment Report to support the application for an amendment to the EA for the Vulcan Coal Mine.



Source: Vitrinite Pty Ltd; ESRI Satellite

RGS	Scale 1:329,983 Datum: GDA94 / MGA zone 55	Matilda Pit Material Geochemical Assessment	5 0 5 10 km
	2022049 Vulcan Matilda Pit Spatial Data.qgz; Project Location	**Project location**	Figure: 1-1 Job Number: 2022049 07/07/2022 N

Figure 1-1: Project location

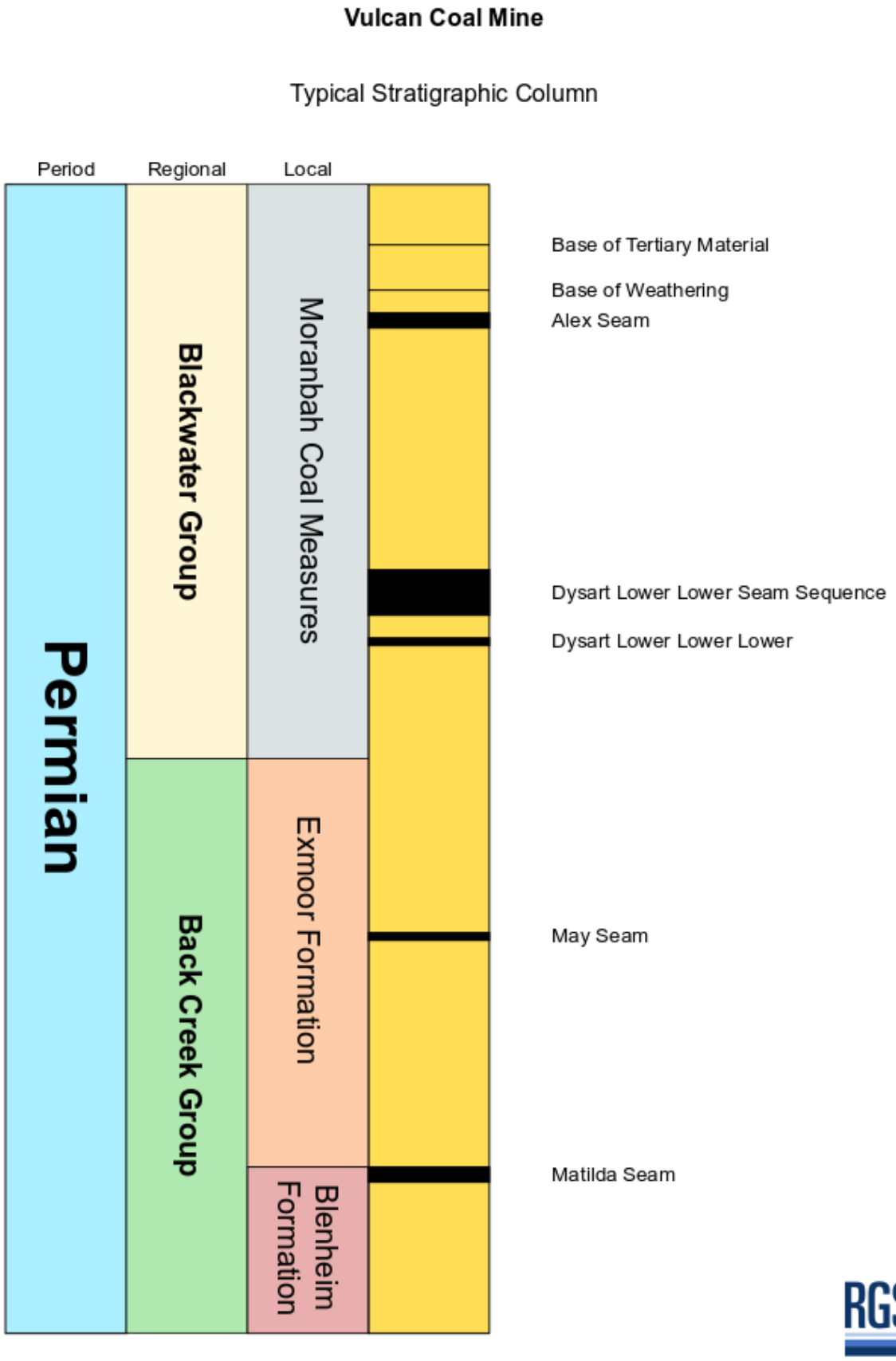


Figure 1-2: Indicative stratigraphic column for the Project area

2 Methodology

RGS personnel worked closely with Vitrinite and METServe personnel to develop an appropriate sampling and geochemical testing plan, which was used to obtain representative samples of waste rock (overburden, interburden, roof, and floor), coal and coal rejects (coarse and fine) associated with the Matilda Pit.

2.1 Sample selection and preparation

The sampling methodology used to obtain representative samples of waste rock, coal, and coal reject materials for the Project was undertaken in accordance with relevant technical guideline documents. While there are no specific regulatory guidelines regarding the number of samples required, existing risk-based technical guidelines for the geochemical assessment of mining waste materials in Australia (AMIRA, 2002; COA, 2016; DEHP, 2013; DME, 1995) and worldwide (INAP, 2022) were used by RGS as a framework for the sampling program.

2.1.1 Waste rock (overburden, interburden, roof, and floor material)

Representative samples of waste rock (overburden, interburden, roof, and floor) materials were identified and collected as drill chips from the 2022 exploration drilling program. A total of 38 waste rock samples were collected from two drill holes at the Project. The locations of the sampled drill holes are shown in **Figure 2-1**.

The samples represented the waste rock (overburden, interburden, roof, and floor materials) expected to be encountered during development activities, from the surface to a depth of approximately 40 m. This covers the entire stratigraphic profile that is currently under consideration for mining at the Project. **Table 2-1** provides the number of samples of each type of material collected and used in the geochemical assessment. Further information on the identity of the 38 individual waste rock samples is provided in **Table B1** (**Attachment B**). The number of samples was selected to provide a good statistical representation of the amount and type of mined material expected to be encountered at the Project, considering the risk profile indicated from the geology and geochemical information from the Project and other nearby coal projects.

Table 2-1: Waste rock samples by material type

Material	Number of Samples Collected
Fresh Sandstone Interburden	3
Fresh Sandstone Overburden	8
Slightly Weathered Sandstone Overburden	5
Fresh Siltstone Floor	2
Fresh Slightly Carbonaceous Siltstone Overburden/Interburden	7
Fresh Siltstone Overburden	6
Fresh Siltstone Roof	2
Slightly Weathered Siltstone Overburden	5
Total:	**38**

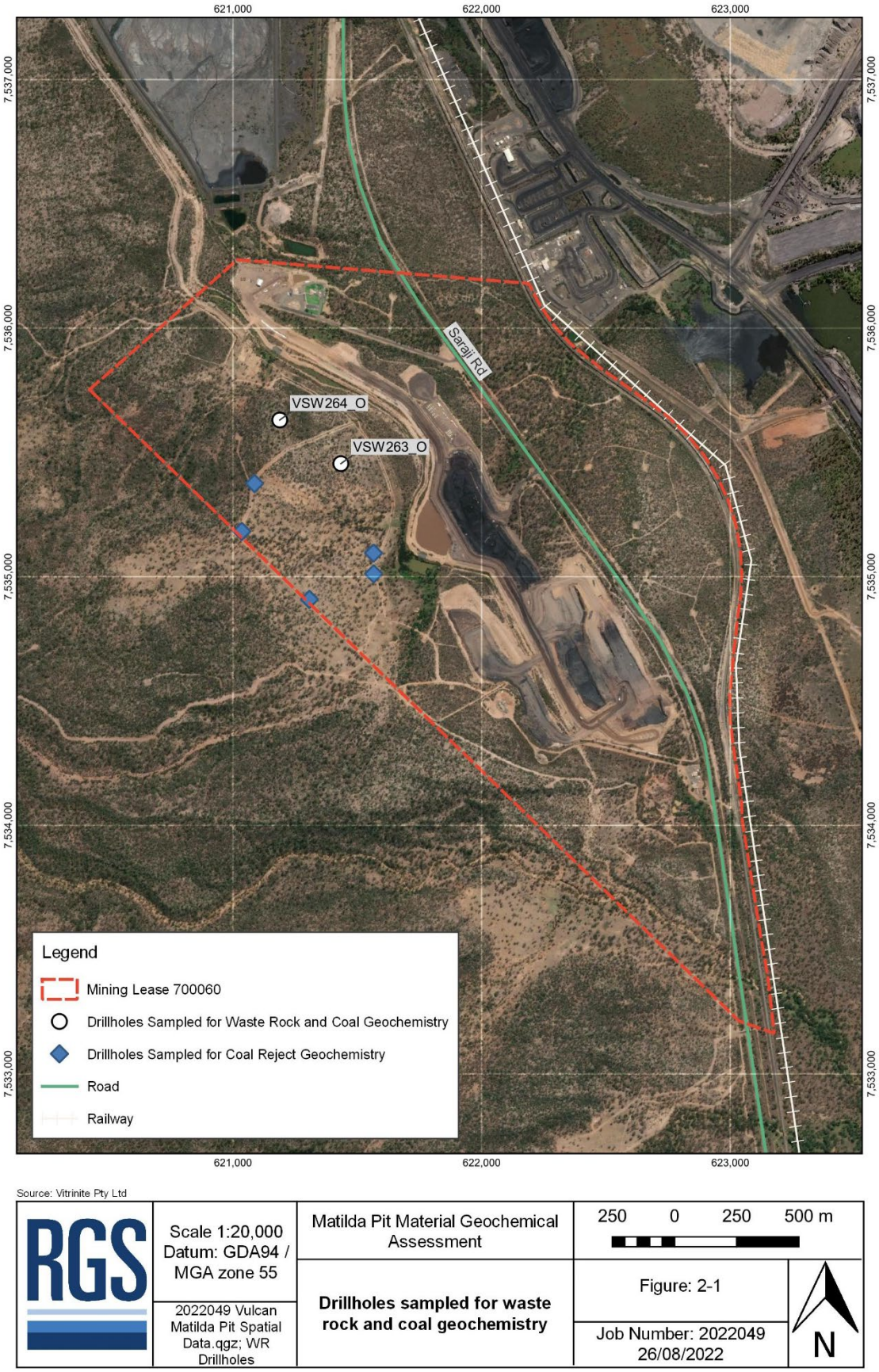


Figure 2-1: Drillholes sampled for waste rock and coal geochemistry

2.1.2 Coal rejects

A total of 14 samples were used for the coal rejects analysis. Two size fractions (coarse: 50 to 2 mm diameter, and fine: less than 0.25 mm diameter) of coal reject materials were selected to best represent the two coal reject streams that are likely to be produced from coal washing on site. Coal core from a total of seven holes was collected by Vitrinite personnel and delivered to the ALS coal quality laboratory in Richlands, Queensland. The locations of the drillholes sampled for coal rejects are shown in **Figure 2-2**. This core was composited into samples of coarse (seven samples) and fine (seven samples) rejects and sent to ALS Environmental Laboratory (ALS) in Stafford, Queensland for geochemical testing.

2.1.3 Raw coal

Two samples of raw coal from the Matilda Seam were collected from the two drillholes (one sample per hole) sampled for waste rock materials (**Figure 2-1**).

2.1.4 Sample preparation

Once received, the waste rock, coal reject, and coal samples were prepared by crushing to less than 20 mm and pulverising to less than 75 µm size, where necessary. This method of sample preparation results in a homogenous sample, but also generates a large sample surface area in contact with the assay solution. This provides a greater potential for dissolution and reaction and represents an assumed initial 'worst case' scenario for these materials.

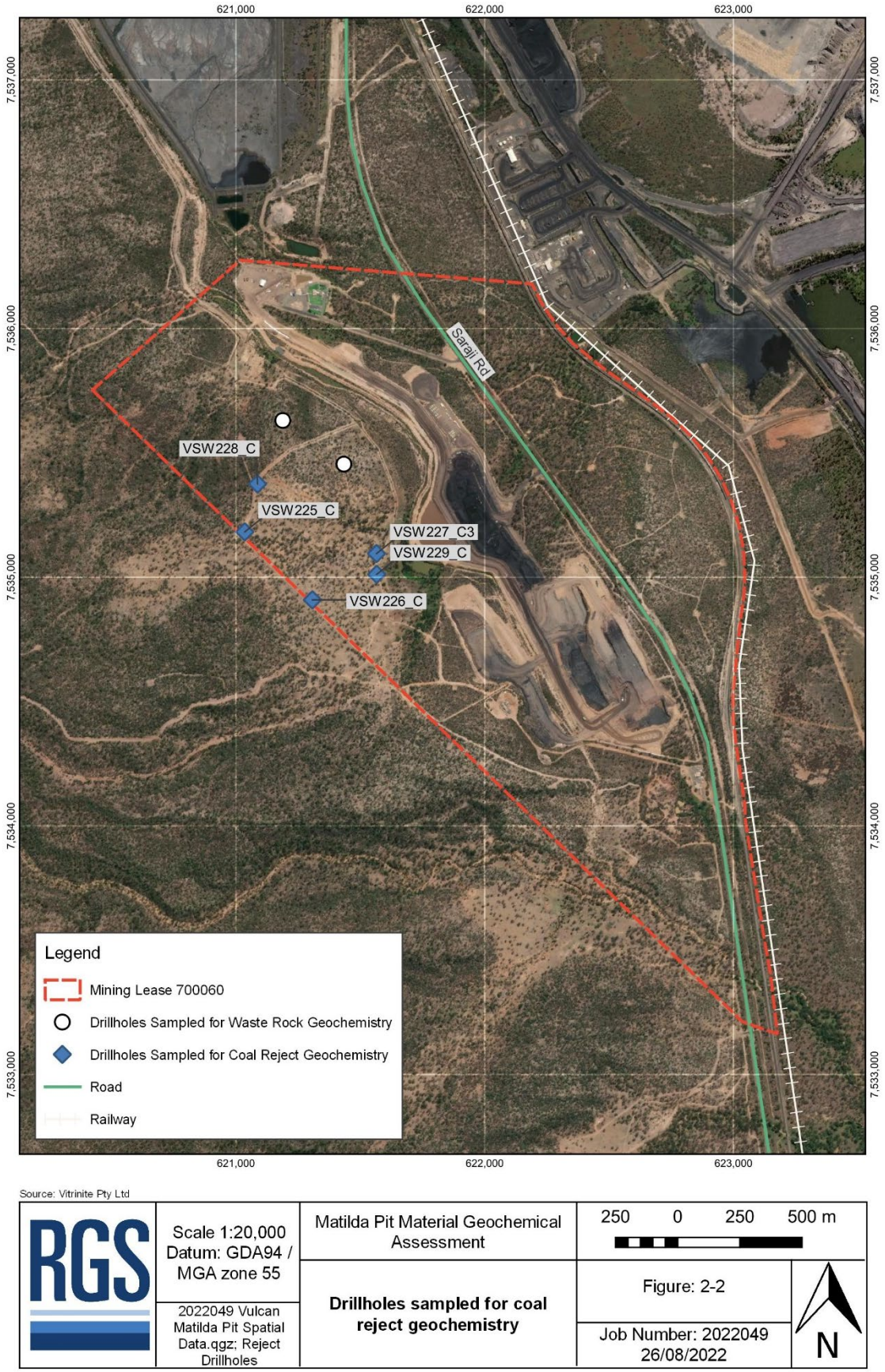


Figure 2-2: Drillholes sampled for coal reject geochemistry

2.2 Geochemical test program

A series of static geochemical and physical tests were completed on the 54 waste rock, coal reject, and coal samples described in **Section 2.1**. The test program was designed to assess the degree of risk from the presence and potential oxidation of sulfides, as well as the generation and the presence/leaching of soluble metals/metalloids, and salts. The assessment also included characterisation of standard soil parameters including salinity, sodicity, cation exchange capacity, exchangeable sodium percentage and major metal/ metalloid concentrations. A detailed summary of the parameters involved in completing a static geochemical characterisation and assessment of mining waste materials is provided in **Attachment A**.

Static geochemical tests provide a 'snapshot' of the characteristics of a sample material at a single point in time. These tests were staged to screen individual samples before selecting either individual and/or composite samples for more detailed static test work.

The Acid Base Account method was used as a screening procedure whereby the acid-neutralising and acid-generating characteristics of the samples were assessed. All 54 samples were screened using the Acid Base Account method, which involved static geochemical testing for the following parameters:

- pH [1:5 w:v. sample:deionised water];
- Electrical conductivity (EC) [1:5 w:v. sample:deionised water];
- Total sulfur [LECO analyser]; and
- Acid Neutralising Capacity (ANC) [AMIRA, 2002 method].

The results of the Acid Base Account screening tests are discussed in **Section 3.1**. After the results of the screening tests were received and interpreted selected samples with a total sulfur content greater than the median crustal abundance for sulfur (0.1 %S) (i.e., 29 waste rock, 14 coal reject, and two coal samples) were also tested for sulfide sulfur, using the chromium reducible sulfur (Scr), Australian Standard (AS 4969.7, 2008) method.

From the total sulfur value (or Scr value, where available), maximum potential acidity (MPA) values were calculated by multiplying using the standard stoichiometric factor of 30.625 for pyrite/marcasite oxidation. Scr data was preferentially used where available, to provide a more accurate representation of the potential MPA, as acid generation primarily forms from the oxidation of reactive sulfide measured by this method.

After the results of the initial static geochemical tests were received and reviewed composite samples were created including eight waste rock, four coal reject (two coarse and two fine), and one coal sample. All 13 composite samples were sent for whole rock multi-element testing at ALS Stafford laboratory. The composite samples were tested for:

- pH and EC [1:5 w:v. sample:deionised water];
- Total major cations (Ca, Mg, K, Na) [HCl and HNO3 acid digest followed by ICP-AES/MS];
- Acidity and alkalinity as $CaCO_3$ mg/L [PC Titrator (1:5 w:v water extracts)];
- Total metals/metalloids (Al, As, B, Ba, Be, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Sb, Se, Th, U, V, and Zn) [HCl and HNO_3 acid digest followed by FIMS and/or ICP-AES/MS]; and
- Soluble major cations (Ca, Mg, K, Na) [ICP-AES/MS (1:5 w:v water extracts)];
- Soluble major anions (Cl, SO_4, F, P, Si) [ICP-AES/MS and PC Titrator (1:5 w:v water extracts)];
- Soluble metals (Al, As, B, Ba, Be, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Sb, Se, Th, U, V, and Zn) [ICPAES/MS (1:5 w:v water extracts)].

Five of the composite waste rock samples representing waste rock were also tested for exchangeable cations (Ca, Mg, Na and K) [ICP-AES], and results were used to calculate the cation exchange capacity (CEC) and exchangeable sodium percentage (ESP). Summary geochemical results tables for the static geochemical test program are provided in **Attachment B**. The ALS laboratory certificates of analysis are provided in **Attachment C**.

3 Geochemical characterisation results

3.1 Acid Base Account

3.1.1 Waste rock

pH: pH results for the waste rock (overburden, interburden, roof, and floor) samples are shown in **Figure 3-1**. The pH results range from 5.5 to 9.4, with a median of pH 8.6. Fresh sandstone overburden, fresh siltstone overburden, and slightly weathered siltstone overburden generally increased in pH with increasing depth. It should be noted that the pH of the deionised water used in the pH tests was 5.4 and therefore most waste rock samples add some alkalinity to initial contact water.

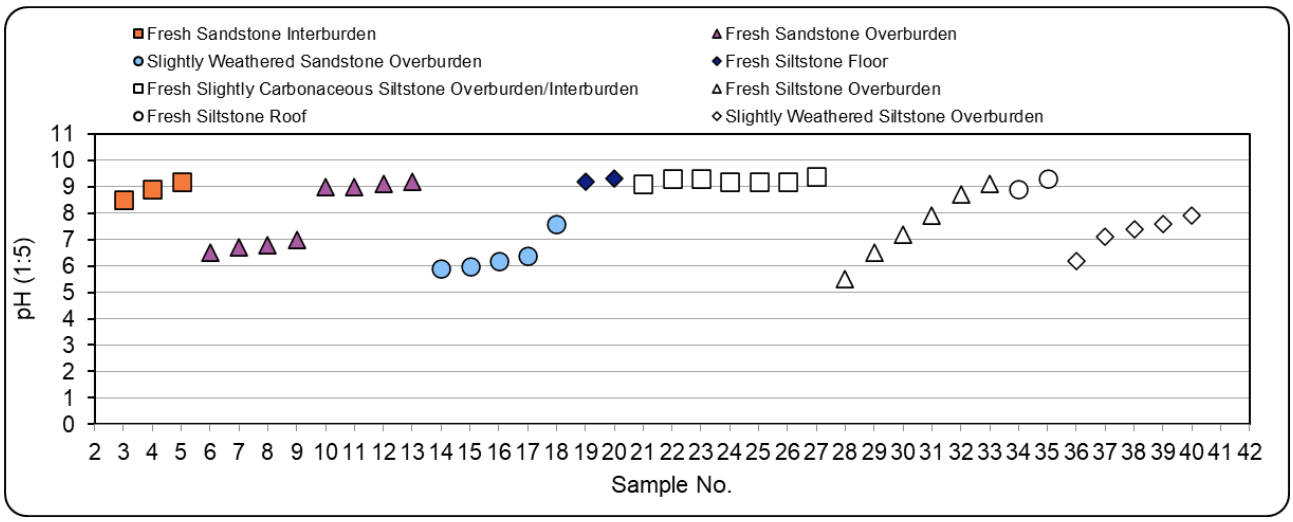


Figure 3-1: pH values for waste rock samples from Vulcan Coal Mine Matilda Pit

EC: EC results for the waste rock samples are shown in **Figure 3-2**. EC results range from 28 to 441 µS/cm, with a median of 184 µS/cm. It should be noted that the EC of the deionised water used in the EC tests was <1 µS/cm and therefore most waste rock samples add some salts to initial contact water.

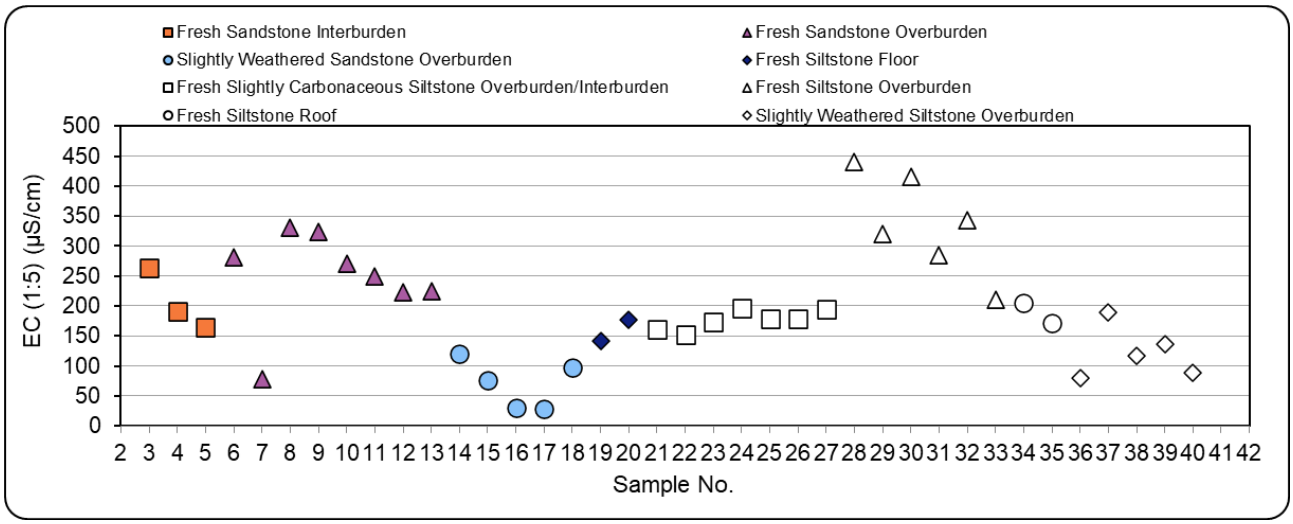


Figure 3-2: EC values for waste rock samples from Vulcan Coal Mine Matilda Pit

To provide additional context, the $EC_{(1:5)}$ and $pH_{(1:5)}$ results for waste rock samples are classified against pH and salinity criteria for mine waste materials, as defined by the Queensland DME (1995) technical guidelines for the environmental management of exploration and mining in Queensland (**Table 3-1**).

Based on the median pH and EC values, the waste rock samples tested are generally regarded as having a 'Medium' to 'High' soil pH and 'Low' salinity characteristics, as indicated by the distribution of samples corresponding to each pH and salinity class.

Table 3-1: Salinity and pH criteria for assessment of waste rock samples

Parameter	Very Low	Low	Medium	High	Very High
$pH_{1:5}$	< 4.5	4.5 – 5.5	5.5 – 7.0	7.0 – 9.0 (Median – 8.6)	> 9.0
$EC_{1:5}$ (µS/cm)	< 150	150 – 450 (Median – 184)	450 – 900	900 – 2,000	> 2,000

Note: Adapted from DME, 1995. Highlighted cells show the category corresponding to the median pH and EC values (orange shading) for the waste rock samples.

The pH and EC tests were completed on pulverised samples (≤ 75 µm) with a large surface area in contact with the leaching solution, thereby providing greater potential for dissolution and reaction, and represent an assumed 'worst case' scenario. It is also expected that the salinity of leachate from low sulfur waste rock materials will diminish with time as salts are flushed from the rock matrix and a state of equilibrium develops. At that point, the salinity of seepage/runoff should stabilise at a lower asymptotic concentration relative to the weathering/erosion of the materials.

Total Sulfur: Total sulfur results for the waste rock samples are shown in **Figure 3-3**. The total sulfur values range from 0.01 to 2.13 % sulfur (%S), with a low median value of 0.18 %S. Some of the fresh siltstone overburden and fresh siltstone roof samples have an elevated total sulfur value relative to other lithologies and weathering extents. In particular overburden samples within the weathering profile (<15 m below ground level) generally have relatively low sulfur content.

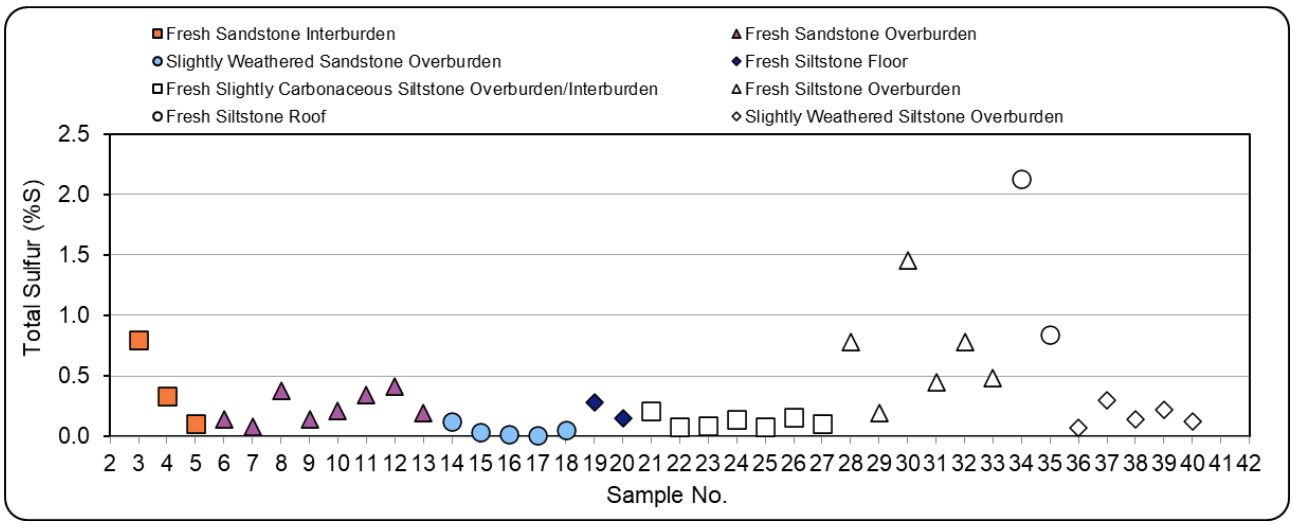


Figure 3-3: Total sulfur values for waste rock samples from Vulcan Coal Mine Matilda Pit

Sulfide Sulfur: Sulfide sulfur concentrations relative to total sulfur concentrations are shown in **Figure 3-4**. Samples with total sulfur concentrations less than 0.1 %S (the median crustal abundance of sulfur (0.07%) rounded to one decimal place (Bowen, 1979; INAP, 2022)) were not analysed for sulfide sulfur and show 0 % sulfide proportions in the figure. Sulfide sulfur results for samples with total sulfur results greater than 0.1 %S range from 0.101 % to 1.790 % sulfide sulfur, with a median value of 0.223% sulfide sulfur.

Figure 3-5 shows the correlation between total sulfur and sulfide sulfur results for waste rock samples with greater than 0.1% total sulfur. There is a strong correlation between total sulfur and sulfide sulfur (R^2 = 0.9946) and linear regression modelling suggests the approximately 85 % of the total sulfur in waste rock samples with total sulfur greater than 0.1 %S is likely to be present as sulfide sulfur.

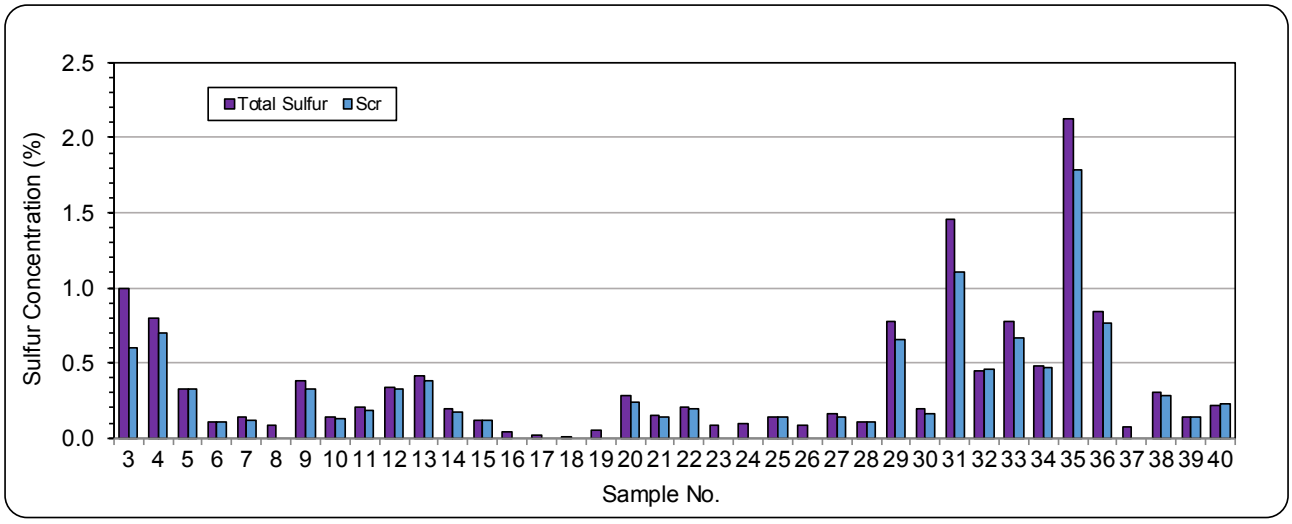


Figure 3-4: Total sulfur, sulfide sulfur, and sulfide proportion values for waste rock samples from Vulcan Coal Mine Matilda Pit

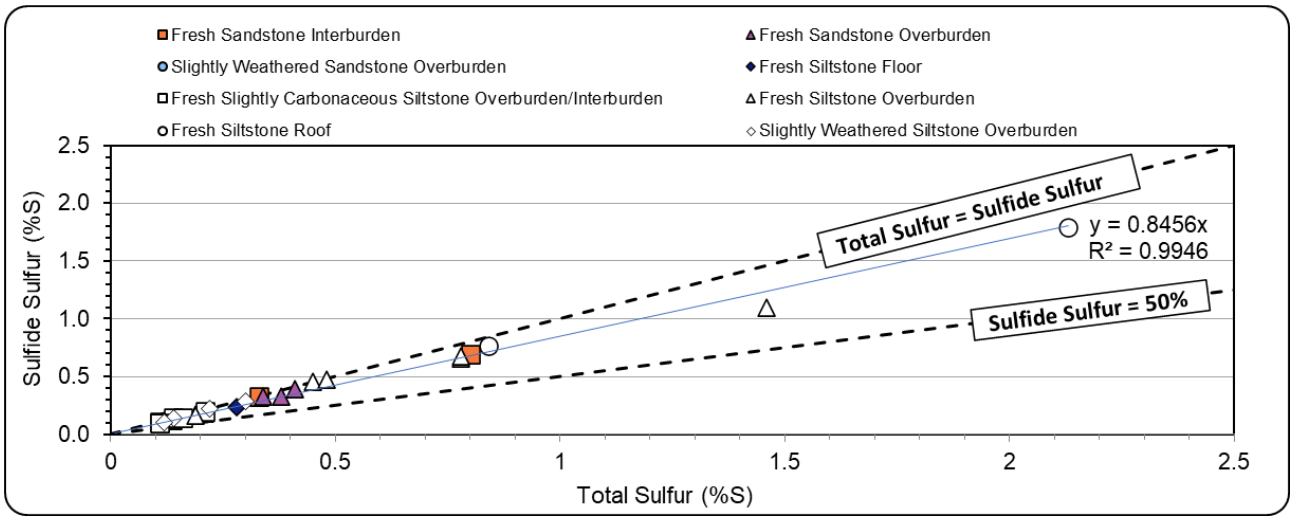


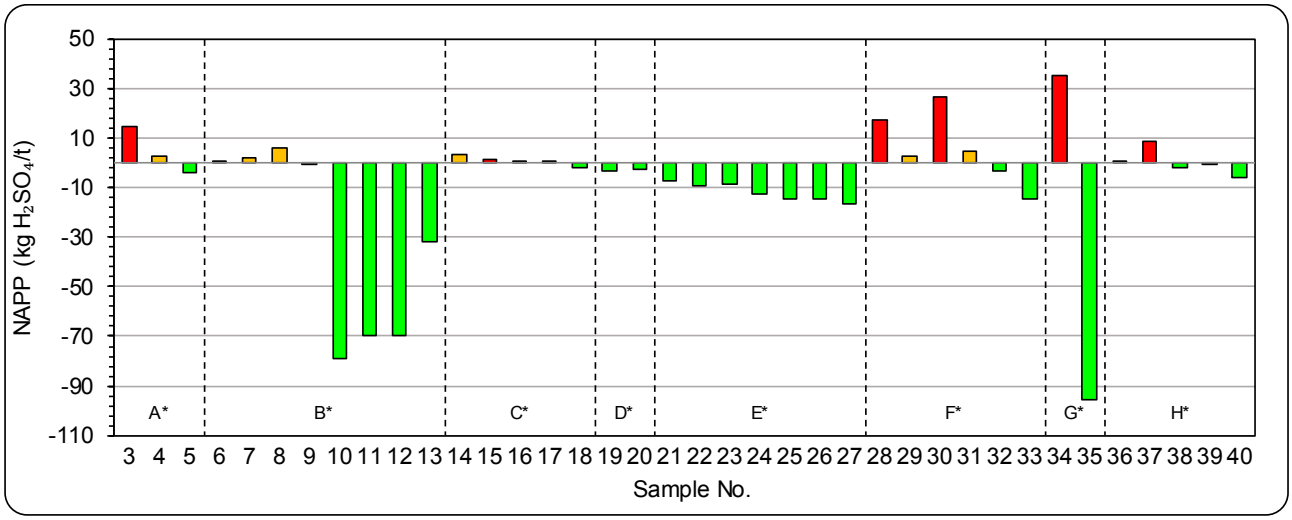
Figure 3-5: Total sulfur vs sulfide sulfur values for waste rock samples from Vulcan Coal Mine Matilda Pit

MPA: Based on the total sulfur content (and sulfide sulfur content, where available), the calculated Maximum Potential Acidity (MPA) that could be generated by the waste rock samples ranges from 0.3 to 54.8 kg H_2SO_4/t. The median MPA for the samples is 4.6 kg H_2SO_4/t.

ANC: The Acid Neutralising Capacity (ANC) values for the waste rock samples range from below the limit of reporting (0.5 kg H_2SO_4/t) to 119.0 kg H_2SO_4/t, with a median value of 4.6 kg H_2SO_4/t.

NAPP: The calculated NAPP values for the waste samples are shown in **Figure 3-6**. The NAPP values range from -95.5 to 35.4 kg H_2SO_4/tonne, with a median value of -1.9 kg H_2SO_4/t. The NAPP results indicate that four samples have a positive NAPP value greater than 10 kg H_2SO_4/t and are classified as Potentially Acid Forming (PAF) and shown in red. The four samples represent one fresh sandstone interburden, two fresh siltstone interburden and one fresh siltstone roof material. Four of the fresh sandstone overburden and

one of the fresh siltstone roof samples have a strongly negative ANC value and represent material that is Non-Acid Forming (NAF) and may have sufficient ANC be considered acid consuming.



* A = Fresh sandstone interburden; B = Fresh sandstone overburden; C = Slightly weathered sandstone overburden; D = Fresh siltstone floor; E = Fresh slightly carbonaceous siltstone overburden/interburden; F = Fresh siltstone overburden; G = Fresh siltstone roof; H = Slightly weathered siltstone overburden

Figure 3-6: NAPP values for waste rock samples from Vulcan Coal Mine Matilda Pit

ANC:MPA ratio: The relationship between the ANC and MPA of waste rock samples is shown in **Figure 3-7**. The ANC:MPA ratio of a sample provides an indication of the risk of acid generation of a sample. Generally, a sample with an ANC:MPA ratio of less than 1 can have an increased risk of acid generation, while a sample with an ANC:MPA ratio of greater than 2 generally has a low to negligible risk of generating acidic drainage.

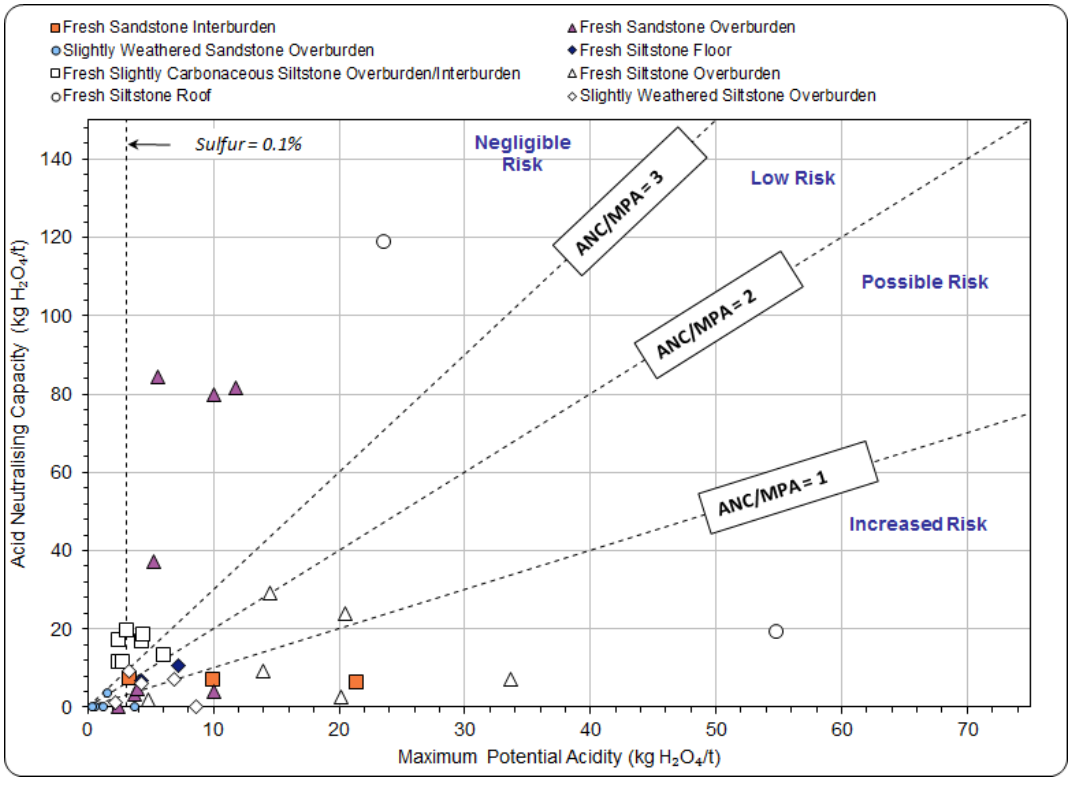


Figure 3-7: MPA vs ANC values for waste rock samples from Vulcan Coal Mine Matilda Pit

Sample Classification: The parameters used to classify the potential for the waste rock (overburden, interburden, roof, and floor) samples to generate AMD and the number of samples which fall into each category are provided in **Table 3-1**. **Figure 3-8** shows the classification of samples by lithology and weathering extent.

A total of 20 of the 38 waste rock samples are classified as NAF or NAF (Barren). A further 12 samples are classified as Uncertain and have a NAPP value that is close to zero and are unlikely to be a source of AMD. Hence, approximately 89 % of the waste rock samples tested are unlikely to be a source of AMD.

Two of the waste rock samples have a NAPP value between 5 and 10 kg H_2SO_4/t and are classified as PAF but have a low capacity to generate AMD (i.e., PAF-LC). Four samples are classified as PAF and have a reduced factor of safety with respect to AMD. The four PAF samples represent one fresh sandstone interburden, two fresh siltstone overburden and one fresh siltstone roof material.

Table 3-2: AMD classification parameters for waste rock samples from Vulcan Coal Mine Matilda Pit

Classification	Total Sulfur (%)	NAPP value (kg H_2SO_4/tonne)	Number of Samples
Non-Acid Forming (Barren)	≤ 0.1	-	9
Non-Acid Forming	> 0.1	≤ -5	11
Uncertain	> 0.1	> -5 to ≤ +5	12
Potentially Acid Forming - Low Capacity	> 0.1	> 5 to ≤ 10	2
Potentially Acid Forming	> 0.1	> 10	4

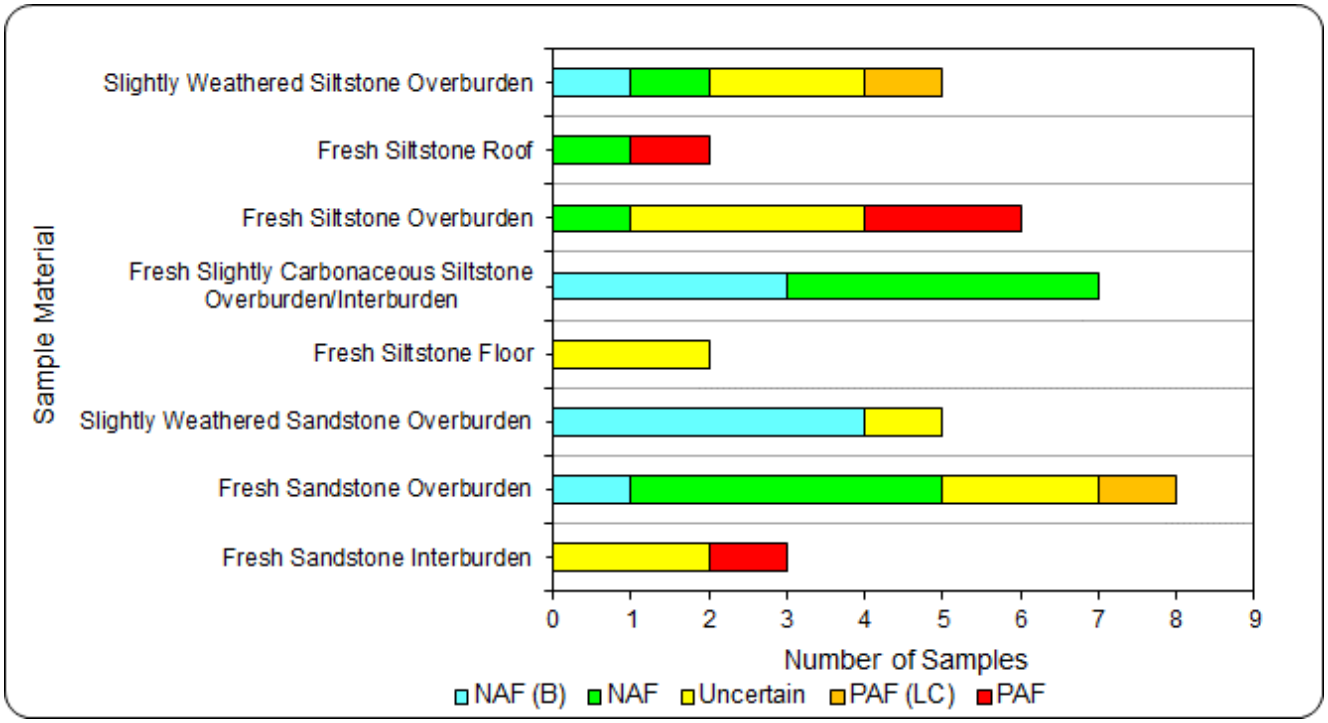


Figure 3-8: AMD classifications for waste rock samples from Vulcan Coal Mine Matilda Pit

3.1.2 Coal rejects

pH: pH results for the coal reject (coarse and fine reject) samples are shown in **Figure 3-9.** The pH results range from pH 3.1 to 6.8, with a median of pH 4.6. Generally, coarse reject samples have a lower pH value than fine rejects. It should be noted that the pH of the deionised water used in the pH tests was 5.7 and therefore all of the coarse reject samples and two of the fine reject samples are likely to add some acidity to initial contact water.

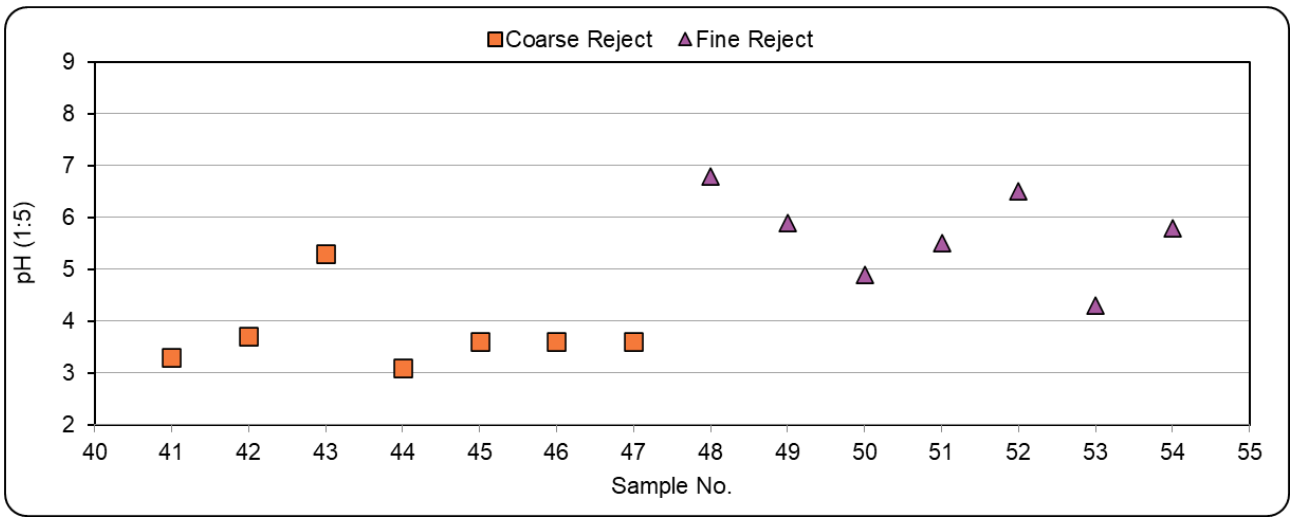


Figure 3-9: pH values for coal reject samples from Vulcan Coal Mine Matilda Pit

EC: EC results for coal reject samples are shown in **Figure 3-10**. The EC results range from 297 to 2,360 µS/cm and have a median value of 963 µS/cm). Coarse reject samples generally have higher EC results than the fine reject samples. It should be noted that the EC of the deionised water used in the EC tests was <1 µS/cm and therefore most coal reject samples add some salts to initial contact water.

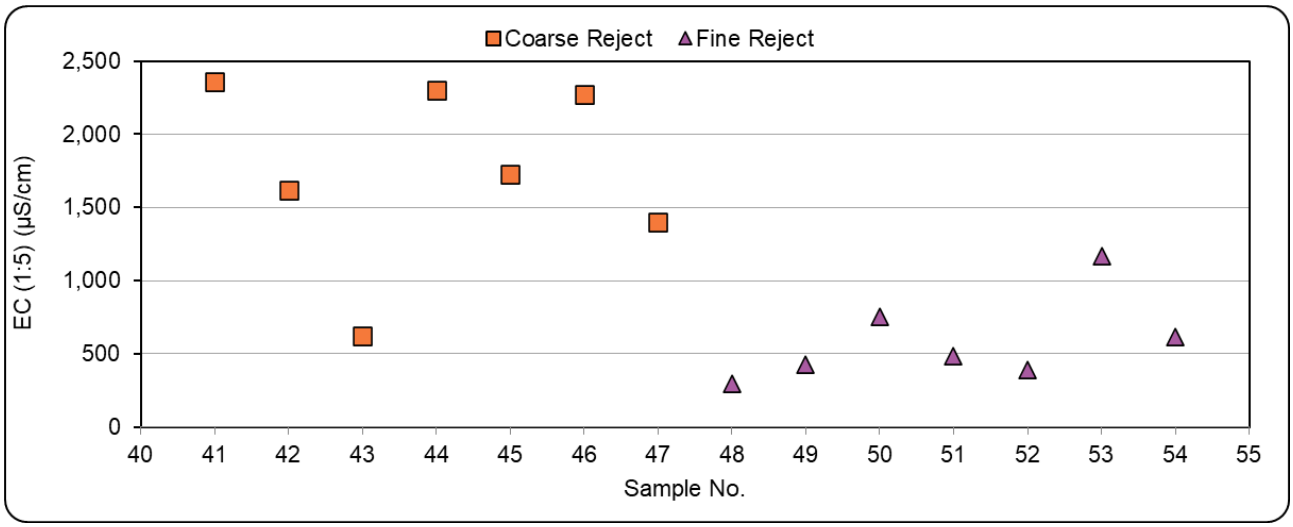


Figure 3-10: EC values for coal reject samples from Vulcan Coal Mine Matilda Pit

Total Sulfur: Total sulfur results for coal reject samples are shown in **Figure 3-11**. The total sulfur values range from 1.04 to 5.16 %S, with an elevated median value of 3.04 %S. Coarse reject samples generally have higher total sulfur results than fine reject samples.

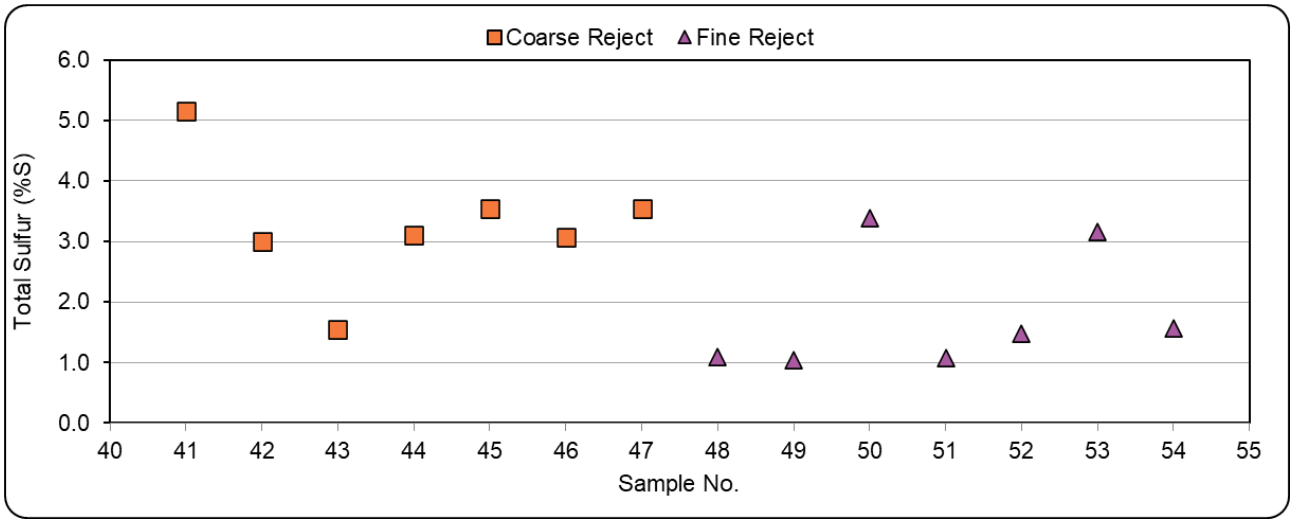


Figure 3-11: Total sulfur values for coal reject samples from Vulcan Coal Mine Matilda Pit

Sulfide Sulfur: Sulfide sulfur concentrations relative to total sulfur concentrations are shown in **Figure 3-12**. Sulfide sulfur results for coal reject samples range from 0.796% to 4.880% sulfide sulfur, with a median of 2.720% sulfide sulfur.

Figure 3-13 shows the correlation between total sulfur and sulfide sulfur results coal reject samples. There is a strong correlation between total sulfur and sulfide sulfur (R^2 = 0.9967) and linear regression modelling suggests the approximately 93 % of the total sulfur in a coal reject sample is likely to be present as sulfide sulfur.

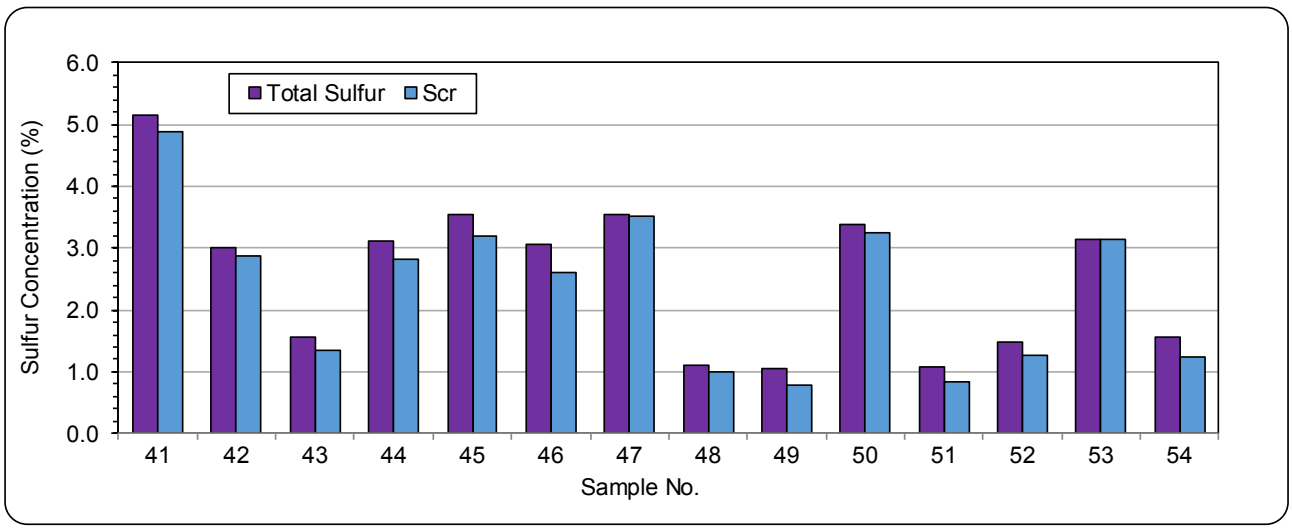


Figure 3-12: Total sulfur and sulfide sulfur values for coal reject samples from Vulcan Coal Mine Matilda Pit

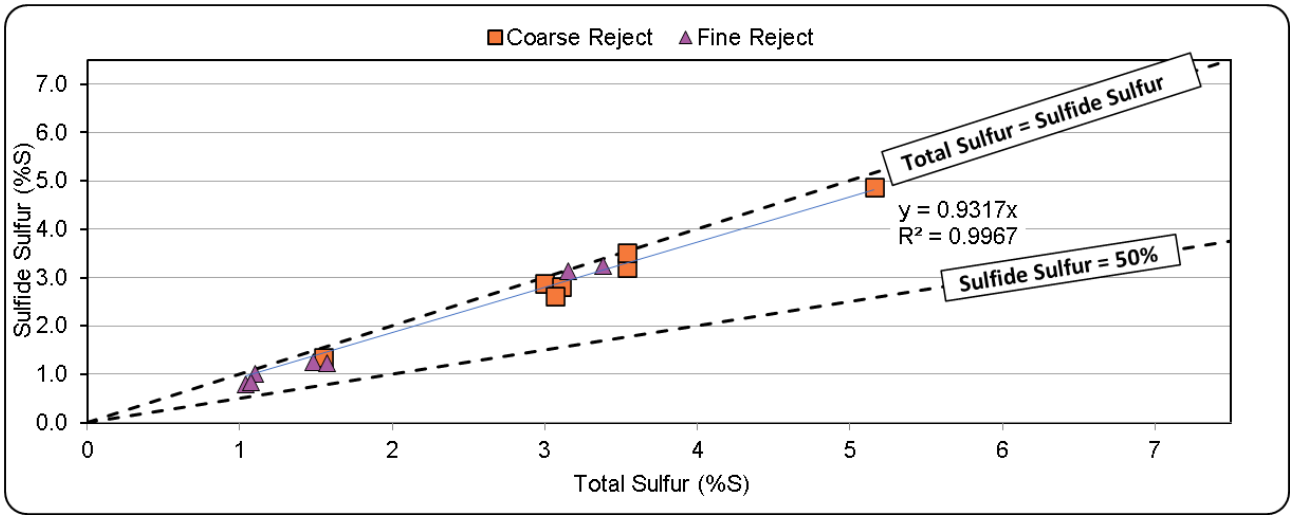


Figure 3-13: Total sulfur vs sulfide sulfur values for coal reject samples from Vulcan Coal Mine Matilda Pit

MPA: Based on the total sulfur content (and sulfide sulfur content, where available), the calculated MPA of the coal reject samples ranges from 24.4 to 149.5 kg H_2SO_4/tonne (median 83.3 kg H_2SO_4/t).

ANC: The ANC of the coal reject samples ranges from 0.3 to 25.3 kg H_2SO_4/t (median 13.5 kg H_2SO_4/t).

NAPP: The calculated NAPP of the coal reject samples is shown in **Figure 3-14**. The NAPP values are all positive and range from 5.3 to 142.8 kg H_2SO_4/tonne (median of 74.4 kg H_2SO_4/t).

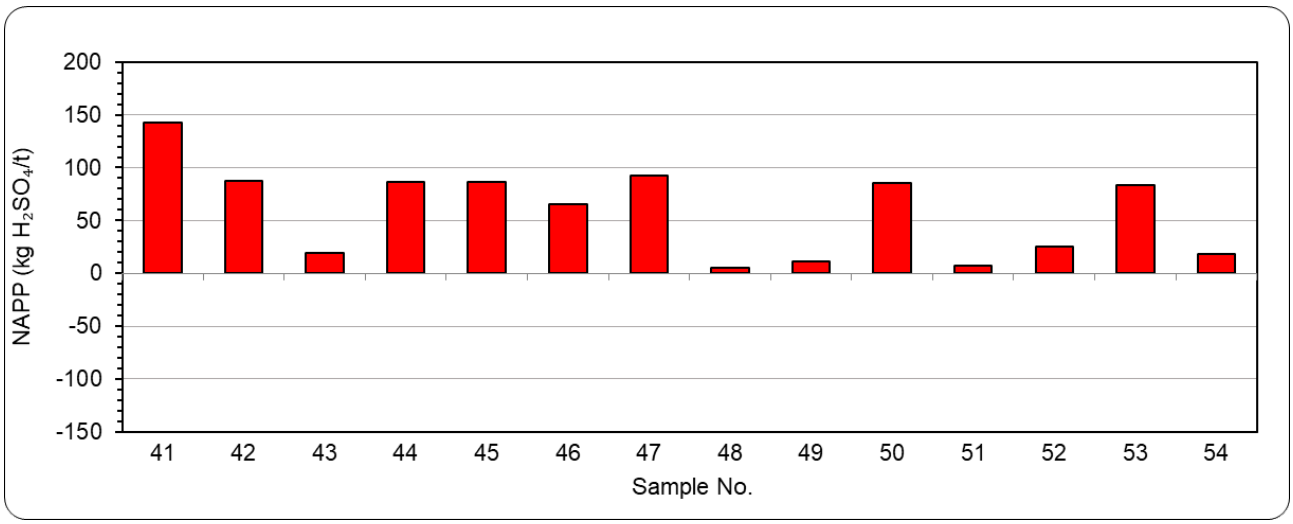


Figure 3-14: NAPP values for coal reject samples from Vulcan Coal Mine Matilda Pit

ANC:MPA ratio: The relationship between the ANC and MPA of coal reject samples is shown in **Figure 3-15**. The ANC:MPA ratio of a sample provides an indication of the risk of acid generation for that sample. Generally, a sample with an ANC:MPA ratio of less than 1 may have an increased risk of acid generation, while a sample with an ANC:MPA ratio of greater than 2 generally has a low to negligible risk of generating acidic drainage.

All the coal reject samples have ANC:MPA ratios of less than 1 indicating the samples are likely to have an increased risk of generating AMD.

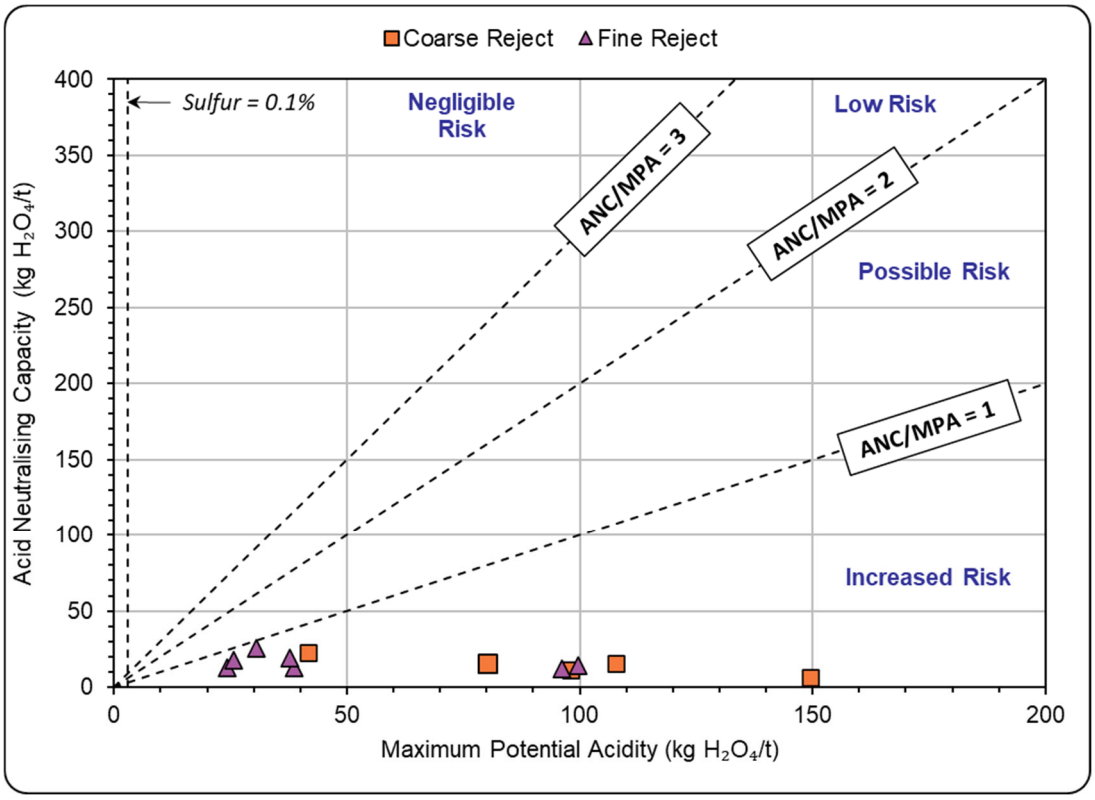


Figure 3-15: MPA vs ANC values for coal reject samples from Vulcan Coal Mine Matilda Pit

Sample Classification: The parameters used to classify the potential of the coal reject samples to generate AMD and the number of samples which fall into each category are shown in **Table 3-3**. **Figure 3-16** shows the classification of samples by reject size (i.e., coarse and fine reject).

All the reject samples are classified as PAF, with two of the fine reject samples classified as PAF-LC. The remainder of the coarse and fine reject samples are classified as PAF.

Table 3-3: AMD classification parameters for coal reject samples from Vulcan Coal Mine Matilda Pit

Classification	Total Sulfur (%)	NAPP value (kg H_2SO_4/tonne)	Number of Samples
Non-Acid Forming (Barren)	≤ 0.1	-	0
Non-Acid Forming	> 0.1	≤ -5	0
Uncertain	> 0.1	> -5 to ≤ +5	0
Potentially Acid Forming - Low Capacity	> 0.1	> 5 to ≤ 10	2
Potentially Acid Forming	> 0.1	> 10	12

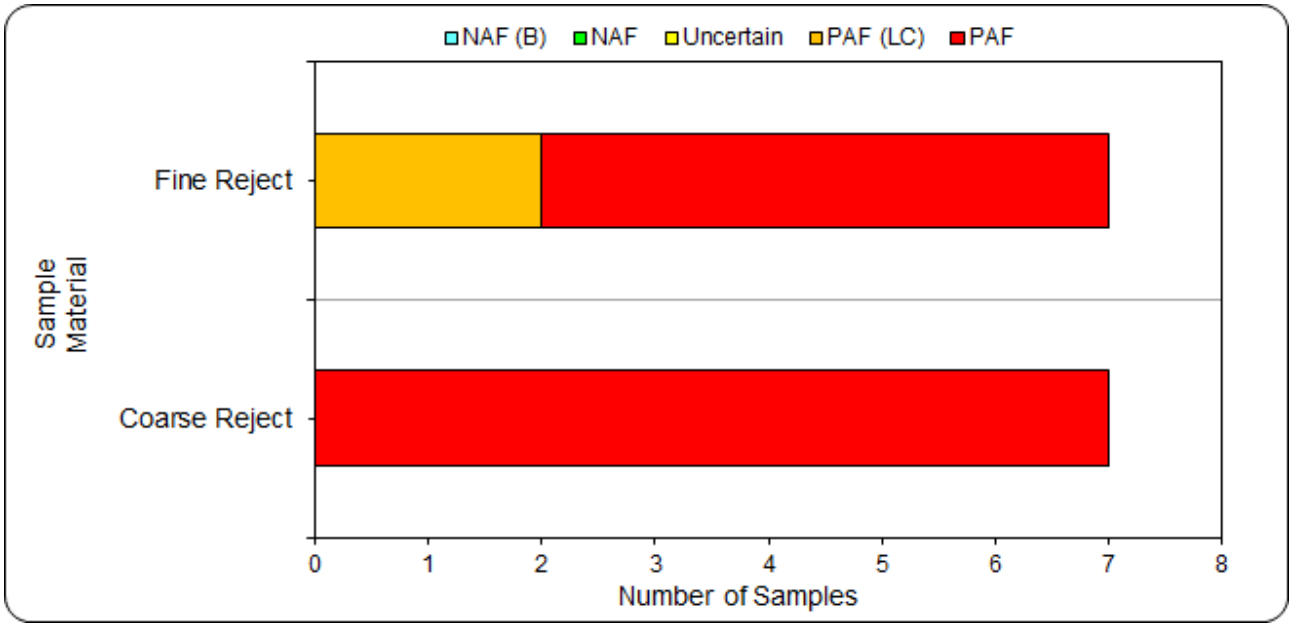


Figure 3-16: AMD classifications for coal reject samples from Vulcan Coal Mine Matilda Pit

3.1.3 Raw coal

pH: The pH results for the two coal samples are shown in **Figure 3-17**. The pH results are moderately alkaline and range from pH 9.1 to 9.2. It should be noted that the pH of the deionised water used in the pH tests was 5.4 and therefore the coal samples are likely to add some alkalinity to initial contact water.

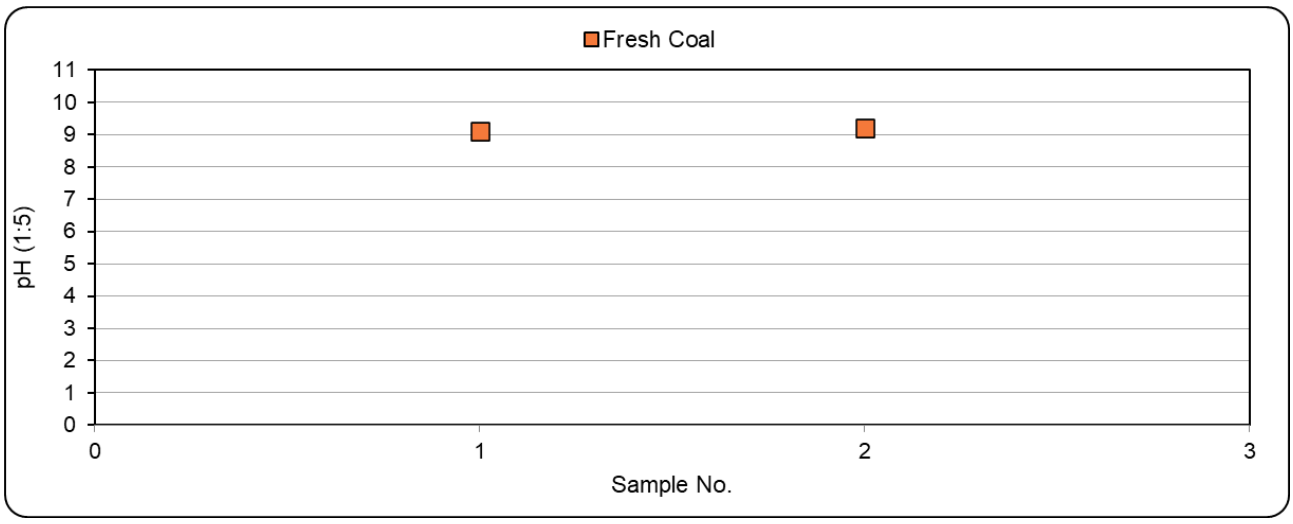


Figure 3-17: pH values for coal samples from Vulcan Coal Mine Matilda Pit

EC: The EC results for the two coal samples are shown in **Figure 3-18**. The EC values are relatively low and range from 120 to 130 µS/cm. It should be noted that the EC of the deionised water used in the EC tests was <1 µS/cm and therefore most waste rock samples add a little salt to initial contact water.

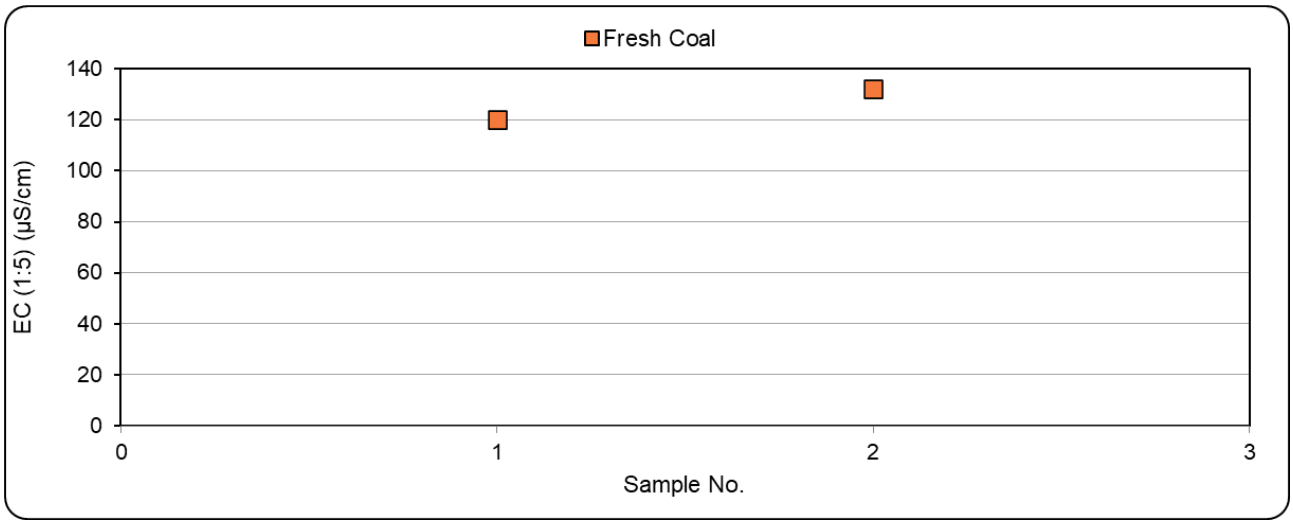


Figure 3-18: EC values for coal samples from Vulcan Coal Mine Matilda Pit

Total sulfur: The total sulfur results for the coal samples are shown in **Figure 3-19**. The total sulfur values range from 1.00 to 1.09 %S.

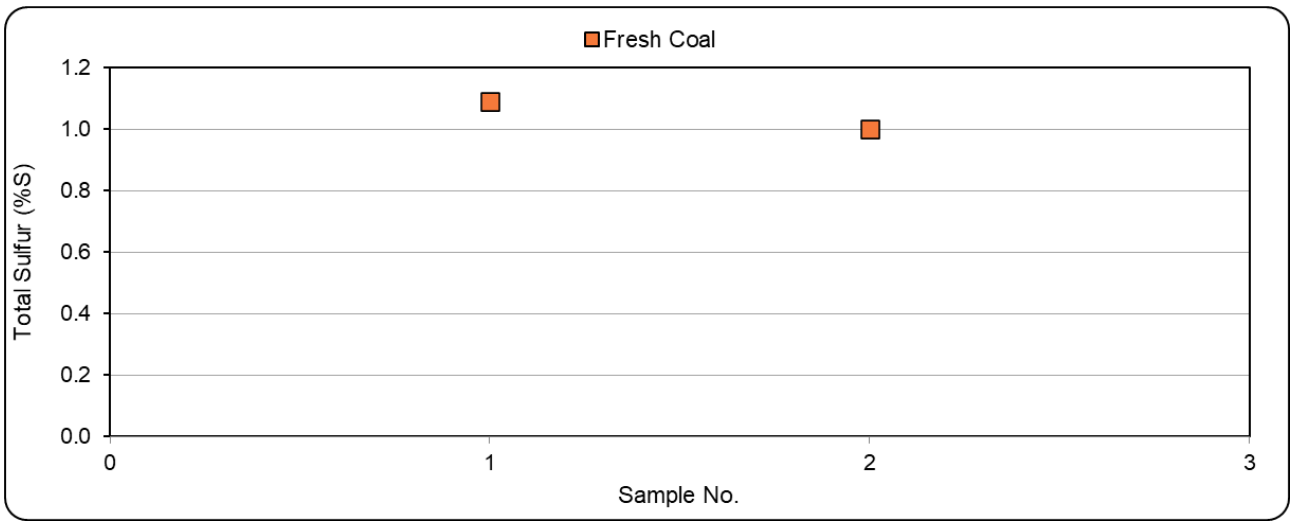


Figure 3-19: Total sulfur values for coal samples from Vulcan Coal Mine Matilda Pit

Sulfide Sulfur: Sulfide sulfur concentrations relative to total sulfur concentrations for the coal samples are shown in **Figure 3-20**. Sulfide sulfur results for coal samples range from 0.605% to 0.732% sulfide sulfur.

Figure 3-21 shows the correlation between total sulfur and sulfide sulfur results for the coal samples. Sulfide sulfur in the coal samples makes up approximately two thirds of the total sulfur in the samples.

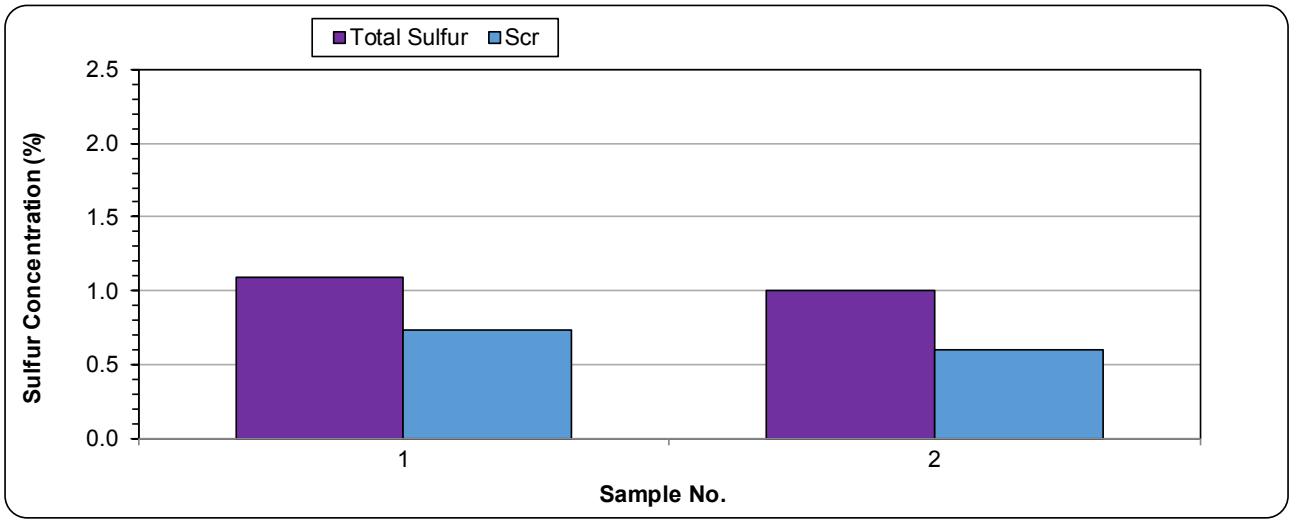


Figure 3-20: Total sulfur and sulfide sulfur values for coal samples from Vulcan Coal Mine Matilda Pit

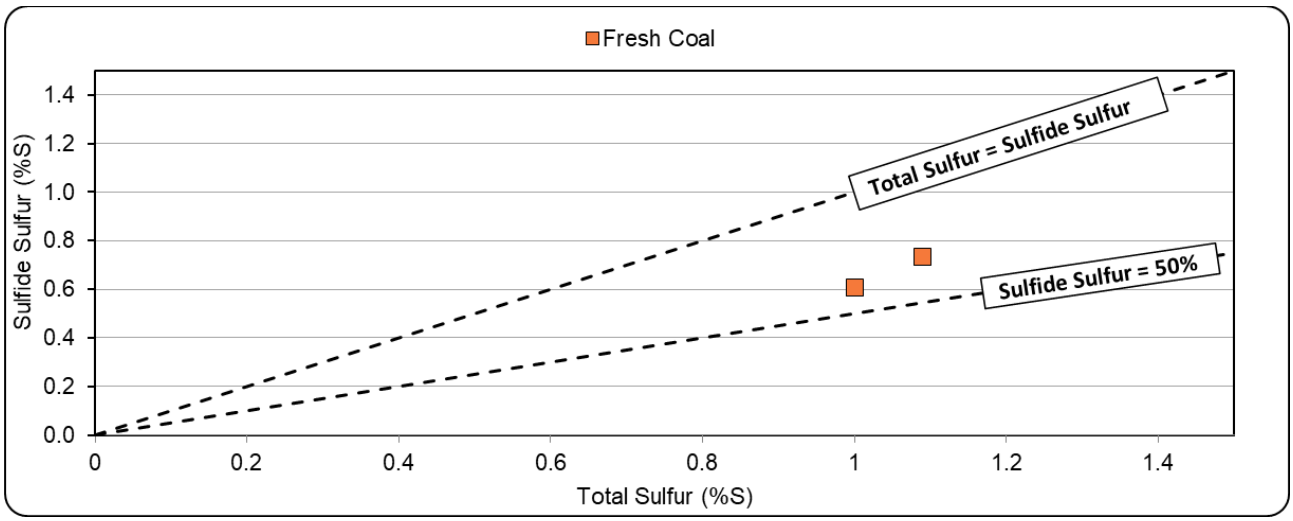


Figure 3-21: Total sulfur vs sulfide sulfur values for coal samples from Vulcan Coal Mine Matilda Pit

MPA: Based on the sulfide sulfur content, the calculated MPA values for the two coal samples range from 18.5 to 22.4 kg H_2SO_4/t.

ANC: The ANC results for the two coal samples range from 13.8 to 72.8 kg H_2SO_4/t.

NAPP: The calculated NAPP values for the coal samples are shown in **Figure 3-22**. The NAPP values range from -54.3 to 8.6 kg H_2SO_4/t.

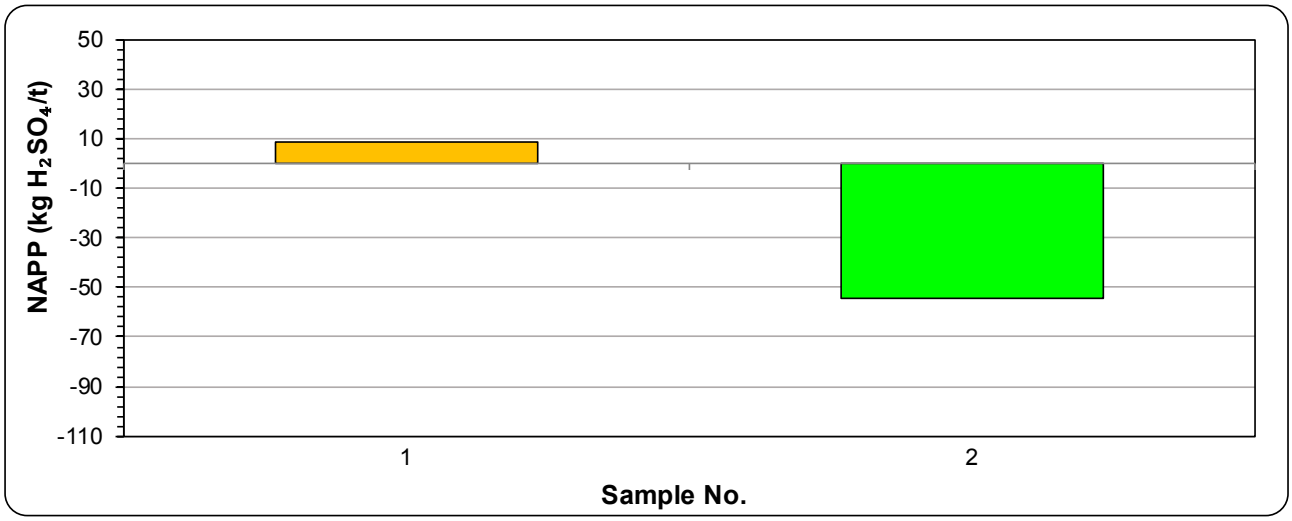


Figure 3-22: NAPP values for coal samples from Vulcan Coal Mine Matilda Pit

ANC:MPA ratio: The relationship between the ANC and MPA values of the two coal samples is shown in **Figure 3-23**. The ANC:MPA ratio of a sample provides an indication of the risk of acid generation for that sample. Generally, a sample with an ANC:MPA ratio of less than 1 is considered to have an increased risk of acid generation, while a sample with an ANC:MPA ratio of greater than 2 generally has a low to negligible risk of generating acidic drainage.

One of the coal samples has an ANC:MPA ratio of less than 1 indicating that material represented by the sample may have an increased risk of generating AMD. The other coal sample has an ANC:MPA ratio of greater than 3 indicating that the sample is likely to have a negligible risk of generating AMD.

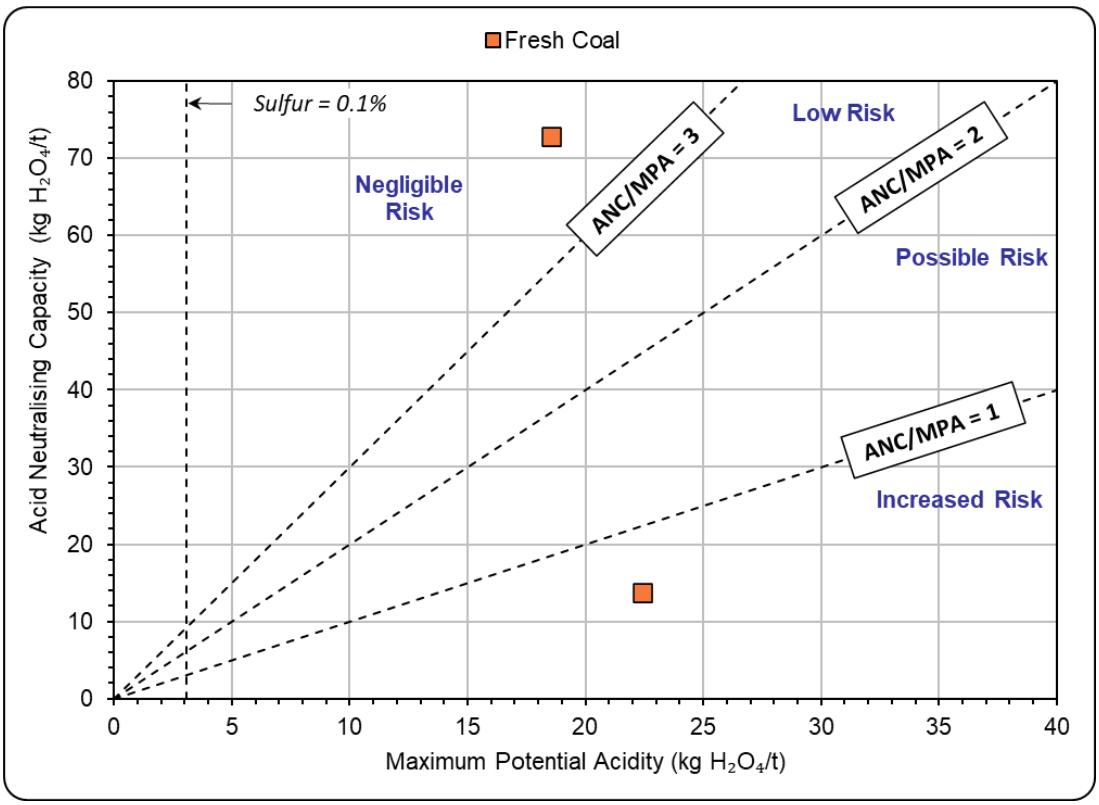


Figure 3-23: MPA vs ANC values for coal samples from Vulcan Coal Mine Matilda Pit

Sample Classification: The parameters used to classify the potential of the coal samples to generate AMD and the number of samples which fall into each category are shown in **Table 3-3**.

One coal sample is classified as NAF, and the other sample is classified as PAF-LC.

Table 3-4: AMD classification parameters for coal samples from Vulcan Coal Mine Matilda Pit

Classification	Total S (%)	NAPP value (kg H_2SO_4/tonne)	Number of Samples
Non-Acid Forming (Barren)	≤ 0.1	-	0
Non-Acid Forming	> 0.1	≤ -5	1
Uncertain	> 0.1	> -5 to ≤ +5	0
Potentially Acid Forming - Low Capacity	> 0.1	> 5 to ≤ 10	1
Potentially Acid Forming	> 0.1	> 10	0

3.2 Multi-element concentration in solids

Multi-element analyses were carried out on 13 mine material samples (eight composite samples of waste rock, four composite samples of coal reject, and one composite sample of coal) as described in **Section 2.2** to identify any metals or metalloids present at concentrations that may be of environmental concern with respect to materials handling, storage, revegetation and water quality.

To provide relevant context, RGS has compared the total metal/metalloid concentrations in samples to National Environmental Protection Council (NEPC) Health-based Investigation Levels (HIL(C)) for soils in public open spaces (NEPC, 2013).

The results from multi-element testing (total metals/metalloids) of the 13 selected composite samples are presented in **Table B2 (Attachment B)**. The results indicate that the sample materials have total metal and metalloid concentrations below the applied NEPC (HIL(C)) guideline for soils.

The results from multi-element testing (total metals/metalloids) of the 13 samples with respect to median crustal abundance in un-mineralised soils are discussed in **Section 3.2.1**.

3.2.1 Geochemical abundance index

Total metal/metalloid concentrations in mining materials can be compared to the median crustal abundance for un-mineralised soils (Bowen, 1979, COA, 2016 and INAP, 2022). The extent of enrichment is reported as the Geochemical Abundance Index (GAI), which relates the actual concentration in a sample with the median crustal abundance on a $\log_{10}$ scale.

The GAI is expressed in integer increments from 0 to 6, where a GAI value of 0 indicates that the element is present at a concentration less than, or similar to, the median crustal abundance; and a GAI value of 6 indicates approximately a 100-fold enrichment above median crustal abundance (see **Table 3-4**).

Table 3-5: Geochemical abundance index values and enrichment factors

GAI	Enrichment Factor	GAI	Enrichment Factor
0	Less than 3-fold enrichment	4	24 – 48-fold enrichment
1	3 – 6-fold enrichment	5	48 – 96-fold enrichment
2	6 – 12-fold enrichment	6	Greater than 96-fold enrichment
3	12 – 24-fold enrichment		

Generally, a GAI value of greater than 3 signifies enrichment that may warrant further examination. This is particularly the case with some environmentally important 'trace' elements, such as arsenic, chromium, cadmium, copper, lead, selenium, and zinc rather than with major rock-forming elements, such as aluminium, calcium, iron, manganese, and sodium.

Elements identified as enriched may not necessarily be a concern for revegetation, drainage water quality or public health, but their significance should still be evaluated. While the GAI provides an indication of metals/metalloids that may be enriched relative to the global median crustal abundance in un-mineralised soils, the following points should also be considered:

- The median crustal abundance varies between different literature sources, thereby affecting the calculated GAI values.
- Samples that are enriched relative to the median crustal abundance, do not necessarily leach metals/metalloids at elevated concentrations. The mobility of metals/metalloids is dependent on mineralogy, adsorption/desorption, and the environment in which it occurs.

Similarly, because an element is not enriched does not mean it will never be a concern, as under some conditions (e.g., low pH) the solubility of common environmentally important elements such as aluminium, copper, cadmium, iron, and zinc increase significantly.

Table B2 (**Attachment B**) provides total metal/metalloid concentrations for the 13 samples of mine materials described in **Section 2.2**. The relative enrichment of metals/metalloids in the samples compared to median crustal abundance (the Geochemical Abundance Index - GAI) is presented in **Table B3** (**Attachment B**).

The GAI results indicate that of the metals/metalloids measured, none of the waste rock, coal reject or coal samples are enriched with most metals/metalloids compared to median crustal abundance in un-mineralised soils (i.e., all samples have a GAI value of less than 3). Whilst the coarse and fine composite coal reject samples which have GAI values for mercury that range from 3.2 and 3.6, a corresponding enrichment in mercury is not observed in roof, floor, or coal samples. The highest mercury concentration of 1.1 mg/kg in the coal reject samples is almost 40 times lower than the health-based NEPM investigation level for residences with garden accessible soil (includes childcare centres, preschools and primary schools) for inorganic mercury (NSW Health, 2022).

The potential solubility of metals/metalloids in the sample materials was investigated further through water extract tests and results are presented in **Section 3.4**.

3.3 Soil characteristics and sodicity

Five of the eight composite waste rock samples were also analysed for soil characteristics and sodicity. The selected composite samples represent materials that could potentially report to the outer surfaces of final landforms and could also be earmarked for use in other site infrastructure and rehabilitation works (i.e., the samples are not classified as PAF and not derived from the roof or floor material of the Matilda Seam). The tests focussed on exchangeable cations and allowed calculation of the effective cation exchange capacity (CEC) and exchangeable sodium percentage values. The test results and calculated values are provided in **Table B2** (**Attachment B**) and are summarised below.

3.3.1 Soil characteristics

The effective CEC results for the five composite waste rock samples are presented in **Table B2** (**Attachment B**). The CEC results range from 2.1 to 6.0 meq/100g and are typically in the very low to low range as described in **Table 4-6** (Hazelton and Murphy, 2007). The slightly weathered samples have calcium:magnesium ratios of less than one. For waste rock materials with a very low to low CEC value and low calcium:magnesium ratio, some fertiliser and gypsum addition may be required to provide a reasonable growth medium for vegetation roots as part of sustainable revegetation and rehabilitation activities.

Table 3-6: Ratings for cation exchange capacity

CEC Rating	CEC (meq/100g)
Very low	<6
Low	6 – 12
Moderate	12 – 25
High	25 – 40
Very high	>40

3.3.2 Sodicity

The exchangeable sodium percentage (ESP) results for the five composite waste rock samples are presented in **Table B2** (**Attachment B**). The ESP value for a sample is the proportion of exchangeable sodium relative to the total effective cation exchange capacity for a sample. Generally, samples with ESP values less than 6 % are considered non-sodic, and greater than 14% are considered strongly sodic and may be susceptible to dispersion and erosion (Isbell, 2002; and Northcote and Skene, 1972). Sodicity can result in surface crusting and low infiltration and hydraulic conductivity within the affected soils (Hazelton and Murphy, 2007).

Exchangeable sodium results for the samples range from 0.2 to 0.6 meq/100g and ESP results for the samples range from 9.3% to 11.7%. These results are expected for waste rock materials found in this part of the Bowen Basin and it is important to note that in materials with low CEC values and moderately sodic ESP results can be caused by relatively low concentrations of exchangeable sodium.

Overall, the results of the ESP tests indicate that most waste rock materials represented by these samples may be moderately sodic; and consequently, may be susceptible to dispersion and erosion. Due to the relatively low exchangeable sodium concentrations and the low CEC values for the samples field trials to assess the tendency of samples to erode may be beneficial in determining appropriate management strategies for these materials. Where required, the addition of gypsum, organic matter and fertilizer to moderately sodic waste rock materials has the potential to reduce the sodicity and reduce the potential for dispersion and erosion.

3.4 Water quality static tests

There are no specific regulatory criteria for metal/metalloid concentrations in leachate from mining waste materials on mine sites in Queensland. As such, RGS has compared the multi-element results in water extracts from the 13 composite samples of mine materials (eight waste rock, four coal reject, and one coal) from the Project, described in **Section 3.2**, with Australian guidelines for livestock drinking water and aquatic freshwater ecosystems (ANZECC & ARMCANZ, 2000; ANZG, 2018) guideline values. These guidelines are provided for context only and are not intended to be interpreted as “maximum permissible levels” for site water storage or discharge.

It should also be recognised that direct comparison of geochemical data with guideline values can be misleading. For this study, guideline values are only provided for broad context and should not be interpreted as arbitrary “maximum” values or “trigger” values. Using sample pulps (ground to passing 75 µm) provides a very high surface area to solution ratio, which encourages mineral reaction and dissolution of the solid phase. Therefore, the results of screening tests on water extract solutions are assumed to represent a ‘worst-case’ scenario for pore water and initial contact water for mining materials.

The results from multi-element testing of water extracts (1:5 solid:water) from the 13 composite samples are presented in **Table B4** (**Attachment B**).

The pH values for the eight waste rock (overburden, interburden, roof, and floor) composite samples range from pH 5.8 to 9.1 and the fresh siltstone floor and fresh slightly carbonaceous siltstone overburden/ interburden composite samples are slightly higher (pH 9.1) than the pH range for 95 % species protection in freshwater aquatic ecosystems (ANZECC & ARMCANZ, 2000; ANZG, 2018). Most waste rock samples are pH to moderately alkaline (pH 7.3 to 9.1) apart from one slightly weathered sandstone overburden sample which has a pH value of 5.8. In most cases it is expected that some alkalinity will be added to initial contact water from these materials as the deionised water used in the tests was pH 5.4.

The pH values for the four coal reject composite samples are acidic to slightly acidic and range from pH 3.4 to 5.3. The coal composite sample has a slightly alkaline pH of 8.8. The pH results for the coarse and fine reject composite samples are below the range of pH 6 to 9 for 95 % species protection in freshwater aquatic ecosystems (ANZECC & ARMCANZ, 2000; ANZG, 2018).

Coal and waste rock composite samples have relatively low EC values compared to the coal rejects composite samples. The coal reject samples have EC values ranging from 533 to 1,790 µS/cm. EC values for the coarse reject samples are 2-3 times higher than the EC values for the fine rejects and only the coarse reject composite samples have EC values which exceeded the 95 % species protection in freshwater aquatic ecosystems trigger value of 1,000 µS/cm (ANZECC & ARMCANZ, 2000; ANZG, 2018)

The calculated net alkalinity values in the water extracts from the waste rock composite samples range from -47 to 6,140 mg $CaCO_3$/L. The slightly weathered sandstone overburden composite sample was the only waste rock sample with a slight excess of acidity relative to alkalinity. All other waste rock samples have more strongly positive net alkalinity values. Alkalinity in the waste rock samples is primarily generated by bicarbonate species rather than carbonates. The coal reject samples all have negative net alkalinity values and the coarse reject samples have lower net alkalinity values compared to the fine reject samples. The coal composite sample has a strongly positive net alkalinity value relative to the other composite samples and again this alkalinity is primarily present as bicarbonate.

The major soluble ions in the waste rock sample water extracts are generally sodium, potassium, and sulfate. In contrast, sulfate, calcium, and magnesium are the primary major ions in the water extracts from the coarse reject samples. The water extracts from the fine reject samples have lower concentrations of major ions relative to the coarse rejects. The major ions with the highest concentrations in the water extracts from the fine reject samples are sulfate and calcium. The major ions in the water extract from the coal sample are primarily sulfate and sodium. The concentrations of calcium, sulfate, and fluoride in all samples are below the applied (ANZECC & ARMCANZ, 2000; ANZG, 2018) water quality guideline criteria (1,000 mg/L calcium, 1,000 mg/L sulfate, and 2 mg/L fluoride) for livestock drinking water.

The concentrations of trace metals/metalloids tested in water extracts from the waste rock and coal samples are typically low and predominantly below the laboratory limit of reporting. Most metal/metalloid concentrations are below the applied water quality guideline criteria. The exception is aluminium in the slightly weathered sandstone overburden water extract, which has a concentration (0.08 mg/L) which is marginally greater than the applied freshwater aquatic ecosystem water quality guideline value (0.055 mg/L) for 95% species protection but is almost two orders of magnitude lower than the applied guideline value (5 mg/L) for livestock drinking water (ANZECC & ARMCANZ, 2000; ANZG, 2018).

Soluble trace metals and metalloid concentrations in water extracts from the coal reject samples are elevated relative to the waste rock and coal composite samples. The concentrations of eight elements in the water extracts from the coarse reject composite samples are greater than the applied guideline values (0.55 mg/L aluminium, 0.024 mg/L arsenic, 0.0002 mg/L cadmium, 0.0014 mg/L copper, 1.9 mg/L manganese, 0.011 mg/L nickel, 0.0034 mg/L lead, and 0.008 mg/L zinc) for 95 % species protection (ANZECC & ARMCANZ, 2000; ANZG, 2018). The water extracts from the fine reject samples have elevated values for four elements; aluminium, copper, nickel, and zinc compared to the applied 95 % aquatic species protection guideline values. All elements tested in the water extracts from both coarse and fine reject samples are below the guideline values for livestock drinking water (ANZECC & ARMCANZ, 2000; ANZG, 2018).

As previously stated, due to the relatively large surface area of the sample materials in contact with the water extracts the results presented above are likely to represent a ‘worst-case’ scenario for pore water and initial contact water for mining materials.

4 Discussion

4.1 AMD potential and management

The geochemical investigations demonstrate that bulk waste rock material located within the weathered zone of the stratigraphic profile at the Matilda Pit (generally less than 15m) typically has low sulfur content, low ANC and is classified as NAF. Fresh waste rock (overburden and interburden) material from deeper in the stratigraphic profile is also likely to be NAF, although PAF materials have been identified for siltstone from 18 to 22 m depth, sandstone at the base of the open pit from 39 to 42 m depth, and for a siltstone roof sample from 32 to 33 m depth. There is also a band of fresh sandstone material from 22 to 29 m depth that has excess ANC and could be considered acid consuming. In terms of material management, it is recommended that fresh waste rock material be backfilled into the open pit and covered with at least 5 m of weathered NAF waste rock material as part of rehabilitation activities. If required, the high ANC acid consuming material could be used as part of the overall management process for pit backfilling.

In contrast, coal reject materials are classified as PAF and ideally should report deep into to the open pit profile as backfill and be progressively covered with NAF waste rock materials. If there is insufficient capacity in the open pit to accommodate coal reject materials and ex-pit disposal is required, encapsulation of coal rejects will be required including a base of NAF waste rock material. Paddock dumping and traffic compaction of coal reject materials during ex-pit placement should be completed prior to covering with NAF waste rock materials. Any surface runoff/seepage from ex-pit coal reject emplacement areas should report to the open pit and/or be captured in the water management system employed under the Water Management Plan.

Most of the coarse reject samples have a pH value between 3 and 4 and are already acidic therefore the high ANC waste rock described above may be a useful source of interim covering/neutralising/alkaline materials during the mining and backfilling process. Traffic compaction of the in- pit coal reject materials will also assist in limiting air entry to the coal rejects to surface diffusion and slow down the overall rate of reaction of the bulk coal reject materials. This outcome will also be favoured using the co-disposal of coarse and fine reject materials whereby fine rejects fill the air gaps in coarse rejects and limit oxygen diffusion into the bulk materials. At the same time the co-disposed coarse rejects provide additional geotechnical stability to the fine rejects. Notwithstanding, as above, the final cover of the backfilled pit should comprise at least 5 m of weathered NAF waste rock material as part of rehabilitation activities

The results from the geochemical assessment of coal samples from the Matilda Seam suggest that some coal has to potential to generate relatively low amounts of AMD. The NAF coal sample has sufficient ANC to neutralise MPA of both samples combined, which suggests that mixed coal from the Matilda Seam in a stockpile may not generate acidic drainage but has the potential to generate neutral mine drainage. Whilst the coal will be stockpiled on site for limited periods of time, it is recommended that surface runoff and seepage from stockpiles be managed appropriately within the site water management system as part of the Water Management Plan.

Previous geochemistry studies at the Vulcan Coal Mine (RGS, 2020) have demonstrated that there is a large volume of NAF waste rock materials with low sulfur content and excess ANC that will be generated from operation of the Vulcan and Jupiter pits, compared to the relatively small Matilda pit. Hence, in the unlikely event that there is a shortfall in NAF waste rock material at the Matilda Pit, NAF waste rock material from the Vulcan and/or Jupiter Pits will be used to implement the PAF material management strategy at Matilda pit.

4.2 Multi-element composition and water quality

4.1.1 Multi-element composition and enrichment

The multi-element results indicate that none of the waste rock, coal reject and coal samples are not significantly enriched with most metals/metalloids compared to applied guideline values and median crustal abundance for un-mineralised soils. The exception is mercury in the coarse and fine reject samples, although the highest mercury concentration of 1.1 mg/kg is almost 40 times lower than the health-based NEPM investigation level for residences with garden accessible soil (includes childcare centres, preschools and primary schools) for inorganic mercury (NSW Health, 2022).

4.1.2 Water quality

The results of static water quality tests demonstrate that coal and waste rock materials will produce neutral to alkaline drainage with low salinity and low concentrations of metals and metalloids relative to the coal reject materials. Drainage from the coal rejects is likely to have a lower pH, higher salinity, and higher concentrations of metals and metalloids in solution.

4.2 Revegetation and rehabilitation

In general, waste rock has a low CEC value and is moderately sodic; and consequently, may be susceptible to dispersion and erosion. Hence, rehabilitation field trials may be beneficial in determining the appropriate management strategies for these materials. Where required, the addition of gypsum, organic matter and fertilizer to waste rock materials has the potential to increase the CEC, reduce the sodicity and reduce the potential for dispersion and erosion.

Additional confirmatory sampling and testing should be completed for bulk waste rock materials when available during the operational phase of the Project to determine the best management option for progressive rehabilitation of these materials during operations and at mine closure. Sampling should focus on collecting representative samples of any waste rock materials planned to be used at the surface of final landforms to supplement any existing subsoil and topsoil salvaged re-used in revegetation and rehabilitation activities. Testing should include typical soil parameters including pH, EC, exchangeable cations, organic matter, total organic carbon, Emerson Aggregate class, particle size distribution, and nutrients (including available potassium, phosphorus, organic carbon, as well as nitrogen and nitrogen species (nitrite, nitrate, and ammonia).

4.3 Management measures

Table 4-1 provides a summary how the waste rock, coal reject and coal materials will be managed through all stages of the mine life including construction, operations, rehabilitation, and decommissioning.

Table 4-1: Material management over mine life

Project Phase	Waste Rock	Coal Rejects	Coal
Construction	Stored at out-of-pit WRD	None produced	None produced
Operations	Stored at out-of-pit WRD and/or backfilled in-pit.	Preferentially co-disposed / backfilled/traffic compacted in-pit and covered with 5 m of NAF waste rock material. Contact water monitored for quality and managed in the mine water management system as part of Water Management Plan	Temporarily stockpiled at ROM. Contact water monitored for quality and managed in the mine water management system as part of Water Management Plan
Rehabilitation	Final landforms rehabilitated/ revegetated	Final landforms rehabilitated/ revegetated	ROM removed and footprint rehabilitated/revegetated
Decommissioning	Final landform performance monitoring moving towards lease relinquishment	Final landform performance monitoring moving towards lease relinquishment	None

5 Conclusions and recommendations

5.1 Conclusions

RGS has completed a geochemical assessment of waste rock (overburden, interburden, roof, and floor materials), coal rejects (coarse and fine fractions), and coal from a proposed pit targeting the Matilda Seam. The main findings of the geochemical assessment are:

- Bulk waste rock material located within the weathered zone of the stratigraphic profile at the Matilda Pit (generally less than 15m) typically has low sulfur content, low ANC and is classified as NAF and is likely to generate low salinity surface runoff/seepage.
- Most of the fresh waste rock (overburden and interburden) material from deeper in the stratigraphic profile is also likely to be NAF, although occasional PAF strata have been identified. A band of high ANC strata has also been identified that may be acid consuming and could be a useful resource if used as part of operational pit backfilling management activities.
- Coal reject materials are likely to be PAF and could generate acidic and brackish leachate with elevated concentrations of major ions (e.g. sulfate) and dissolved metals/metalloids and will require management.
- Coal from the Matilda Pit has variable geochemical characteristics and surface runoff/seepage from these materials will require management.
- Mine materials generated from the Matilda Pit are generally not significantly enriched with most metals/metalloids compared to applied guideline values and median crustal abundance for un-mineralised soils.
- Most metals/metalloids are sparingly soluble at the neutral to alkaline pH of initial leachate expected from bulk waste rock materials. Dissolved metal/metalloid concentrations in surface runoff and leachate from bulk NAF waste rock materials are expected to be low and unlikely to pose a significant risk to the quality of surface and groundwater resources at relevant storage facilities.
- NAF weathered waste rock materials should be amenable to revegetation as part of rehabilitation activities, although, gypsum, fertiliser and organic matter addition may improve material characteristics and outcomes if used as part of rehabilitation activities.

5.2 Recommendations

The main recommendations of the geochemical assessment are:

- Based on the outcomes of the static geochemical characterisation program and in line with the management measures described in **Section 4.3,** it is recommended that coal rejects are preferentially co-disposed and traffic compacted as part of in-pit backfill operations and finally covered with 5 m of NAF waste rock material.
- The potential for reuse of the high ANC (acid consuming) waste rock material as part of the operational pit backfilling management activities should be investigated.
- Contact water from any PAF mine materials should be monitored for quality and managed in the mine water management system as part of Water Management Plan.
- Rehabilitation field trials should be undertaken on waste rock materials from the Matilda Pit to determine the appropriate amelioration measures and management strategies for these materials.

6 References

AMIRA (2002). *ARD Test Handbook: Project 387A Prediction and Kinetic Control of Acid Mine Drainage*. Australian Minerals Industry Research Association, Ian Wark Research Institute and Environmental Geochemistry International Pty Ltd, May 2002.

ANZECC & ARMCANZ (2000). *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Australian and New Zealand Environment Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra, ACT (2000). Now superseded by:

ANZG (2018). *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Australian and New Zealand Environment Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra, ACT (2018). Livestock drinking water (low risk trigger levels).

Bowen, H.J.M. (1979). *Environmental Chemistry of the Elements*. Academic Press, New York.

COA (2016). Leading Practice Sustainable Development Program for the Mining Industry - Managing Acid and Metalliferous Drainage. Commonwealth of Australia, Canberra.

DEHP (2013). Application Requirements for Activities with Impacts to Land Guideline. Queensland Department of Environment and Heritage Protection.

DME (1995). Draft Technical Guidelines for the Environmental Management of Exploration and Mining in Queensland, Technical Guideline – Assessment and Management of Acid Drainage and Saline/Sodic Wastes. Queensland Department of Minerals and Energy (DME).

Hazelton, P. and Murphy, B. (2007). Interpreting soil test results: What do all the numbers mean?. CSIRO publishing.

INAP (2022). *Global Acid Rock Drainage Guide (GARD Guide)*. Document prepared by Golder Associates on behalf of the International Network on Acid Prevention (INAP). June 2009 (http://www.inap.com.au/).

Isbell, RF. (2002). The Australian Soil Classification (revised edition). CSIRO Publishing. Victoria.

NEPC (2013). *National Environmental Protection (Assessment of Site Contamination) Measure (NEPM)*, Amendment of Schedule B1-B7 of 1999 version. National Environmental Protection Council (NEPC).

NSW Health (2022). https://www.health.nsw.gov.au/environment/factsheets/Pages/mercury.aspx.

Northcote, KH. and Skene, JKM. (1972). *Australian Soils with Saline and Sodic properties.* CSIRO Australia, Soil Publication No. 27, Canberra.

RGS (2020). *Geochemical Assessment of Waste Rock and Coal Reject. Vulcan Complex Project*. Prepared on behalf of Mining & Energy Technical Services Pty Ltd for Vitrinite Pty Ltd by RGS Environmental Pty Ltd. 18 June.

7 Attachments

Attachment A: Geochemical Assessment of Mining Materials

ACID GENERATION AND PREDICTION

Acid generation is caused by the exposure of sulfide minerals, most commonly pyrite (FeS_2), to atmospheric oxygen and water. Sulfur assay results are used to calculate the potential acidity that could be generated by the sample typically by determining the sulfidic S content directly. Pyrite reacts under oxidising conditions to generate acid according to the following overall reaction:

$$FeS_2 + 15/4\ O_2 + 7/2\ H_2O \text{ ---> } Fe(OH)_3 + 2\ H_2SO_4$$

According to this reaction, the maximum potential acidity (MPA) of a sample containing 1% S as pyrite would be 30.6 kg H_2SO_4/t. The chemical components of the acid generation process consist of the above sulfide oxidation reaction and acid neutralization, which is mainly provided by inherent carbonates and to a lesser extent silicate minerals. The amount and rate of acid generation is determined by the interaction and overall balance of the acid generation and neutralisation components.

Net Acid Producing Potential

The net acid producing potential (NAPP) is used as an indicator of materials that may be of concern with respect to acid generation. The NAPP calculation represents the balance between the maximum potential acidity (MPA) of a sample, which is derived from the sulfide sulfur content, and the acid neutralising capacity (ANC) of the material, which is determined experimentally. By convention, the NAPP result is expressed in units of kg H_2SO_4/t sample. If the capacity of the solids to neutralise acid (ANC) exceeds their capacity to generate acid (MPA), then the NAPP of the material is negative. Conversely, if the MPA exceeds the ANC, the NAPP of the material is positive. A NAPP assessment involves a series of analytical tests that include:

Determination of pH and EC

pH and EC measured on 1:5 w/w water extract. This gives an indication of the inherent acidity and salinity of the waste material when initially exposed in a waste emplacement area.

Total sulfur content and Maximum Potential Acidity (MPA)

Total sulfur content is determined by the Leco high temperature combustion method. The total sulfur content is then used to calculate the MPA, which assumes that the entire sulfur content is present as reactive pyrite. Direct determination of the pyritic sulfur content can provide a more accurate estimate of the MPA.

Acid neutralising capacity (ANC)

By addition of acid to a known weight of sample, then titration with NaOH to determine the amount of residual acid. The ANC measures the capacity of a sample to react with and neutralise acid. The ANC can be further evaluated by slow acid titration to a set end-point in the Acid Buffering Characteristic Curve (ABCC) test through calculation of the amount of acid consumed and evaluation of the resultant titration curve.

ASSESSMENT OF ELEMENT ENRICHMENT AND SOLUBILITY

In mineralised areas it is common to find a suite of enriched elements that have resulted from natural geological processes. Multi-element scans are carried out to identify any elements that are present in a material (or readily leachable from a material) at concentrations that may be of environmental concern with respect to surface water quality, revegetation and public health. The samples are generally analysed for the following elements:

Major elements: Al, Ca, Fe, K, Mg, Na and S.

Minor elements: As, B, Cd, Co, Cr, Cu, F, Hg, Mn, Mo, Ni, Pb, Sb, Se, and Zn.

The concentration of these elements in samples can be directly compared with relevant state or national environmental and health-based concentration guideline criteria to determine the level of significance. Water

extracts are used to determine the immediate element solubilities under the existing sample pH conditions of the sample. The following tests are normally carried out:

Multi-element composition of solids.

Multi-element composition of solid samples determined using a combination of ICP-mass spectroscopy (ICP-MS), ICP-optical emission spectroscopy (OES), and atomic absorption spectrometry (AAS).

Multi-element composition of water extracts (1:5 sample:deionised water).

Multi-element composition of water extracts from solid samples determined using a combination of ICP-mass spectroscopy (ICP-MS), ICP-optical emission spectroscopy (OES), and atomic absorption spectrometry (AAS).

Under some conditions (*e.g.* low pH) the solubility and mobility of common environmentally important elements can increase significantly. If element mobility under initial pH conditions is deemed likely and/or subsequent low pH conditions may occur, kinetic leach column test work may be completed on representative samples.

Attachment B: Static Geochemical Test Results

Table B1: Acid Base Account Results for Waste Rock and Coal from the Vulcan Coal Mine Matilda Pit Project

Sample No.	Date	RGS Sample ID	ALS Lab ID	Drill Hole ID	Client Sample ID	Sample Lithology	Weathering	Sample Location in Pit	From	To	Interval	pH (1:5)	EC (1:5)	Total S	Scr	ANC[2]	MPA[2]	NAPP[2]	ANC: MPA Ratio	Sample Classification[3]	Composite
1	2022	2022049_016	EB2218704016	VSW263_O	147220	Coal	Fresh	Coal	35.00	36.00	1.00	9.1	120	1.09	0.732	13.8	22.4	8.6	0.6	Potentially Acid Forming - Low Capacity	2022049_C001
2	2022	2022049_036	EB2218704036	VSW264_O	147250	Coal	Fresh	Coal	33.00	34.00	1.00	9.2	132	1.00	0.605	72.8	18.5	-54.3	3.9	Non-Acid Forming	2022049_C001
3	2022	2022049_040	EB2218704040	VSW264_O	147240	Sandstone	Fresh	Interburden	39.00	42.00	3.00	8.5	263	0.80	0.697	6.5	21.3	14.8	0.3	Potentially Acid Forming	2022049_C002
4	2022	2022049_039	EB2218704039	VSW264_O	147239	Sandstone	Fresh	Interburden	36.00	39.00	3.00	8.9	192	0.33	0.324	7.2	9.9	2.7	0.7	Uncertain	2022049_C002
5	2022	2022049_020	EB2218704020	VSW263_O	147219	Sandstone	Fresh	Interburden	40.00	42.00	2.00	9.2	165	0.11	0.106	7.4	3.2	-4.2	2.3	Uncertain	2022049_C002
6	2022	2022049_026	EB2218704026	VSW264_O	147227	Sandstone	Fresh	Overburden	14.00	16.00	2.00	6.5	281	0.14	0.120	3.3	3.7	0.4	0.9	Uncertain	2022049_C003
7	2022	2022049_006	EB2218704006	VSW263_O	147206	Sandstone	Fresh	Overburden	13.00	16.00	3.00	6.7	78	0.08		<0.5	2.5	2.2	0.1	Non-Acid Forming (Barren)	2022049_C003
8	2022	2022049_028	EB2218704028	VSW264_O	147229	Sandstone	Fresh	Overburden	17.00	19.00	2.00	6.8	330	0.38	0.326	4.1	10.0	5.9	0.4	Potentially Acid Forming - Low Capacity	2022049_C003
9	2022	2022049_007	EB2218704007	VSW263_O	147207	Sandstone	Fresh	Overburden	16.00	18.00	2.00	7.0	324	0.14	0.129	4.8	4.0	-0.8	1.2	Uncertain	2022049_C003
10	2022	2022049_010	EB2218704010	VSW263_O	147210	Sandstone	Fresh	Overburden	24.00	27.00	3.00	9.0	271	0.21	0.182	84.5	5.6	-78.9	15.2	Non-Acid Forming	2022049_C003
11	2022	2022049_030	EB2218704030	VSW264_O	147231	Sandstone	Fresh	Overburden	22.00	25.00	3.00	9.0	249	0.34	0.328	79.7	10.0	-69.7	7.9	Non-Acid Forming	2022049_C003
12	2022	2022049_031	EB2218704031	VSW264_O	147232	Sandstone	Fresh	Overburden	25.00	27.00	2.00	9.1	223	0.41	0.386	81.7	11.8	-69.9	6.9	Non-Acid Forming	2022049_C003
13	2022	2022049_011	EB2218704011	VSW263_O	147211	Sandstone	Fresh	Overburden	27.00	29.00	2.00	9.2	224	0.19	0.170	37.2	5.2	-32.0	7.1	Non-Acid Forming	2022049_C003
14	2022	2022049_025	EB2218704025	VSW264_O	147226	Sandstone	Slightly Weathered	Overburden	11.00	14.00	3.00	5.9	120	0.12	0.120	<0.5	3.7	3.4	0.1	Uncertain	2022049_C004
15	2022	2022049_022	EB2218704022	VSW264_O	147223	Sandstone	Slightly Weathered	Overburden	3.00	6.00	3.00	6.0	76	0.04		<0.5	1.2	1.0	0.2	Non-Acid Forming (Barren)	2022049_C004
16	2022	2022049_001	EB2218704001	VSW263_O	147201	Sandstone	Slightly Weathered	Overburden	0.10	3.00	2.90	6.2	31	0.02		<0.5	0.6	0.4	0.4	Non-Acid Forming (Barren)	2022049_C004
17	2022	2022049_021	EB2218704021	VSW264_O	147222	Sandstone	Slightly Weathered	Overburden	0.10	3.00	2.90	6.4	28	0.01		<0.5	0.3	0.1	0.8	Non-Acid Forming (Barren)	2022049_C004
18	2022	2022049_003	EB2218704003	VSW263_O	147203	Sandstone	Slightly Weathered	Overburden	6.00	7.00	1.00	7.6	97	0.05		3.5	1.5	-2.0	2.3	Non-Acid Forming (Barren)	2022049_C004
19	2022	2022049_037	EB2218704037	VSW264_O	147237	Siltstone	Fresh	Floor	34.00	35.00	1.00	9.2	142	0.28	0.236	10.5	7.2	-3.3	1.5	Uncertain	2022049_C005
20	2022	2022049_017	EB2218704017	VSW263_O	147216	Siltstone	Fresh	Floor	36.00	37.00	1.00	9.3	177	0.15	0.140	6.7	4.3	-2.4	1.6	Uncertain	2022049_C005
21	2022	2022049_038	EB2218704038	VSW264_O	147238	Siltstone	Fresh	Interburden	35.00	36.00	1.00	9.1	161	0.21	0.196	13.6	6.0	-7.6	2.3	Non-Acid Forming	2022049_C006
22	2022	2022049_018	EB2218704018	VSW263_O	147217	Siltstone	Fresh	Interburden	37.00	38.00	1.00	9.3	153	0.08		11.7	2.5	-9.3	4.8	Non-Acid Forming (Barren)	2022049_C006
23	2022	2022049_019	EB2218704019	VSW263_O	147218	Siltstone	Fresh	Interburden	38.00	40.00	2.00	9.3	173	0.09		11.7	2.8	-8.9	4.2	Non-Acid Forming (Barren)	2022049_C006
24	2022	2022049_014	EB2218704014	VSW263_O	147214	Siltstone	Fresh	Overburden	33.00	34.00	1.00	9.2	197	0.14	0.140	16.9	4.3	-12.6	3.9	Non-Acid Forming	2022049_C006
25	2022	2022049_033	EB2218704033	VSW264_O	147234	Siltstone	Fresh	Overburden	30.00	31.00	1.00	9.2	178	0.08		17.3	2.5	-14.9	7.1	Non-Acid Forming (Barren)	2022049_C006
26	2022	2022049_034	EB2218704034	VSW264_O	147235	Siltstone	Fresh	Overburden	31.00	32.00	1.00	9.2	178	0.16	0.143	18.8	4.4	-14.4	4.3	Non-Acid Forming	2022049_C006
27	2022	2022049_013	EB2218704013	VSW263_O	147213	Siltstone	Fresh	Overburden	32.00	33.00	1.00	9.4	194	0.11	0.101	19.9	3.1	-16.8	6.4	Non-Acid Forming	2022049_C006
28	2022	2022049_008	EB2218704008	VSW263_O	147208	Siltstone	Fresh	Overburden	18.00	21.00	3.00	5.5	441	0.78	0.657	2.6	20.1	17.5	0.1	Potentially Acid Forming	2022049_C007
29	2022	2022049_027	EB2218704027	VSW264_O	147228	Siltstone	Fresh	Overburden	16.00	17.00	1.00	6.5	320	0.19	0.158	1.9	4.8	2.9	0.4	Uncertain	2022049_C007
30	2022	2022049_029	EB2218704029	VSW264_O	147230	Siltstone	Fresh	Overburden	19.00	22.00	3.00	7.2	416	1.46	1.100	7.3	33.7	26.4	0.2	Potentially Acid Forming	2022049_C007
31	2022	2022049_009	EB2218704009	VSW263_O	147209	Siltstone	Fresh	Overburden	21.00	24.00	3.00	7.9	285	0.45	0.454	9.2	13.9	4.7	0.7	Uncertain	2022049_C007
32	2022	2022049_012	EB2218704012	VSW263_O	147212	Siltstone	Fresh	Overburden	29.00	32.00	3.00	8.7	344	0.78	0.670	23.8	20.5	-3.3	1.2	Uncertain	2022049_C007
33	2022	2022049_032	EB2218704032	VSW264_O	147233	Siltstone	Fresh	Overburden	27.00	30.00	3.00	9.1	210	0.48	0.472	29.3	14.5	-14.8	2.0	Non-Acid Forming	2022049_C007
34	2022	2022049_035	EB2218704035	VSW264_O	147236	Siltstone	Fresh	Roof	32.00	33.00	1.00	8.9	206	2.13	1.790	19.4	54.8	35.4	0.4	Potentially Acid Forming	2022049_C008
35	2022	2022049_015	EB2218704015	VSW263_O	147215	Siltstone	Fresh	Roof	34.00	35.00	1.00	9.3	171	0.84	0.767	119.0	23.5	-95.5	5.1	Non-Acid Forming	2022049_C008
36	2022	2022049_002	EB2218704002	VSW263_O	147202	Siltstone	Slightly Weathered	Overburden	3.00	6.00	3.00	6.2	80	0.07		1.3	2.1	0.8	0.6	Non-Acid Forming (Barren)	2022049_C009
37	2022	2022049_024	EB2218704024	VSW264_O	147225	Siltstone	Slightly Weathered	Overburden	9.00	11.00	2.00	7.1	190	0.30	0.282	<0.5	8.6	8.4	0.0	Potentially Acid Forming - Low Capacity	2022049_C009
38	2022	2022049_023	EB2218704023	VSW264_O	147224	Siltstone	Slightly Weathered	Overburden	6.00	9.00	3.00	7.4	117	0.14	0.139	6.0	4.3	-1.7	1.4	Uncertain	2022049_C009
39	2022	2022049_005	EB2218704005	VSW263_O	147205	Siltstone	Slightly Weathered	Overburden	10.00	13.00	3.00	7.6	136	0.22	0.223	7.0	6.8	-0.2	1.0	Uncertain	2022049_C009
40	2022	2022049_004	EB2218704004	VSW263_O	147204	Siltstone	Slightly Weathered	Overburden	7.00	10.00	3.00	7.9	89	0.12	0.106	9.4	3.2	-6.2	2.9	Non-Acid Forming	2022049_C009
41	44776	2022049_041	EB2222926001	VSW205_C	179695-180303	Coarse Reject	Fresh	Coarse Reject				3.3	2,360	5.16	4.880	6.7	149.5	142.8	0.0	Potentially Acid Forming	2022049_C010
42	44776	2022049_043	EB2222926003	VSW206_C	180306-180311	Coarse Reject	Fresh	Coarse Reject				3.7	1,620	3.00	2.870	<0.5	87.9	87.6	0.0	Potentially Acid Forming	2022049_C010
43	44776	2022049_045	EB2222926005	VSW225_C	164433-164440	Coarse Reject	Fresh	Coarse Reject				5.3	619	1.55	1.360	22.8	41.7	18.9	0.5	Potentially Acid Forming	2022049_C010
44	44776	2022049_047	EB2222926007	VSW226_C	164355-164360	Coarse Reject	Fresh	Coarse Reject				3.1	2,300	3.11	2.820	<0.5	86.4	86.1	0.0	Potentially Acid Forming	2022049_C011
45	44776	2022049_049	EB2222926009	VSW227_C3	164387-164391	Coarse Reject	Fresh	Coarse Reject				3.6	1,730	3.54	3.200	11.1	98.0	86.9	0.1	Potentially Acid Forming	2022049_C011
46	44776	2022049_051	EB2222926011	VSW228_C	164380-164384	Coarse Reject	Fresh	Coarse Reject				3.6	2,270	3.07	2.620	15.2	80.2	65.0	0.2	Potentially Acid Forming	2022049_C011
47	44776	2022049_053	EB2222926013	VSW229_C	145103-145108	Coarse Reject	Fresh	Coarse Reject				3.6	1,400	3.54	3.520	15.8	107.8	92.0	0.1	Potentially Acid Forming	2022049_C011
48	44776	2022049_046	EB2222926006	VSW225_C	164433-164440	Fine Reject	Fresh	Fine Reject				6.8	297	1.10	1.000	25.3	30.6	5.3	0.8	Potentially Acid Forming - Low Capacity	2022049_C012
49	44776	2022049_048	EB2222926008	VSW226_C	164355-164360	Fine Reject	Fresh	Fine Reject				5.9	427	1.04	0.796	12.8	24.4	11.6	0.5	Potentially Acid Forming	2022049_C012
50	44776	2022049_054	EB2222926014	VSW229_C	145103-145108	Fine Reject	Fresh	Fine Reject				4.9	755	3.38	3.250	13.9	99.5	85.6	0.1	Potentially Acid Forming	2022049_C012
51	44776	2022049_042	EB2222926002	VSW205_C	179695-180303	Fine Reject	Fresh	Fine Reject				5.5	484	1.07	0.841	18.1	25.8	7.7	0.7	Potentially Acid Forming - Low Capacity	2022049_C013
52	44776	2022049_044	EB2222926004	VSW206_C	180306-180311	Fine Reject	Fresh	Fine Reject				6.5	387	1.48	1.260	13.0	38.6	25.6	0.3	Potentially Acid Forming	2022049_C013
53	44776	2022049_050	EB2222926010	VSW227_C3	164387-164391	Fine Reject	Fresh	Fine Reject				4.3	1,170	3.15	3.140	12.4	96.2	83.8	0.1	Potentially Acid Forming	2022049_C013
54	44776	2022049_052	EB2222926012	VSW228_C	164380-164384	Fine Reject	Fresh	Fine Reject				5.8	616	1.57	1.230	19.2	37.7	18.5	0.5	Potentially Acid Forming	2022049_C013

Notes:

1. Current pH, EC, Alkalinity and Acidity provided for 1:5 sample:water extracts
2. Scr = Chromium Reducible Sulfur; MPA = Maximum Potential Acidity; ANC = Acid Neutralising Capacity; NAPP = Net Acid Producing Potential; NAG = Net Acid Generation.
3. Sample classification criteria detail provided in report text.

* Where total sulfur or ANC results are less than the laboratory LoR a value of half of the LoR is used .

Table B2: Multi-Element and Exchangeable Cation Results for Waste Rock and Coal from the Vulcan Coal Mine Matilda Pit Project

	RGS Sample Number →		2022049_C001	2022049_C002	2022049_C003	2022049_C004	2022049_C005
	Sampling Date →		01/08/2022	01/08/2022	01/08/2022	01/08/2022	01/08/2022
	ALS Laboratory ID →		EB2222546001	EB2222546002	EB2222546003	EB2222546004	EB2222546005
Parameters	**Limit of Reporting**	NEPC[1] Health-Based Investigation Level (HILs)-C	Fresh Coal	Fresh Sandstone Interburden	Fresh Sandstone Overburden	Slightly Weathered Sandstone Overburden	Fresh Siltstone Floor
pH	0.1	-	8.8	8.7	8.7	5.8	9.1
Electrical Conductivity	1	-	164	215	310	60	175
Major Cations		-	All units mg/kg				
Calcium (Ca)	50	-	45,000	2,210	13,700	190	2,230
Magnesium (Mg)	50	-	1,780	1,110	2,840	440	1,480
Potassium (K)	50	-	1,170	1,220	1,490	1,170	1,350
Sodium (Na)	50	-	230	180	250	60	200
Aluminium (Al)	50	-	1,550	1,410	1,930	1,830	1,310
Iron (Fe)	50	-	28,500	15,500	21,800	9,980	13,100
Minor and Trace Elements		-	All units mg/kg				
Arsenic (As)	0.1	300	9.0	3.9	5.4	4.6	6.1
Boron (B)	50	20,000	<50	<50	<50	<50	<50
Barium (Ba)	0.1	-	119.0	52.4	61.8	30.2	23.5
Beryllium (Be)	0.1	90	0.7	0.4	0.6	0.3	0.5
Cadmium (Cd)	0.1	90	0.1	<0.1	<0.1	<0.1	<0.1
Cobalt (Co)	0.1	300	6.6	4.5	7.0	3.5	8.0
Chromium (Cr) *	0.1	300	0.7	2.0	3.1	2.6	1.9
Copper (Cu)	0.1	17,000	29.6	6.4	8.2	5.1	20.0
Mercury (Hg)	0.1	80	0.1	<0.1	<0.1	<0.1	<0.1
Manganese (Mn)	0.1	19,000	525.0	177.0	334.0	98.2	143.0
Molybdenum (Mo)	0.1	-	1.1	0.5	0.6	0.5	0.8
Nickel (Ni)	0.1	1,200	4.3	7.8	10.6	5.3	13.8
Lead (Pb)	0.1	600	11.1	16.2	14.3	10.8	20.6
Antimony (Sb)	0.1	-	0.3	0.2	0.2	0.2	0.2
Selenium (Se)	1	700	1	<1	<1	<1	<1
Thorium (Th)	0.1	-	2.3	1.4	2.1	1.2	2.2
Uranium (U)	0.1	-	0.5	0.3	0.4	0.2	0.4
Vanadium (V)	1	-	8	3	10	3	3
Zinc (Zn)	0.5	30,000	64.2	33.9	46.5	28.4	66.1
Exchangeable Cations		-	All units meq/100g (except Exchangable Sodium Percentage (%))				
Exchangeable Calcium	0.2	-	----	1.1	1.7	0.5	----
Exchangeable Potassium	0.2	-	----	0.2	0.4	0.2	----
Exchangeable Magnesium	0.2	-	----	0.8	1.8	1.0	----
Exchangeable Sodium	0.2	-	----	<0.2	0.5	0.2	----
Cation Exchange Capacity	0.2	-	----	2.1	4.3	2.1	----
Exchangeable Sodium Percent	0.2	-	----	<0.2	11.0	9.3	----
Calcium/Magnesium Ratio	0.2	-	----	1.4	1.0	0.5	----
Magnesium/Potassium Ratio	0.2	-	----	3.5	4.3	4.1	----

Notes:
< indicates less than the laboratory limit of reporting. Shaded cells exceed applied guideline limit.
* Guideline level for Cr(VI) = 300 mg/kg.
1. NEPC (2013). National Environmental Protection Council (NEPC). National Environmental Protection (Assessment of Site Contamination) Measure (NEPM), Amendment of Schedule B1-B7 of 1999 version. Guideline on Investigation Levels for Soil and Groundwater. Health-Based Investigation Level - HIL(C); public open spaces - recreational use.

Table B2: Multi-Element and Exchangeable Cation Results for Waste Rock and Coal from the Vulcan Coal Mine Matilda Pit Project

	RGS Sample Number →		2022049_C006	2022049_C007	2022049_C008	2022049_C009	2022049_C10
	Sampling Date →		01/08/2022	01/08/2022	01/08/2022	01/08/2022	17/08/2022
	ALS Laboratory ID →		EB2222546006	EB2222546007	EB2222546008	EB2222546009	EB2224164001
Parameters	**Limit of Reporting**	NEPC[1] Health-Based Investigation Level (HILs)-C	Fresh Slightly Carbonaceous Siltstone Overburden/Interburden	Fresh Siltstone Overburden	Fresh Siltstone Roof	Slightly Weathered Siltstone Overburden	Coarse Rejects
pH	0.1	-	9.1	8.4	8.9	7.3	4.0
Electrical Conductivity	1	-	195	363	230	135	1,390
Major Cations		-	All units mg/kg				
Calcium (Ca)	50	-	4,620	3,860	34,400	610	3,890
Magnesium (Mg)	50	-	3,040	3,040	4,900	1,580	1,920
Potassium (K)	50	-	1,530	1,770	1,360	1,600	1,080
Sodium (Na)	50	-	320	270	310	160	330
Aluminium (Al)	50	-	1,760	2,060	1,710	1,620	1,450
Iron (Fe)	50	-	30,600	33,700	38,900	25,900	49,400
Minor and Trace Elements		-	All units mg/kg				
Arsenic (As)	0.1	300	6.0	8.1	10.5	7.1	26.8
Boron (B)	50	20,000	<50	<50	<50	<50	<50
Barium (Ba)	0.1	-	25.8	28.6	178.0	48.2	38.4
Beryllium (Be)	0.1	90	0.6	0.6	0.7	0.9	1.8
Cadmium (Cd)	0.1	90	<0.1	<0.1	<0.1	0.1	0.1
Cobalt (Co)	0.1	300	7.8	8.2	5.5	9.6	10.4
Chromium (Cr) *	0.1	300	2.8	3.3	2.8	3.0	0.5
Copper (Cu)	0.1	17,000	16.8	13.8	19.4	17.3	76.8
Mercury (Hg)	0.1	80	<0.1	0.2	0.1	<0.1	1.1
Manganese (Mn)	0.1	19,000	369.0	402.0	625.0	329.0	745.0
Molybdenum (Mo)	0.1	-	0.6	0.6	1.7	0.7	1.0
Nickel (Ni)	0.1	1,200	11.8	16.1	7.5	15.5	7.8
Lead (Pb)	0.1	600	17.8	19.6	13.6	20.5	12.1
Antimony (Sb)	0.1	-	0.2	0.2	0.2	0.3	0.6
Selenium (Se)	1	700	<1	<1	<1	<1	2
Thorium (Th)	0.1	-	2.0	1.9	3.9	2.2	1.9
Uranium (U)	0.1	-	0.4	0.3	0.5	0.4	0.4
Vanadium (V)	1	-	10	9	12	7	5
Zinc (Zn)	0.5	30,000	60.2	59.5	44.9	82.4	64.3
Exchangeable Cations		-	All units meq/100g (except Exchangable Sodium Percentage (%))				
Exchangeable Calcium	0.2	-	1.8	----	----	1.0	----
Exchangeable Potassium	0.2	-	0.4	----	----	0.6	----
Exchangeable Magnesium	0.2	-	1.4	----	----	3.7	----
Exchangeable Sodium	0.2	-	0.5	----	----	0.6	----
Cation Exchange Capacity	0.2	-	4.1	----	----	6.0	----
Exchangeable Sodium Percent	0.2	-	11.7	----	----	10.0	----
Calcium/Magnesium Ratio	0.2	-	1.3	----	----	0.3	----
Magnesium/Potassium Ratio	0.2	-	3.4	----	----	6.6	----

Notes:
< indicates less than the laboratory limit of reporting. Shaded cells exceed applied guideline limit.
* Guideline level for Cr(VI) = 300 mg/kg.
1. NEPC (2013). National Environmental Protection Council (NEPC). National Environmental Protection (Assessment of Site Contamination) Measure (NEPM), Amendment of Schedule B1-B7 of 1999 version. Guideline on Investigation Levels for Soil and Groundwater. Health-Based Investigation Level - HIL(C); public open spaces - recreational use.

Table B2: Multi-Element and Exchangeable Cation Results for Waste Rock and Coal from the Vulcan Coal Mine Matilda Pit Project

	RGS Sample Number →		2022049_C11	2022049_C12	2022049_C13
	Sampling Date →		17/08/2022	17/08/2022	17/08/2022
	ALS Laboratory ID →		EB2224164002	EB2224164003	EB2224164004
Parameters	**Limit of Reporting**	NEPC[1] Health-Based Investigation Level (HILs)-C	Coarse Rejects	Fine Rejects	Fine Rejects
pH	0.1	-	3.4	5.3	5.1
Electrical Conductivity	1	-	1,790	533	652
Major Cations		-	All units mg/kg		
Calcium (Ca)	50	-	6,020	3,990	3,410
Magnesium (Mg)	50	-	1,910	1,710	1,480
Potassium (K)	50	-	1,180	1,310	1,220
Sodium (Na)	50	-	350	300	410
Aluminium (Al)	50	-	2,180	1,970	2,120
Iron (Fe)	50	-	38,900	45,300	34,200
Minor and Trace Elements		-	All units mg/kg		
Arsenic (As)	0.1	300	18.4	21.1	15.1
Boron (B)	50	20,000	<50	<50	<50
Barium (Ba)	0.1	-	39.7	63.1	61.5
Beryllium (Be)	0.1	90	0.9	1.1	0.9
Cadmium (Cd)	0.1	90	0.1	0.2	0.2
Cobalt (Co)	0.1	300	4.7	12.7	5.6
Chromium (Cr) *	0.1	300	0.2	1.3	0.7
Copper (Cu)	0.1	17,000	62.2	38.3	50.7
Mercury (Hg)	0.1	80	0.8	0.9	0.9
Manganese (Mn)	0.1	19,000	365.0	382.0	295.0
Molybdenum (Mo)	0.1	-	1.1	1.4	0.9
Nickel (Ni)	0.1	1,200	3.1	11.6	4.9
Lead (Pb)	0.1	600	10.9	13.7	17.3
Antimony (Sb)	0.1	-	0.7	0.4	0.5
Selenium (Se)	1	700	2	2	2
Thorium (Th)	0.1	-	2.1	1.9	1.7
Uranium (U)	0.1	-	0.7	0.4	0.4
Vanadium (V)	1	-	4	4	4
Zinc (Zn)	0.5	30,000	59.0	138.0	121.0
Exchangeable Cations		-	All units meq/100g (except Exchangable Sodium Percentage (%))		
Exchangeable Calcium	0.2	-	----	----	----
Exchangeable Potassium	0.2	-	----	----	----
Exchangeable Magnesium	0.2	-	----	----	----
Exchangeable Sodium	0.2	-	----	----	----
Cation Exchange Capacity	0.2	-	----	----	----
Exchangeable Sodium Percent	0.2	-	----	----	----
Calcium/Magnesium Ratio	0.2	-	----	----	----
Magnesium/Potassium Ratio	0.2	-	----	----	----

Notes:
< indicates less than the laboratory limit of reporting. Shaded cells exceed applied guideline limit.
* Guideline level for Cr(VI) = 300 mg/kg.
1. NEPC (2013). National Environmental Protection Council (NEPC). National Environmental Protection (Assessment of Site Contamination) Measure (NEPM), Amendment of Schedule B1-B7 of 1999 version. Guideline on Investigation Levels for Soil and Groundwater. Health-Based Investigation Level - HIL(C); public open spaces - recreational use.

Table B3: Geochemical Abundance Index (GAI) Results for Waste Rock and Coal from the Vulcan Coal Mine Matilda Pit Project

		RGS Sample Number →	2022049_C001	2022049_C002	2022049_C003	2022049_C004	2022049_C005
		Sampling Date →	01/08/2022	01/08/2022	01/08/2022	01/08/2022	01/08/2022
		ALS Laboratory ID →	EB2222546001	EB2222546002	EB2222546003	EB2222546004	EB2222546005
Parameters	**Limit of Reporting**	Median Crustal Abundance[1,2,3]	Fresh Coal	Fresh Sandstone Interburden	Fresh Sandstone Overburden	Slightly Weathered Sandstone Overburden	Fresh Siltstone Floor
Major Cations	(All units in mg/kg)		Geochemical Abundance Index				
Calcium (Ca)	50	15,000	1.0	0.0	0.0	0.0	0.0
Magnesium (Mg)	50	5,000	0.0	0.0	0.0	0.0	0.0
Potassium (K)	50	14,000	0.0	0.0	0.0	0.0	0.0
Sodium (Na)	50	5,000	0.0	0.0	0.0	0.0	0.0
Aluminium (Al)	50	71,000	0.0	0.0	0.0	0.0	0.0
Iron (Fe)	50	40,000	0.0	0.0	0.0	0.0	0.0
Minor and Trace Elements	(All units in mg/kg)		Geochemical Abundance Index				
Arsenic (As)	0.1	6	0.0	0.0	0.0	0.0	0.0
Boron (B)	50	20	0.0	0.0	0.0	0.0	0.0
Barium (Ba)	0.1	500	0.0	0.0	0.0	0.0	0.0
Beryllium (Be)	0.1	0.3	0.6	0.0	0.4	0.0	0.2
Cadmium (Cd)	0.1	0.35	0.0	0.0	0.0	0.0	0.0
Cobalt (Co)	0.1	8	0.0	0.0	0.0	0.0	0.0
Chromium (Cr)	0.1	70	0.0	0.0	0.0	0.0	0.0
Copper (Cu)	0.1	30	0.0	0.0	0.0	0.0	0.0
Mercury (Hg)	0.1	0.06	0.2	0.0	0.0	0.0	0.0
Manganese (Mn)	0.1	1000	0.0	0.0	0.0	0.0	0.0
Molybdenum (Mo)	0.1	1.2	0.0	0.0	0.0	0.0	0.0
Nickel (Ni)	0.1	50	0.0	0.0	0.0	0.0	0.0
Lead (Pb)	0.1	35	0.0	0.0	0.0	0.0	0.0
Antimony (Sb)	0.1	1	0.0	0.0	0.0	0.0	0.0
Selenium (Se)	1	0.4	0.7	0.0	0.0	0.0	0.0
Thorium (Th)	0.1	9	0.0	0.0	0.0	0.0	0.0
Uranium (U)	0.1	2	0.0	0.0	0.0	0.0	0.0
Vanadium (V)	1	90	0.0	0.0	0.0	0.0	0.0
Zinc (Zn)	0.5	90	0.0	0.0	0.0	0.0	0.0

Notes: GAI's greater than or equal to 3 are highlighted.

1. Median Crustal Abundance values sourced from the "GARD Guide", Chapter 5 (INAP, 2009).

2. When no GARD Guide value is available for particular element, then values are taken from Bowen (1979) Environmental Chemistry of the Elements, p 60-61.

3. If no guide value from GARD or Bowen H.J.M. (1979) exists, up to date, curated data is provided by CRC Handbook of Chemistry and Physics (2000).

Table B3: Geochemical Abundance Index (GAI) Results for Waste Rock and Coal from the Vulcan Coal Mine Matilda Pit Project

		RGS Sample Number →	2022049_C006	2022049_C007	2022049_C008	2022049_C009	2022049_C10
		Sampling Date →	01/08/2022	01/08/2022	01/08/2022	01/08/2022	17/08/2022
		ALS Laboratory ID →	EB2222546006	EB2222546007	EB2222546008	EB2222546009	EB2224164001
Parameters	**Limit of Reporting**	Median Crustal Abundance[1,2,3]	Fresh Slightly Carbonaceous Siltstone Overburden/Interburden	Fresh Siltstone Overburden	Fresh Siltstone Roof	Slightly Weathered Siltstone Overburden	Coarse Rejects
Major Cations	(All units in mg/kg)		Geochemical Abundance Index				
Calcium (Ca)	50	15,000	0.0	0.0	0.6	0.0	0.0
Magnesium (Mg)	50	5,000	0.0	0.0	0.0	0.0	0.0
Potassium (K)	50	14,000	0.0	0.0	0.0	0.0	0.0
Sodium (Na)	50	5,000	0.0	0.0	0.0	0.0	0.0
Aluminium (Al)	50	71,000	0.0	0.0	0.0	0.0	0.0
Iron (Fe)	50	40,000	0.0	0.0	0.0	0.0	0.0
Minor and Trace Elements	(All units in mg/kg)		Geochemical Abundance Index				
Arsenic (As)	0.1	6	0.0	0.0	0.2	0.0	1.6
Boron (B)	50	20	0.0	0.0	0.0	0.0	0.0
Barium (Ba)	0.1	500	0.0	0.0	0.0	0.0	0.0
Beryllium (Be)	0.1	0.3	0.4	0.4	0.6	1.0	2.0
Cadmium (Cd)	0.1	0.35	0.0	0.0	0.0	0.0	0.0
Cobalt (Co)	0.1	8	0.0	0.0	0.0	0.0	0.0
Chromium (Cr)	0.1	70	0.0	0.0	0.0	0.0	0.0
Copper (Cu)	0.1	30	0.0	0.0	0.0	0.0	0.8
Mercury (Hg)	0.1	0.06	0.0	1.2	0.2	0.0	3.6
Manganese (Mn)	0.1	1000	0.0	0.0	0.0	0.0	0.0
Molybdenum (Mo)	0.1	1.2	0.0	0.0	0.0	0.0	0.0
Nickel (Ni)	0.1	50	0.0	0.0	0.0	0.0	0.0
Lead (Pb)	0.1	35	0.0	0.0	0.0	0.0	0.0
Antimony (Sb)	0.1	1	0.0	0.0	0.0	0.0	0.0
Selenium (Se)	1	0.4	0.0	0.0	0.0	0.0	1.7
Thorium (Th)	0.1	9	0.0	0.0	0.0	0.0	0.0
Uranium (U)	0.1	2	0.0	0.0	0.0	0.0	0.0
Vanadium (V)	1	90	0.0	0.0	0.0	0.0	0.0
Zinc (Zn)	0.5	90	0.0	0.0	0.0	0.0	0.0

Notes: GAI's greater than or equal to 3 are highlighted.

1. Median Crustal Abundance values sourced from the "GARD Guide", Chapter 5 (INAP, 2009).

2. When no GARD Guide value is available for particular element, then values are taken from Bowen (1979) Environmental Chemistry of the Elements, p 60-61.

3. If no guide value from GARD or Bowen H.J.M. (1979) exists, up to date, curated data is provided by CRC Handbook of Chemistry and Physics (2000).

Table B3: Geochemical Abundance Index (GAI) Results for Waste Rock and Coal from the Vulcan Coal Mine Matilda Pit Project

	RGS Sample Number →		2022049_C11	2022049_C12	2022049_C13
	Sampling Date →		17/08/2022	17/08/2022	17/08/2022
	ALS Laboratory ID →		EB2224164002	EB2224164003	EB2224164004
Parameters	**Limit of Reporting**	Median Crustal Abundance[1,2,3]	Coarse Rejects	Fine Rejects	Fine Rejects
Major Cations	(All units in mg/kg)		Geochemical Abundance Index		
Calcium (Ca)	50	15,000	0.0	0.0	0.0
Magnesium (Mg)	50	5,000	0.0	0.0	0.0
Potassium (K)	50	14,000	0.0	0.0	0.0
Sodium (Na)	50	5,000	0.0	0.0	0.0
Aluminium (Al)	50	71,000	0.0	0.0	0.0
Iron (Fe)	50	40,000	0.0	0.0	0.0
Minor and Trace Elements	(All units in mg/kg)		Geochemical Abundance Index		
Arsenic (As)	0.1	6	1.0	1.2	0.7
Boron (B)	50	20	0.0	0.0	0.0
Barium (Ba)	0.1	500	0.0	0.0	0.0
Beryllium (Be)	0.1	0.3	1.0	1.3	1.0
Cadmium (Cd)	0.1	0.35	0.0	0.0	0.0
Cobalt (Co)	0.1	8	0.0	0.1	0.0
Chromium (Cr)	0.1	70	0.0	0.0	0.0
Copper (Cu)	0.1	30	0.5	0.0	0.2
Mercury (Hg)	0.1	0.06	3.2	3.3	3.3
Manganese (Mn)	0.1	1000	0.0	0.0	0.0
Molybdenum (Mo)	0.1	1.2	0.0	0.0	0.0
Nickel (Ni)	0.1	50	0.0	0.0	0.0
Lead (Pb)	0.1	35	0.0	0.0	0.0
Antimony (Sb)	0.1	1	0.0	0.0	0.0
Selenium (Se)	1	0.4	1.7	1.7	1.7
Thorium (Th)	0.1	9	0.0	0.0	0.0
Uranium (U)	0.1	2	0.0	0.0	0.0
Vanadium (V)	1	90	0.0	0.0	0.0
Zinc (Zn)	0.5	90	0.0	0.0	0.0

Notes: GAI's greater than or equal to 3 are highlighted.

1. Median Crustal Abundance values sourced from the "GARD Guide", Chapter 5 (INAP, 2009).

2. When no GARD Guide value is available for particular element, then values are taken from Bowen (1979) Environmental Chemistry of the Elements, p 60-61.

3. If no guide value from GARD or Bowen H.J.M. (1979) exists, up to date, curated data is provided by CRC Handbook of Chemistry and Physics (2000).

Table B4: Multi-Element Test Results for Water Extracts from Waste Rock and Coal from the Vulcan Coal Mine Matilda Pit Project

		RGS Sample Number →	2022049_C001	2022049_C002	2022049_C003	2022049_C004	2022049_C005
		Sample Date →	01/08/2022	01/08/2022	01/08/2022	01/08/2022	01/08/2022
		ALS Laboratory ID →	EB2222546001	EB2222546002	EB2222546003	EB2222546004	EB2222546005
Parameters	**Limit of Reporting**	Aquatic Ecosystems (freshwater)[1]	Livestock Drinking Water[2]	Fresh Coal	Fresh Sandstone Interburden	Fresh Sandstone Overburden	Slightly Weathered Sandstone Overburden	Fresh Siltstone Floor
pH	0.1 pH unit	6 to 9	-	8.8	8.7	8.7	5.8	9.1
Electrical Conductivity	1 µS/cm	<1,000#	3,580^	164	215	310	60	175
Carbonate Alkalinity (mg CaCO /L)	1 mg/L	-	-	180	<0.2	<0.2	<0.2	180
Bicarbonate Alkalinity (mg CaCO /L)	1 mg/L	-	-	5,760	990	3,520	108	540
Total Alkalinity (mg CaCO /L)	1 mg/L	-	-	5,940	990	3,520	108	720
Acidity (mg CaCO /L)	1 mg/L	-	-	<0.2	5	<0.2	155	<0.2
Net Alkalinity (mg CaCO /L)	1 mg/L	-	-	5,940	985	3,520	-47	720
Major Ions				All units mg/L				
Calcium (Ca)	2	-	1,000	8	10	12	<2	4
Magnesium (Mg)	2	-	-	4	4	8	<2	<2
Potassium (K)	2	-	-	8	20	24	12	16
Sodium (Na)	2	-	-	24	24	34	6	26
Chloride (Cl)	2	-	-	4	12	8	2	6
Fluoride (F)	0.2	-	2	1.2	0.2	0.6	<0.2	0.6
Sulfate (SO)	2	-	1,000	40	58	72	18	40
Silica (Si)	0.2	-	-	3.0	4.4	4.8	13.8	5.2
Reactive Phosphorus (P)	0.02	-	-	<0.02	<0.02	<0.02	<0.02	<0.02
Trace Metals/Metalloids				All units mg/L				
Aluminium (Al)	0.02	0.055	5	<0.02	0.02	0.02	0.08	0.04
Arsenic (As)	0.002	0.024 **	0.5	<0.002	0.002	0.002	<0.002	0.018
Boron (B)	0.2	0.37	5	<0.2	<0.2	<0.2	<0.2	<0.2
Barium (Ba)	0.002	-	-	0.036	0.028	0.012	<0.002	0.004
Beryllium (Be)	0.002	-	-	<0.002	<0.002	<0.002	<0.002	<0.002
Cadmium (Cd)	0.002	0.0002	0.01	<0.002	<0.002	<0.002	<0.002	<0.002
Cobalt (Co)	0.002	-	1	<0.002	<0.002	<0.002	<0.002	<0.002
Chromium (Cr)	0.002	0.001 (hex)*	1 (total)	<0.002	<0.002	<0.002	<0.002	<0.002
Copper (Cu)	0.002	0.0014	1	<0.002	<0.002	<0.002	<0.002	<0.002
Iron (Fe)	0.2	-	-	<0.2	<0.2	<0.2	<0.2	<0.2
Mercury (Hg)	0.0001	0.0006	0.002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Manganese (Mn)	0.002	1.9	-	<0.002	0.004	0.008	0.004	<0.002
Molybdenum (Mo)	0.002	-	0.15	0.010	0.018	0.022	<0.002	0.056
Nickel (Ni)	0.002	0.011	1	<0.002	<0.002	<0.002	<0.002	<0.002
Lead (Pb)	0.002	0.0034	0.1	<0.002	<0.002	<0.002	<0.002	<0.002
Antimony (Sb)	0.002	-	-	<0.002	0.006	0.004	<0.002	0.008
Selenium (Se)	0.02	0.011	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Thorium (Th)	0.002	-	-	<0.002	<0.002	<0.002	<0.002	<0.002
Uranium (U)	0.002	-	-	<0.002	<0.002	<0.002	<0.002	<0.002
Vanadium (V)	0.02	-	-	<0.02	<0.02	<0.02	<0.02	<0.02
Zinc (Zn)	0.01	0.008	20	<0.01	<0.01	<0.01	<0.01	<0.01

Notes: < indicates concentration less than the detection limit. Shaded cells exceed applied guideline values. * Cr (VI) = hexavalent. ** 0.013 mg/L for pentavalent Arsenic (V).

for still water bodies only, moving rivers at low flow rates should not exceed 2,200µS/cm. ^ calculated based on total dissolved solids (TDS) conversion rate of 0.67% of EC.

TDS is an approximate measure of inorganic dissolved salts and should not exceed 2,400mg/L for livestock drinking water. pH and EC of composites are median pH and EC values of individual samples reported in Table C2.

1. ANZG (2018). Trigger values for freshwater aquatic ecosystems (95% species protection level)

2. ANZG (2018). Recommended guideline limits for Livestock Drinking Water.

Table B4: Multi-Element Test Results for Water Extracts from Waste Rock and Coal from the Vulcan Coal Mine Matilda Pit Project

		RGS Sample Number →	2022049_C006	2022049_C007	2022049_C008	2022049_C009	2022049_C10
		Sample Date →	01/08/2022	01/08/2022	01/08/2022	01/08/2022	17/08/2022
		ALS Laboratory ID →	EB2222546006	EB2222546007	EB2222546008	EB2222546009	EB2224164001
Parameters	**Limit of Reporting**	Aquatic Ecosystems (freshwater)[1]	Livestock Drinking Water[2]	Fresh Slightly Carbonaceous Siltstone Overburden/Interburden	Fresh Siltstone Overburden	Fresh Siltstone Roof	Slightly Weathered Siltstone Overburden	Coarse Rejects
pH	0.1 pH unit	6 to 9	-	9.1	8.4	8.9	7.3	4.0
Electrical Conductivity	1 µS/cm	<1,000#	3,580^	195	363	230	135	1,390
Carbonate Alkalinity (mg $CaCO_3$ /L)	1 mg/L	-	-	<0.2	<0.2	18	<0.2	<0.2
Bicarbonate Alkalinity (mg $CaCO_3$ /L)	1 mg/L	-	-	1,008	738	6,120	306	18
Total Alkalinity (mg $CaCO_3$ /L)	1 mg/L	-	-	1,008	738	6,140	306	18
Acidity (mg $CaCO_3$ /L)	1 mg/L	-	-	<0.2	8	<0.2	74	416
Net Alkalinity (mg $CaCO_3$ /L)	1 mg/L	-	-	1,008	730	6,140	232	-398
Major Ions				All units mg/L				
Calcium (Ca)	2	-	1,000	2	16	8	<2	88
Magnesium (Mg)	2	-	-	<2	8	4	<2	60
Potassium (K)	2	-	-	14	30	12	16	16
Sodium (Na)	2	-	-	34	36	36	18	38
Chloride (Cl)	2	-	-	6	8	8	2	4
Fluoride (F)[4]	0.2	-	2	0.4	0.4	1.0	0.6	0.6
Sulfate (SO_4^{2-})	2	-	1,000	32	116	52	44	784
Silica (Si)	0.2	-	-	5.4	5.0	4.6	8.2	4.2
Reactive Phosphorus (P)	0.02	-	-	<0.02	<0.02	<0.02	<0.02	<0.02
Trace Metals/Metalloids				All units mg/L				
Aluminium (Al)	0.02	0.055	5	0.04	<0.02	0.02	<0.02	1.50
Arsenic (As)	0.002	0.024 **	0.5	0.014	<0.002	0.004	<0.002	0.016
Boron (B)	0.2	0.37	5	<0.2	<0.2	<0.2	<0.2	<0.2
Barium (Ba)	0.002	-	-	<0.002	0.006	0.064	0.004	0.052
Beryllium (Be)	0.002	-	-	<0.002	<0.002	<0.002	<0.002	0.020
Cadmium (Cd)	0.002	0.0002	0.01	<0.002	<0.002	<0.002	<0.002	<0.002
Cobalt (Co)	0.002	-	1	<0.002	<0.002	<0.002	<0.002	0.260
Chromium (Cr)	0.002	0.001 (hex)*	1 (total)	<0.002	<0.002	<0.002	<0.002	<0.002
Copper (Cu)	0.002	0.0014	1	<0.002	<0.002	<0.002	<0.002	0.266
Iron (Fe)	0.2	-	-	<0.2	<0.2	<0.2	<0.2	193.6
Mercury (Hg)	0.0001	0.0006	0.002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Manganese (Mn)	0.002	1.9	-	<0.002	0.014	0.002	0.044	3.540
Molybdenum (Mo)	0.002	-	0.15	0.058	0.022	0.038	0.002	0.004
Nickel (Ni)	0.002	0.011	1	<0.002	<0.002	<0.002	0.002	0.222
Lead (Pb)	0.002	0.0034	0.1	<0.002	<0.002	<0.002	<0.002	0.004
Antimony (Sb)	0.002	-	-	0.010	0.004	0.004	<0.002	<0.002
Selenium (Se)	0.02	0.011	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Thorium (Th)	0.002	-	-	<0.002	<0.002	<0.002	<0.002	<0.002
Uranium (U)	0.002	-	-	<0.002	<0.002	<0.002	<0.002	<0.002
Vanadium (V)	0.02	-	-	<0.02	<0.02	<0.02	<0.02	<0.02
Zinc (Zn)	0.01	0.008	20	<0.01	<0.01	<0.01	<0.01	0.51

Notes: < indicates concentration less than the detection limit. Shaded cells exceed applied guideline values. * Cr (VI) = hexavalent. ** 0.013 mg/L for pentavalent Arsenic (V).

for still water bodies only, moving rivers at low flow rates should not exceed 2,200µS/cm. ^ calculated based on total dissolved solids (TDS) conversion rate of 0.67% of EC.

TDS is an approximate measure of inorganic dissolved salts and should not exceed 2,400mg/L for livestock drinking water. pH and EC of composites are median pH and EC values of individual samples reported in Table C2.

1. ANZG (2018). Trigger values for freshwater aquatic ecosystems (95% species protection level)

2. ANZG (2018). Recommended guideline limits for Livestock Drinking Water.

Table B4: Multi-Element Test Results for Water Extracts from Waste Rock and Coal from the Vulcan Coal Mine Matilda Pit Project

		RGS Sample Number →		2022049_C11	2022049_C12	2022049_C13
		Sample Date →		17/08/2022	17/08/2022	17/08/2022
		ALS Laboratory ID →		EB2224164002	EB2224164003	EB2224164004
Parameters	**Limit of Reporting**	Aquatic Ecosystems (freshwater)[1]	Livestock Drinking Water[2]	Coarse Rejects	Fine Rejects	Fine Rejects
pH	0.1 pH unit	6 to 9	-	3.4	5.3	5.1
Electrical Conductivity	1 µS/cm	<1,000#	3,580^	1,790	533	652
Carbonate Alkalinity (mg $CaCO_3$ /L)	1 mg/L	-	-	<0.2	<0.2	<0.2
Bicarbonate Alkalinity (mg $CaCO_3$ /L)	1 mg/L	-	-	<0.2	12	21
Total Alkalinity (mg $CaCO_3$ /L)	1 mg/L	-	-	<0.2	12	21
Acidity (mg $CaCO_3$ /L)	1 mg/L	-	-	742	58	74
Net Alkalinity (mg $CaCO_3$ /L)	1 mg/L	-	-	-742	-46	-54
Major Ions				All units mg/L		
Calcium (Ca)	2	-	1,000	116	38	52
Magnesium (Mg)	2	-	-	60	20	30
Potassium (K)	2	-	-	20	10	10
Sodium (Na)	2	-	-	38	30	32
Chloride (Cl)	2	-	-	4	22	20
Fluoride (F)[4]	0.2	-	2	0.6	<0.2	<0.2
Sulfate (SO_4^{2-})	2	-	1,000	946	216	310
Silica (Si)	0.2	-	-	6.8	7.0	6.0
Reactive Phosphorus (P)	0.02	-	-	<0.02	<0.02	<0.02
Trace Metals/Metalloids				All units mg/L		
Aluminium (Al)	0.02	0.055	5	2.72	0.04	0.08
Arsenic (As)	0.002	0.024 **	0.5	0.026	<0.002	<0.002
Boron (B)	0.2	0.37	5	<0.2	<0.2	<0.2
Barium (Ba)	0.002	-	-	0.048	0.048	0.048
Beryllium (Be)	0.002	-	-	0.024	<0.002	<0.002
Cadmium (Cd)	0.002	0.0002	0.01	0.002	<0.002	<0.002
Cobalt (Co)	0.002	-	1	0.244	0.058	0.036
Chromium (Cr)	0.002	0.001 (hex)*	1 (total)	<0.002	<0.002	<0.002
Copper (Cu)	0.002	0.0014	1	0.444	0.026	0.040
Iron (Fe)	0.2	-	-	256.0	3.4	12.6
Mercury (Hg)	0.0001	0.0006	0.002	<0.0001	<0.0001	<0.0001
Manganese (Mn)	0.002	1.9	-	1.196	0.286	0.378
Molybdenum (Mo)	0.002	-	0.15	<0.002	<0.002	<0.002
Nickel (Ni)	0.002	0.011	1	0.228	0.048	0.030
Lead (Pb)	0.002	0.0034	0.1	0.016	<0.002	<0.002
Antimony (Sb)	0.002	-	-	0.004	<0.002	<0.002
Selenium (Se)	0.02	0.011	0.02	<0.02	<0.02	<0.02
Thorium (Th)	0.002	-	-	<0.002	<0.002	<0.002
Uranium (U)	0.002	-	-	0.004	<0.002	<0.002
Vanadium (V)	0.02	-	-	<0.02	<0.02	<0.02
Zinc (Zn)	0.01	0.008	20	0.44	0.52	0.67

Notes: < indicates concentration less than the detection limit. Shaded cells exceed applied guideline values. * Cr (VI) = hexavalent. ** 0.013 mg/L for pentavalent Arsenic (V).

for still water bodies only, moving rivers at low flow rates should not exceed 2,200µS/cm. ^ calculated based on total dissolved solids (TDS) conversion rate of 0.67% of EC.

TDS is an approximate measure of inorganic dissolved salts and should not exceed 2,400mg/L for livestock drinking water. pH and EC of composites are median pH and EC values of individual samples reported in Table C2.

1. ANZG (2018). Trigger values for freshwater aquatic ecosystems (95% species protection level)

2. ANZG (2018). Recommended guideline limits for Livestock Drinking Water.

Attachment C: ALS Laboratory Results

(Certificates of Analysis)

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB2218704**	Page	: 1 of 12
Client	: **RGS ENVIRONMENTAL CONSULTANTS PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: PETER LONG	Contact	: Customer Services EB
Address	: 3/30 LENSWORTH STREET COOPERS PLAINS 4107	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: 07 3344 1222	Telephone	: +61-7-3243 7222
Project	: 2022049 Vulcan Coal Mine Matilda Pit	Date Samples Received	: 27-Jun-2022 10:40
Order number	: ----	Date Analysis Commenced	: 01-Jul-2022
C-O-C number	: ----	Issue Date	: 08-Jul-2022 11:21
Sampler	: PRIYA RAJENDRAN		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 41		
No. of samples analysed	: 41		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ben Felgendrejeris	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contract for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- ASS: EA013 (ANC) Fizz Rating: 0- None; 1- Slight; 2- Moderate; 3- Strong; 4- Very Strong; 5- Lime.

Analytical Results

Sub-Matrix: **COAL**
(Matrix: **SOIL**)

			Sample ID	2022049_016 147220 VSW263_O Coal	2022049_036 147250 VSW264_O Coal	----	----	----
			Sampling date / time	22-Jun-2022 00:00	22-Jun-2022 00:00	----	----	----
Compound	CAS Number	LOR	Unit	EB2218704-016	EB2218704-036	--------	--------	--------
				Result	Result	----	----	----
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	**9.1**	**9.2**	**----**	**----**	**----**
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	**19.6**	**-42.2**	**----**	**----**	**----**
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	**120**	**132**	**----**	**----**	**----**
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	**13.8**	**72.8**	**----**	**----**	**----**
ANC as CaCO3	----	0.1	% CaCO3	**1.4**	**7.4**	**----**	**----**	**----**
Fizz Rating	----	0	Fizz Unit	**1**	**2**	**----**	**----**	**----**
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	**1.09**	**1.00**	**----**	**----**	**----**

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	Sample ID	2022049_001 147201 VSW263_O Sandstone	2022049_002 147202 VSW263_O Siltstone	2022049_003 147203 VSW263_O Sandstone	2022049_004 147204 VSW263_O Siltstone	2022049_005 147205 VSW263_O Siltstone
				Sampling date / time	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00
					EB2218704-001	EB2218704-002	EB2218704-003	EB2218704-004	EB2218704-005
					Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit		**6.2**	**6.2**	**7.6**	**7.9**	**7.6**
EA009: Net Acid Production Potential									
Net Acid Production Potential	----	0.5	kg H2SO4/t		**0.6**	**0.8**	**-2.0**	**-5.7**	**-0.3**
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm		**31**	**80**	**97**	**89**	**136**
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		<0.5	**1.3**	**3.5**	**9.4**	**7.0**
ANC as CaCO3	----	0.1	% CaCO3		<0.1	**0.1**	**0.4**	**1.0**	**0.7**
Fizz Rating	----	0	Fizz Unit		**0**	**0**	**0**	**1**	**0**
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		**0.02**	**0.07**	**0.05**	**0.12**	**0.22**

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	Sample ID	2022049_006 147206 VSW263_O Sandstone	2022049_007 147207 VSW263_O Sandstone	2022049_008 147208 VSW263_O Siltstone	2022049_009 147209 VSW263_O Siltstone	2022049_010 147210 VSW263_O Sandstone
				Sampling date / time	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00
					EB2218704-006	EB2218704-007	EB2218704-008	EB2218704-009	EB2218704-010
					Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit		**6.7**	**7.0**	**5.5**	**7.9**	**9.0**
EA009: Net Acid Production Potential									
Net Acid Production Potential	----	0.5	kg H2SO4/t		**2.4**	**-0.5**	**21.3**	**4.6**	**-78.1**
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm		**78**	**324**	**441**	**285**	**271**
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		<0.5	**4.8**	**2.6**	**9.2**	**84.5**
ANC as CaCO3	----	0.1	% CaCO3		<0.1	**0.5**	**0.3**	**0.9**	**8.6**
Fizz Rating	----	0	Fizz Unit		**0**	**0**	**0**	**1**	**2**
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		**0.08**	**0.14**	**0.78**	**0.45**	**0.21**

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	Sample ID	2022049_011 147211 VSW263_O Sandstone	2022049_012 147212 VSW263_O Siltstone	2022049_013 147213 VSW263_O Siltstone	2022049_014 147214 VSW263_O Siltstone	2022049_015 147215 VSW263_O Siltstone
				Sampling date / time	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00
					EB2218704-011	EB2218704-012	EB2218704-013	EB2218704-014	EB2218704-015
					Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit		**9.2**	**8.7**	**9.4**	**9.2**	**9.3**
EA009: Net Acid Production Potential									
Net Acid Production Potential	----	0.5	kg H2SO4/t		**-31.4**	<0.5	**-16.5**	**-12.6**	**-93.3**
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm		**224**	**344**	**194**	**197**	**171**
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		**37.2**	**23.8**	**19.9**	**16.9**	**119**
ANC as CaCO3	----	0.1	% CaCO3		**3.8**	**2.4**	**2.0**	**1.7**	**12.1**
Fizz Rating	----	0	Fizz Unit		**2**	**1**	**1**	**1**	**2**
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		**0.19**	**0.78**	**0.11**	**0.14**	**0.84**

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	Sample ID	2022049_017 147216 VSW263_O Siltstone	2022049_018 147217 VSW263_O Siltstone	2022049_019 147218 VSW263_O Siltstone	2022049_020 147219 VSW263_O Sandstone	2022049_021 147222 VSW263_O Sandstone
				Sampling date / time	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00
					EB2218704-017	EB2218704-018	EB2218704-019	EB2218704-020	EB2218704-021
					Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit		**9.3**	**9.3**	**9.3**	**9.2**	**6.4**
EA009: Net Acid Production Potential									
Net Acid Production Potential	----	0.5	kg H2SO4/t		**-2.1**	**-9.2**	**-8.9**	**-4.0**	<0.5
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm		**177**	**153**	**173**	**165**	**28**
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		**6.7**	**11.7**	**11.7**	**7.4**	<0.5
ANC as CaCO3	----	0.1	% CaCO3		**0.7**	**1.2**	**1.2**	**0.8**	<0.1
Fizz Rating	----	0	Fizz Unit		**1**	**1**	**1**	**1**	**0**
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		**0.15**	**0.08**	**0.09**	**0.11**	**0.01**

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	Sample ID	2022049_022 147223 VSW264_O Sandstone	2022049_023 147224 VSW264_O Siltstone	2022049_024 147225 VSW264_O Siltstone	2022049_025 147226 VSW264_O Sandstone	2022049_026 147227 VSW264_O Sandstone
				Sampling date / time	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00
					EB2218704-022	EB2218704-023	EB2218704-024	EB2218704-025	EB2218704-026
					Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit		**6.0**	**7.4**	**7.1**	**5.9**	**6.5**
EA009: Net Acid Production Potential									
Net Acid Production Potential	----	0.5	kg H2SO4/t		**1.2**	**-1.7**	**9.2**	**3.7**	**1.0**
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm		**76**	**117**	**190**	**120**	**281**
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		<0.5	**6.0**	<0.5	<0.5	**3.3**
ANC as CaCO3	----	0.1	% CaCO3		<0.1	**0.6**	<0.1	<0.1	**0.3**
Fizz Rating	----	0	Fizz Unit		**0**	**1**	**0**	**0**	**0**
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		**0.04**	**0.14**	**0.30**	**0.12**	**0.14**

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	Sample ID	2022049_027 147228 VSW264_O Siltstone	2022049_028 147229 VSW264_O Sandstone	2022049_029 147230 VSW264_O Siltstone	2022049_030 147231 VSW264_O Sandstone	2022049_031 147232 VSW264_O Sandstone
				Sampling date / time	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00
					EB2218704-027	EB2218704-028	EB2218704-029	EB2218704-030	EB2218704-031
					Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit		**6.5**	**6.8**	**7.2**	**9.0**	**9.1**
EA009: Net Acid Production Potential									
Net Acid Production Potential	----	0.5	kg H2SO4/t		**3.9**	**7.5**	**37.4**	**-69.3**	**-69.2**
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm		**320**	**330**	**416**	**249**	**223**
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		**1.9**	**4.1**	**7.3**	**79.7**	**81.7**
ANC as CaCO3	----	0.1	% CaCO3		**0.2**	**0.4**	**0.7**	**8.1**	**8.3**
Fizz Rating	----	0	Fizz Unit		**0**	**0**	**0**	**2**	**2**
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		**0.19**	**0.38**	**1.46**	**0.34**	**0.41**

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	Sample ID	2022049_032 147233 VSW264_O Siltstone	2022049_033 147234 VSW264_O Siltstone	2022049_034 147235 VSW264_O Siltstone	2022049_035 147236 VSW264_O Siltstone	2022049_037 147237 VSW264_O Siltstone
				Sampling date / time	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00
					EB2218704-032	EB2218704-033	EB2218704-034	EB2218704-035	EB2218704-037
					Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit		**9.1**	**9.2**	**9.2**	**8.9**	**9.2**
EA009: Net Acid Production Potential									
Net Acid Production Potential	----	0.5	kg H2SO4/t		**-14.6**	**-14.8**	**-13.9**	**45.8**	**-1.9**
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm		**210**	**178**	**178**	**206**	**142**
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		**29.3**	**17.3**	**18.8**	**19.4**	**10.5**
ANC as CaCO3	----	0.1	% CaCO3		**3.0**	**1.8**	**1.9**	**2.0**	**1.1**
Fizz Rating	----	0	Fizz Unit		**1**	**1**	**1**	**1**	**1**
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		**0.48**	**0.08**	**0.16**	**2.13**	**0.28**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2022049_038 147238 VSW264_O Siltstone	2022049_039 147239 VSW264_O Sandstone	2022049_040 147240 VSW264_O Sandstone	----	----
			Sampling date / time	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	----	----
Compound	CAS Number	LOR	Unit	EB2218704-038	EB2218704-039	EB2218704-040	--------	--------
				Result	Result	Result	----	----
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	**9.1**	**8.9**	**8.5**	**----**	**----**
EA009: Net Acid Production Potential								
Net Acid Production Potential	----	0.5	kg H2SO4/t	**-7.2**	**2.9**	**18.0**	**----**	**----**
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	**161**	**192**	**263**	**----**	**----**
EA013: Acid Neutralising Capacity								
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t	**13.6**	**7.2**	**6.5**	**----**	**----**
ANC as CaCO3	----	0.1	% CaCO3	**1.4**	**0.7**	**0.7**	**----**	**----**
Fizz Rating	----	0	Fizz Unit	**1**	**0**	**1**	**----**	**----**
ED042T: Total Sulfur by LECO								
Sulfur - Total as S (LECO)	----	0.01	%	**0.21**	**0.33**	**0.80**	**----**	**----**

Analytical Results

Sub-Matrix: **WATER** (Matrix: **SOIL**)				Sample ID	**DI water for PH and EC**	**----**	**----**	**----**	**----**
				Sampling date / time	22-Jun-2022 00:00	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*		**EB2218704-041**	**--------**	**--------**	**--------**	**--------**
					Result	----	----	----	----
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit		**5.4**	**----**	**----**	**----**	**----**
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm		<1	**----**	**----**	**----**	**----**

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB2220042**	Page	: 1 of 9
Client	: **RGS ENVIRONMENTAL CONSULTANTS PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: PETER LONG	Contact	: Customer Services EB
Address	: 3/30 LENSWORTH STREET COOPERS PLAINS 4108	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: 07 3344 1222	Telephone	: +61-7-3243 7222
Project	: 2022049 Vulcan Coal Mine Matilda Pit	Date Samples Received	: 08-Jul-2022 13:55
Order number	: ----	Date Analysis Commenced	: 18-Jul-2022
C-O-C number	: ----	Issue Date	: 19-Jul-2022 11:18
Sampler	: PRIYA RAJENDRAN		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 31		
No. of samples analysed	: 31		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ben Felgendrejeris	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contract for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2022049_004 147204 VSW263_O Siltstone	2022049_005 147205 VSW263_O Siltstone	2022049_007 147207 VSW263_O Sandstone	2022049_008 147208 VSW263_O Siltstone	2022049_009 147209 VSW263_O Siltstone
			Sampling date / time	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00
Compound	CAS Number	LOR	Unit	EB2220042-001	EB2220042-002	EB2220042-003	EB2220042-004	EB2220042-005
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	**0.106**	**0.223**	**0.129**	**0.657**	**0.454**

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

				Sample ID	2022049_010 147210 VSW263_O Sandstone	2022049_011 147211 VSW263_O Sandstone	2022049_012 147212 VSW263_O Siltstone	2022049_013 147213 VSW263_O Siltstone	2022049_014 147214 VSW263_O Siltstone
				Sampling date / time	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00
Compound	CAS Number	LOR	Unit		EB2220042-006	EB2220042-007	EB2220042-008	EB2220042-009	EB2220042-010
					Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur									
Chromium Reducible Sulphur	----	0.005	%		**0.182**	**0.170**	**0.670**	**0.101**	**0.140**

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	Sample ID	2022049_015 147215 VSW263_O Siltstone	2022049_016 147220 VSW263_O Coal	2022049_017 147216 VSW263_O Siltstone	2022049_020 147219 VSW263_O Sandstone	2022049_023 147224 VSW264_O Siltstone
				Sampling date / time	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00
				EB2220042-011	EB2220042-012	EB2220042-013	EB2220042-014	EB2220042-015	
				Result	Result	Result	Result	Result	
EA026 : Chromium Reducible Sulfur									
Chromium Reducible Sulphur	----	0.005	%	**0.767**	**0.732**	**0.140**	**0.106**	**0.139**	

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2022049_024 147225 VSW264_O Siltstone	2022049_025 147226 VSW264_O Sandstone	2022049_026 147227 VSW264_O Sandstone	2022049_027 147228 VSW264_O Siltstone	2022049_028 147229 VSW264_O Sandstone
			Sampling date / time	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00
Compound	CAS Number	LOR	Unit	EB2220042-016	EB2220042-017	EB2220042-018	EB2220042-019	EB2220042-020
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	**0.282**	**0.120**	**0.120**	**0.158**	**0.326**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2022049_029 147230 VSW264_O Siltstone	2022049_030 147231 VSW264_O Sandstone	2022049_031 147232 VSW264_O Sandstone	2022049_032 147233 VSW264_O Siltstone	2022049_034 147235 VSW264_O Siltstone
			Sampling date / time	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00
Compound	CAS Number	LOR	Unit	EB2220042-021	EB2220042-022	EB2220042-023	EB2220042-024	EB2220042-025
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	**1.10**	**0.328**	**0.386**	**0.472**	**0.143**

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2022049_035 147236 VSW264_O Siltstone	2022049_036 147250 VSW264_O Coal	2022049_037 147237 VSW264_O Siltstone	2022049_038 147238 VSW264_O Siltstone	2022049_039 147239 VSW264_O Sandstone
			Sampling date / time	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00	22-Jun-2022 00:00
Compound	CAS Number	LOR	Unit	EB2220042-026	EB2220042-027	EB2220042-028	EB2220042-029	EB2220042-030
				Result	Result	Result	Result	Result
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	**1.79**	**0.605**	**0.236**	**0.196**	**0.324**

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			Sample ID	**2022049_040 147240 VSW264_O Sandstone**	**----**	**----**	**----**	**----**
			Sampling date / time	22-Jun-2022 00:00	----	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**EB2220042-031**	**--------**	**--------**	**--------**	**--------**
				Result	----	----	----	----
EA026 : Chromium Reducible Sulfur								
Chromium Reducible Sulphur	----	0.005	%	**0.697**	**----**	**----**	**----**	**----**

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB2222926**	Page	: 1 of 5
Client	: **RGS ENVIRONMENTAL CONSULTANTS PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: PETER LONG	Contact	: Customer Services EB
Address	: 3/30 LENSWORTH STREET COOPERS PLAINS 4108	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: 07 3344 1222	Telephone	: +61-7-3243 7222
Project	: 2022049 Vulcan Coal Mine Matilda Pit	Date Samples Received	: 04-Aug-2022 14:57
Order number	: ----	Date Analysis Commenced	: 08-Aug-2022
C-O-C number	: ----	Issue Date	: 15-Aug-2022 11:34
Sampler	: ----		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 15		
No. of samples analysed	: 15		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ben Felgendrejeris	Senior Acid Sulfate Soil Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contract for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- ASS: EA013 (ANC) Fizz Rating: 0- None; 1- Slight; 2- Moderate; 3- Strong; 4- Very Strong; 5- Lime.

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	Sample ID	2022049_41 179695-180303 Coarse Reject VSW205_C Coarse Reject	2022049_42 179695-180303 Fine Reject VSW205_C Fine Reject	2022049_43 180306-180311 Coarse Reject VSW206_C Coarse Reject	2022049_44 180306-180311 Fine Reject VSW206_C Fine Reject	2022049_45 164433-164440 Coarse Reject VSW225_C Coarse Reject
				Sampling date / time	03-Aug-2022 00:00	03-Aug-2022 00:00	03-Aug-2022 00:00	03-Aug-2022 00:00	03-Aug-2022 00:00
					EB2222926-001	EB2222926-002	EB2222926-003	EB2222926-004	EB2222926-005
					Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit		**3.3**	**5.5**	**3.7**	**6.5**	**5.3**
EA009: Net Acid Production Potential									
Net Acid Production Potential	----	0.5	kg H2SO4/t		**151**	**14.6**	**91.8**	**32.3**	**24.6**
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm		**2360**	**484**	**1620**	**387**	**619**
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		**6.7**	**18.1**	<0.5	**13.0**	**22.8**
ANC as CaCO3	----	0.1	% CaCO3		**0.7**	**1.8**	<0.1	**1.3**	**2.3**
Fizz Rating	----	0	Fizz Unit		**1**	**1**	**0**	**1**	**1**
EA026 : Chromium Reducible Sulfur									
Chromium Reducible Sulphur	----	0.005	%		**4.88**	**0.841**	**2.87**	**1.26**	**1.36**
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		**5.16**	**1.07**	**3.00**	**1.48**	**1.55**

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	Sample ID	2022049_46 164433-164440 Fine Reject VSW225_C Fine Reject	2022049_47 164355-164360 Coarse Reject VSW226_C Coarse Reject	2022049_48 164355-164360 Fine Reject VSW226_C Fine Reject	2022049_49 164387-164391 Coarse Reject VSW227_C3 Coarse Reject	2022049_50 164387-164391 Fine Reject VSW227_C3 Fine Reject
				Sampling date / time	03-Aug-2022 00:00	03-Aug-2022 00:00	03-Aug-2022 00:00	03-Aug-2022 00:00	03-Aug-2022 00:00
					EB2222926-006	EB2222926-007	EB2222926-008	EB2222926-009	EB2222926-010
					Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit		**6.8**	**3.1**	**5.9**	**3.6**	**4.3**
EA009: Net Acid Production Potential									
Net Acid Production Potential	----	0.5	kg H2SO4/t		**8.4**	**95.2**	**19.0**	**97.2**	**84.0**
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm		**297**	**2300**	**427**	**1730**	**1170**
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		**25.3**	<0.5	**12.8**	**11.1**	**12.4**
ANC as CaCO3	----	0.1	% CaCO3		**2.6**	<0.1	**1.3**	**1.1**	**1.3**
Fizz Rating	----	0	Fizz Unit		**1**	**0**	**1**	**1**	**1**
EA026 : Chromium Reducible Sulfur									
Chromium Reducible Sulphur	----	0.005	%		**1.00**	**2.82**	**0.796**	**3.20**	**3.14**
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		**1.10**	**3.11**	**1.04**	**3.54**	**3.15**

Analytical Results

Sub-Matrix: **SOIL**
(Matrix: **SOIL**)

Compound	CAS Number	LOR	Unit	Sample ID	2022049_51 164380-164384 Coarse Reject VSW228_C Coarse Reject	2022049_52 164380-164384 Fine Reject VSW228_C Fine Reject	2022049_53 145103-145108 Coarse Reject VSW229_C Coarse Reject	2022049_54 145103-145108 Fine Reject VSW229_C Fine Reject	pH and EC of DI water
				Sampling date / time	03-Aug-2022 00:00	03-Aug-2022 00:00	03-Aug-2022 00:00	03-Aug-2022 00:00	03-Aug-2022 00:00
					EB2222926-011	EB2222926-012	EB2222926-013	EB2222926-014	EB2222926-015
					Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)									
pH Value	----	0.1	pH Unit		**3.6**	**5.8**	**3.6**	**4.9**	**5.7**
EA009: Net Acid Production Potential									
Net Acid Production Potential	----	0.5	kg H2SO4/t		**78.7**	**28.8**	**92.5**	**89.5**	**----**
EA010: Conductivity (1:5)									
Electrical Conductivity @ 25°C	----	1	µS/cm		**2270**	**616**	**1400**	**755**	<1
EA013: Acid Neutralising Capacity									
ANC as H2SO4	----	0.5	kg H2SO4 equiv./t		**15.2**	**19.2**	**15.8**	**13.9**	**----**
ANC as CaCO3	----	0.1	% CaCO3		**1.6**	**2.0**	**1.6**	**1.4**	**----**
Fizz Rating	----	0	Fizz Unit		**1**	**1**	**1**	**1**	**----**
EA026 : Chromium Reducible Sulfur									
Chromium Reducible Sulphur	----	0.005	%		**2.62**	**1.23**	**3.52**	**3.25**	**----**
ED042T: Total Sulfur by LECO									
Sulfur - Total as S (LECO)	----	0.01	%		**3.07**	**1.57**	**3.54**	**3.38**	**----**

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB2222546**	Page	: 1 of 8
Client	: **RGS ENVIRONMENTAL CONSULTANTS PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: PETER LONG	Contact	: Customer Services EB
Address	: 3/30 LENSWORTH STREET COOPERS PLAINS 4108	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: 07 3344 1222	Telephone	: +61-7-3243 7222
Project	: 2022049 Vulcan Coal Mine Matilda Pit	Date Samples Received	: 02-Aug-2022 12:57
Order number	: ----	Date Analysis Commenced	: 04-Aug-2022
C-O-C number	: ----	Issue Date	: 11-Aug-2022 15:45
Sampler	: ASITHA JAJASINGHE		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 9		
No. of samples analysed	: 9		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Kim McCabe	Senior Inorganic Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Layla Hafner	Acid Sulphate Soils - Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contract for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- ED037 (Alkalinity): NATA accreditation does not cover the performance of this service.
- ED038 (Acidity): NATA accreditation does not cover the performance of this service.
- ALS is not NATA accredited for the analysis of Exchangeable Aluminium and Exchange Acidity in soils when performed under ALS Method ED005.
- ALS is not NATA accredited for the analysis of Exchangeable Cations on Alkaline Soils when performed under ALS Method ED006.
- EG005T-Total Metals by ICP-AES: Sample EB2222681-002 shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- ED007 and ED008: When Exchangeable Al is reported from these methods, it should be noted that Rayment & Lyons (2011) suggests Exchange Acidity by 1M KCl - Method 15G1 (ED005) is a more suitable method for the determination of exchange acidity (H+ + Al3+).

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Sample ID	2022049_C001	2022049_C002	2022049_C003	2022049_C004	2022049_C005
			Sampling date / time	01-Aug-2022 00:00	01-Aug-2022 00:00	01-Aug-2022 00:00	01-Aug-2022 00:00	01-Aug-2022 00:00
Compound	CAS Number	LOR	Unit	EB2222546-001	EB2222546-002	EB2222546-003	EB2222546-004	EB2222546-005
				Result	Result	Result	Result	Result
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	8.8	8.7	8.7	5.8	9.1
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	164	215	310	60	175
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	----	<1.0	<1.0	<1.0	----
ED005: Exchange Acidity								
ø Exchange Acidity	----	0.1	meq/100g	----	----	----	1.3	----
ø Exchangeable Aluminium	----	0.1	meq/100g	----	----	----	0.7	----
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	----	1.1	1.7	----	----
ø Exchangeable Magnesium	----	0.2	meq/100g	----	0.8	1.8	----	----
ø Exchangeable Potassium	----	0.2	meq/100g	----	0.2	0.4	----	----
ø Exchangeable Sodium	----	0.2	meq/100g	----	<0.2	0.5	----	----
ø Cation Exchange Capacity	----	0.2	meq/100g	----	2.1	4.3	----	----
ø Exchangeable Sodium Percent	----	0.2	%	----	<0.2	11.0	----	----
ø Calcium/Magnesium Ratio	----	0.2	-	----	1.4	1.0	----	----
ø Magnesium/Potassium Ratio	----	0.2	-	----	3.5	4.3	----	----
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	----	----	----	0.5	----
Exchangeable Magnesium	----	0.1	meq/100g	----	----	----	1.0	----
Exchangeable Potassium	----	0.1	meq/100g	----	----	----	0.2	----
Exchangeable Sodium	----	0.1	meq/100g	----	----	----	0.2	----
Cation Exchange Capacity	----	0.1	meq/100g	----	----	----	2.1	----
Exchangeable Sodium Percent	----	0.1	%	----	----	----	9.3	----
Calcium/Magnesium Ratio	----	0.1	-	----	----	----	0.5	----
Magnesium/Potassium Ratio	----	0.1	-	----	----	----	4.1	----
ED037: Alkalinity								
ø Total Alkalinity as CaCO3	----	1	mg/kg	29700	4950	17600	540	3600
ø Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	28800	4950	17600	540	2700
ø Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	900	<5	<5	<5	900
ED038A: Acidity								
Acidity	----	1	mg/kg	<5	24	<5	776	<5
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	200	290	360	90	200

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Sample ID	2022049_C001	2022049_C002	2022049_C003	2022049_C004	2022049_C005
			Sampling date / time	01-Aug-2022 00:00	01-Aug-2022 00:00	01-Aug-2022 00:00	01-Aug-2022 00:00	01-Aug-2022 00:00
Compound	CAS Number	LOR	Unit	EB2222546-001	EB2222546-002	EB2222546-003	EB2222546-004	EB2222546-005
				Result	Result	Result	Result	Result
ED040S : Soluble Sulfate by ICPAES - Continued								
Silica	7631-86-9	1	mg/kg	15	22	24	69	26
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	20	60	40	10	30
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	40	50	60	<10	20
Magnesium	7439-95-4	10	mg/kg	20	20	40	<10	<10
Sodium	7440-23-5	10	mg/kg	120	120	170	30	130
Potassium	7440-09-7	10	mg/kg	40	100	120	60	80
ED093T: Total Major Cations								
Sodium	7440-23-5	50	mg/kg	230	180	250	60	200
Potassium	7440-09-7	50	mg/kg	1170	1220	1490	1170	1350
Calcium	7440-70-2	50	mg/kg	45000	2210	13700	190	2230
Magnesium	7439-95-4	50	mg/kg	1780	1110	2840	440	1480
EG005(ED093)S : Soluble Metals by ICPAES								
Boron	7440-42-8	1	mg/kg	<1	<1	<1	<1	<1
Iron	7439-89-6	1	mg/kg	<1	<1	<1	<1	<1
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	1550	1410	1930	1830	1310
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	<50
Iron	7439-89-6	50	mg/kg	28500	15500	21800	9980	13100
EG020S: Soluble Metals by ICPMS								
Arsenic	7440-38-2	0.01	mg/kg	<0.01	0.01	0.01	<0.01	0.09
Selenium	7782-49-2	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1
Barium	7440-39-3	0.01	mg/kg	0.18	0.14	0.06	<0.01	0.02
Beryllium	7440-41-7	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Cadmium	7440-43-9	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Cobalt	7440-48-4	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Chromium	7440-47-3	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Thorium	7440-29-1	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Copper	7440-50-8	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Manganese	7439-96-5	0.01	mg/kg	<0.01	0.02	0.04	0.02	<0.01
Molybdenum	7439-98-7	0.01	mg/kg	0.05	0.09	0.11	<0.01	0.28
Nickel	7440-02-0	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01
Lead	7439-92-1	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	<0.01

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)				Sample ID	2022049_C001	2022049_C002	2022049_C003	2022049_C004	2022049_C005
				Sampling date / time	01-Aug-2022 00:00	01-Aug-2022 00:00	01-Aug-2022 00:00	01-Aug-2022 00:00	01-Aug-2022 00:00
Compound	CAS Number	LOR	Unit		EB2222546-001	EB2222546-002	EB2222546-003	EB2222546-004	EB2222546-005
					Result	Result	Result	Result	Result
EG020S: Soluble Metals by ICPMS - Continued									
Antimony	7440-36-0	0.01	mg/kg		<0.01	**0.03**	**0.02**	<0.01	**0.04**
Uranium	7440-61-1	0.01	mg/kg		<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	7440-66-6	0.05	mg/kg		<0.05	<0.05	<0.05	<0.05	<0.05
Vanadium	7440-62-2	0.1	mg/kg		<0.1	<0.1	<0.1	<0.1	<0.1
Aluminium	7429-90-5	0.1	mg/kg		<0.1	**0.1**	**0.1**	**0.4**	**0.2**
EG020T: Total Metals by ICP-MS									
Arsenic	7440-38-2	0.1	mg/kg		**9.0**	**3.9**	**5.4**	**4.6**	**6.1**
Selenium	7782-49-2	1	mg/kg		**1**	<1	<1	<1	<1
Barium	7440-39-3	0.1	mg/kg		**119**	**52.4**	**61.8**	**30.2**	**23.5**
Beryllium	7440-41-7	0.1	mg/kg		**0.7**	**0.4**	**0.6**	**0.3**	**0.5**
Cadmium	7440-43-9	0.1	mg/kg		**0.1**	<0.1	<0.1	<0.1	<0.1
Cobalt	7440-48-4	0.1	mg/kg		**6.6**	**4.5**	**7.0**	**3.5**	**8.0**
Chromium	7440-47-3	0.1	mg/kg		**0.7**	**2.0**	**3.1**	**2.6**	**1.9**
Copper	7440-50-8	0.1	mg/kg		**29.6**	**6.4**	**8.2**	**5.1**	**20.0**
Thorium	7440-29-1	0.1	mg/kg		**2.3**	**1.4**	**2.1**	**1.2**	**2.2**
Manganese	7439-96-5	0.1	mg/kg		**525**	**177**	**334**	**98.2**	**143**
Molybdenum	7439-98-7	0.1	mg/kg		**1.1**	**0.5**	**0.6**	**0.5**	**0.8**
Nickel	7440-02-0	0.1	mg/kg		**4.3**	**7.8**	**10.6**	**5.3**	**13.8**
Lead	7439-92-1	0.1	mg/kg		**11.1**	**16.2**	**14.3**	**10.8**	**20.6**
Antimony	7440-36-0	0.1	mg/kg		**0.3**	**0.2**	**0.2**	**0.2**	**0.2**
Uranium	7440-61-1	0.1	mg/kg		**0.5**	**0.3**	**0.4**	**0.2**	**0.4**
Zinc	7440-66-6	0.5	mg/kg		**64.2**	**33.9**	**46.5**	**28.4**	**66.1**
Vanadium	7440-62-2	1	mg/kg		**8**	**3**	**10**	**3**	**3**
EG035S: Soluble Mercury by FIMS									
Mercury	7439-97-6	0.0005	mg/kg		<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
EG035T: Total Recoverable Mercury by FIMS									
Mercury	7439-97-6	0.1	mg/kg		**0.1**	<0.1	<0.1	<0.1	<0.1
EK040S: Fluoride Soluble									
Fluoride	16984-48-8	1	mg/kg		**6**	**1**	**3**	<1	**3**
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.1	mg/kg		<0.1	<0.1	<0.1	<0.1	<0.1

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Sample ID	2022049_C006	2022049_C007	2022049_C008	2022049_C009	----
			Sampling date / time	01-Aug-2022 00:00	01-Aug-2022 00:00	01-Aug-2022 00:00	01-Aug-2022 00:00	----
Compound	CAS Number	LOR	Unit	EB2222546-006	EB2222546-007	EB2222546-008	EB2222546-009	--------
				Result	Result	Result	Result	----
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	9.1	8.4	8.9	7.3	----
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	195	363	230	135	----
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	<1.0	----	----	<1.0	----
ED006: Exchangeable Cations on Alkaline Soils								
ø Exchangeable Calcium	----	0.2	meq/100g	1.8	----	----	----	----
ø Exchangeable Magnesium	----	0.2	meq/100g	1.4	----	----	----	----
ø Exchangeable Potassium	----	0.2	meq/100g	0.4	----	----	----	----
ø Exchangeable Sodium	----	0.2	meq/100g	0.5	----	----	----	----
ø Cation Exchange Capacity	----	0.2	meq/100g	4.1	----	----	----	----
ø Exchangeable Sodium Percent	----	0.2	%	11.7	----	----	----	----
ø Calcium/Magnesium Ratio	----	0.2	-	1.3	----	----	----	----
ø Magnesium/Potassium Ratio	----	0.2	-	3.4	----	----	----	----
ED007: Exchangeable Cations								
Exchangeable Calcium	----	0.1	meq/100g	----	----	----	1.0	----
Exchangeable Magnesium	----	0.1	meq/100g	----	----	----	3.7	----
Exchangeable Potassium	----	0.1	meq/100g	----	----	----	0.6	----
Exchangeable Sodium	----	0.1	meq/100g	----	----	----	0.6	----
Cation Exchange Capacity	----	0.1	meq/100g	----	----	----	6.0	----
Exchangeable Sodium Percent	----	0.1	%	----	----	----	10.0	----
Calcium/Magnesium Ratio	----	0.1	-	----	----	----	0.3	----
Magnesium/Potassium Ratio	----	0.1	-	----	----	----	6.6	----
ED037: Alkalinity								
ø Total Alkalinity as CaCO3	----	1	mg/kg	5040	3690	30700	1530	----
ø Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	5040	3690	30600	1530	----
ø Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	<5	<5	90	<5	----
ED038A: Acidity								
Acidity	----	1	mg/kg	<5	41	<5	368	----
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	160	580	260	220	----
Silica	7631-86-9	1	mg/kg	27	25	23	41	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	30	40	40	10	----

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Sample ID	2022049_C006	2022049_C007	2022049_C008	2022049_C009	----
			Sampling date / time	01-Aug-2022 00:00	01-Aug-2022 00:00	01-Aug-2022 00:00	01-Aug-2022 00:00	----
Compound	CAS Number	LOR	Unit	EB2222546-006	EB2222546-007	EB2222546-008	EB2222546-009	--------
				Result	Result	Result	Result	----
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	**10**	**80**	**40**	<10	----
Magnesium	7439-95-4	10	mg/kg	<10	**40**	**20**	<10	----
Sodium	7440-23-5	10	mg/kg	**170**	**180**	**180**	**90**	----
Potassium	7440-09-7	10	mg/kg	**70**	**150**	**60**	**80**	----
ED093T: Total Major Cations								
Sodium	7440-23-5	50	mg/kg	**320**	**270**	**310**	**160**	----
Potassium	7440-09-7	50	mg/kg	**1530**	**1770**	**1360**	**1600**	----
Calcium	7440-70-2	50	mg/kg	**4620**	**3860**	**34400**	**610**	----
Magnesium	7439-95-4	50	mg/kg	**3040**	**3040**	**4900**	**1580**	----
EG005(ED093)S : Soluble Metals by ICPAES								
Boron	7440-42-8	1	mg/kg	<1	<1	<1	<1	----
Iron	7439-89-6	1	mg/kg	<1	<1	<1	<1	----
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	**1760**	**2060**	**1710**	**1620**	----
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	----
Iron	7439-89-6	50	mg/kg	**30600**	**33700**	**38900**	**25900**	----
EG020S: Soluble Metals by ICPMS								
Arsenic	7440-38-2	0.01	mg/kg	**0.07**	<0.01	**0.02**	<0.01	----
Selenium	7782-49-2	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	----
Barium	7440-39-3	0.01	mg/kg	<0.01	**0.03**	**0.32**	**0.02**	----
Beryllium	7440-41-7	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	----
Cadmium	7440-43-9	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	----
Cobalt	7440-48-4	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	----
Chromium	7440-47-3	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	----
Thorium	7440-29-1	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	----
Copper	7440-50-8	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	----
Manganese	7439-96-5	0.01	mg/kg	<0.01	**0.07**	**0.01**	**0.22**	----
Molybdenum	7439-98-7	0.01	mg/kg	**0.29**	**0.11**	**0.19**	**0.01**	----
Nickel	7440-02-0	0.01	mg/kg	<0.01	<0.01	<0.01	**0.01**	----
Lead	7439-92-1	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	----
Antimony	7440-36-0	0.01	mg/kg	**0.05**	**0.02**	**0.02**	<0.01	----
Uranium	7440-61-1	0.01	mg/kg	<0.01	<0.01	<0.01	<0.01	----
Zinc	7440-66-6	0.05	mg/kg	<0.05	<0.05	<0.05	<0.05	----
Vanadium	7440-62-2	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	----

Analytical Results

Sub-Matrix: SOLID (Matrix: SOIL)			Sample ID	2022049_C006	2022049_C007	2022049_C008	2022049_C009	----
			Sampling date / time	01-Aug-2022 00:00	01-Aug-2022 00:00	01-Aug-2022 00:00	01-Aug-2022 00:00	----
Compound	CAS Number	LOR	Unit	EB2222546-006	EB2222546-007	EB2222546-008	EB2222546-009	--------
				Result	Result	Result	Result	----
EG020S: Soluble Metals by ICPMS - Continued								
Aluminium	7429-90-5	0.1	mg/kg	**0.2**	<0.1	**0.1**	<0.1	----
EG020T: Total Metals by ICP-MS								
Arsenic	7440-38-2	0.1	mg/kg	**6.0**	**8.1**	**10.5**	**7.1**	----
Selenium	7782-49-2	1	mg/kg	<1	<1	<1	<1	----
Barium	7440-39-3	0.1	mg/kg	**25.8**	**28.6**	**178**	**48.2**	----
Beryllium	7440-41-7	0.1	mg/kg	**0.6**	**0.6**	**0.7**	**0.9**	----
Cadmium	7440-43-9	0.1	mg/kg	<0.1	<0.1	<0.1	**0.1**	----
Cobalt	7440-48-4	0.1	mg/kg	**7.8**	**8.2**	**5.5**	**9.6**	----
Chromium	7440-47-3	0.1	mg/kg	**2.8**	**3.3**	**2.8**	**3.0**	----
Copper	7440-50-8	0.1	mg/kg	**16.8**	**13.8**	**19.4**	**17.3**	----
Thorium	7440-29-1	0.1	mg/kg	**2.0**	**1.9**	**3.9**	**2.2**	----
Manganese	7439-96-5	0.1	mg/kg	**369**	**402**	**625**	**329**	----
Molybdenum	7439-98-7	0.1	mg/kg	**0.6**	**0.6**	**1.7**	**0.7**	----
Nickel	7440-02-0	0.1	mg/kg	**11.8**	**16.1**	**7.5**	**15.5**	----
Lead	7439-92-1	0.1	mg/kg	**17.8**	**19.6**	**13.6**	**20.5**	----
Antimony	7440-36-0	0.1	mg/kg	**0.2**	**0.2**	**0.2**	**0.3**	----
Uranium	7440-61-1	0.1	mg/kg	**0.4**	**0.3**	**0.5**	**0.4**	----
Zinc	7440-66-6	0.5	mg/kg	**60.2**	**59.5**	**44.9**	**82.4**	----
Vanadium	7440-62-2	1	mg/kg	**10**	**9**	**12**	**7**	----
EG035S: Soluble Mercury by FIMS								
Mercury	7439-97-6	0.0005	mg/kg	<0.0005	<0.0005	<0.0005	<0.0005	----
EG035T: Total Recoverable Mercury by FIMS								
Mercury	7439-97-6	0.1	mg/kg	<0.1	**0.2**	**0.1**	<0.1	----
EK040S: Fluoride Soluble								
Fluoride	16984-48-8	1	mg/kg	**2**	**2**	**5**	**3**	----
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	14265-44-2	0.1	mg/kg	<0.1	<0.1	<0.1	<0.1	----

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EB2224164**	Page	: 1 of 5
Client	: **RGS ENVIRONMENTAL CONSULTANTS PTY LTD**	Laboratory	: Environmental Division Brisbane
Contact	: PETER LONG	Contact	: Customer Services EB
Address	: 3/30 LENSWORTH STREET COOPERS PLAINS 4108	Address	: 2 Byth Street Stafford QLD Australia 4053
Telephone	: 07 3344 1222	Telephone	: +61-7-3243 7222
Project	: 2022049 Vulcan Coal Mine Matilda Pit	Date Samples Received	: 17-Aug-2022 16:00
Order number	: ----	Date Analysis Commenced	: 19-Aug-2022
C-O-C number	: ----	Issue Date	: 25-Aug-2022 10:10
Sampler	: ASITHA JAJASINGHE		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 4		
No. of samples analysed	: 4		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Kim McCabe	Senior Inorganic Chemist	Brisbane Inorganics, Stafford, QLD
Layla Hafner	Acid Sulphate Soils - Chemist	Brisbane Acid Sulphate Soils, Stafford, QLD
Layla Hafner	Acid Sulphate Soils - Chemist	Brisbane Inorganics, Stafford, QLD

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contract for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EG020-S (Soluble Metals by ICP-MS): Sample 2022049_C10 (EB2224164-001) shows poor duplicate results due to sample heterogeneity. Confirmed by visual inspection.
- ED037 (Alkalinity): NATA accreditation does not cover the performance of this service.
- ED038 (Acidity): NATA accreditation does not cover the performance of this service.
- EG005T (Total Metals by ICP-AES): EB2224045-009 shows poor duplicate results due to sample heterogeneity. This has been confirmed by visual inspection.
- EG005T (Total Metals by ICP-AES): 2022049_C13 (EB2224164-004) shows poor matrix spike recovery due to sample heterogeneity. This has been confirmed by visual inspection.
- EG005S (Soluble Metals by ICP-AES): 2022049_C10 (EB2224164-001) shows poor duplicate results due to sample heterogeneity. This has been confirmed by visual inspection.

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Sample ID	2022049_C10 Coarse Rejects	2022049_C11 Coarse Rejects	2022049_C12 Fine Rejects	2022049_C13 Fine Rejects	----
			Sampling date / time	17-Aug-2022 00:00	17-Aug-2022 00:00	17-Aug-2022 00:00	17-Aug-2022 00:00	----
Compound	CAS Number	LOR	Unit	EB2224164-001	EB2224164-002	EB2224164-003	EB2224164-004	--------
				Result	Result	Result	Result	----
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	4.0	3.4	5.3	5.1	----
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	1390	1790	533	652	----
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	2.1	1.2	2.6	2.4	----
ED037: Alkalinity								
ø Total Alkalinity as CaCO3	----	1	mg/kg	90	<5	61	104	----
ø Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/kg	90	<5	61	104	----
ø Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/kg	<5	<5	<5	<5	----
ED038A: Acidity								
Acidity	----	1	mg/kg	2080	3710	289	372	----
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	3920	4730	1080	1550	----
Silica	7631-86-9	1	mg/kg	21	34	35	30	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	20	20	110	100	----
ED093S: Soluble Major Cations								
Calcium	7440-70-2	10	mg/kg	440	580	190	260	----
Magnesium	7439-95-4	10	mg/kg	300	300	100	150	----
Sodium	7440-23-5	10	mg/kg	190	190	150	160	----
Potassium	7440-09-7	10	mg/kg	80	100	50	50	----
ED093T: Total Major Cations								
Sodium	7440-23-5	50	mg/kg	330	350	300	410	----
Potassium	7440-09-7	50	mg/kg	1080	1180	1310	1220	----
Calcium	7440-70-2	50	mg/kg	3890	6020	3990	3410	----
Magnesium	7439-95-4	50	mg/kg	1920	1910	1710	1480	----
EG005(ED093)S : Soluble Metals by ICPAES								
Boron	7440-42-8	1	mg/kg	<1	<1	<1	<1	----
Iron	7439-89-6	1	mg/kg	968	1280	17	63	----
EG005(ED093)T: Total Metals by ICP-AES								
Aluminium	7429-90-5	50	mg/kg	1450	2180	1970	2120	----
Boron	7440-42-8	50	mg/kg	<50	<50	<50	<50	----
Iron	7439-89-6	50	mg/kg	49400	38900	45300	34200	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Sample ID	2022049_C10 Coarse Rejects	2022049_C11 Coarse Rejects	2022049_C12 Fine Rejects	2022049_C13 Fine Rejects	----
				Sampling date / time	17-Aug-2022 00:00	17-Aug-2022 00:00	17-Aug-2022 00:00	17-Aug-2022 00:00	----
Compound	CAS Number	LOR	Unit		EB2224164-001	EB2224164-002	EB2224164-003	EB2224164-004	--------
					Result	Result	Result	Result	----
EG020S: Soluble Metals by ICPMS									
Arsenic	7440-38-2	0.01	mg/kg		**0.08**	**0.13**	<0.01	<0.01	----
Selenium	7782-49-2	0.1	mg/kg		<0.1	<0.1	<0.1	<0.1	----
Barium	7440-39-3	0.01	mg/kg		**0.26**	**0.24**	**0.24**	**0.24**	----
Beryllium	7440-41-7	0.01	mg/kg		**0.10**	**0.12**	<0.01	<0.01	----
Cadmium	7440-43-9	0.01	mg/kg		<0.01	**0.01**	<0.01	<0.01	----
Cobalt	7440-48-4	0.01	mg/kg		**1.30**	**1.22**	**0.29**	**0.18**	----
Chromium	7440-47-3	0.01	mg/kg		<0.01	<0.01	<0.01	<0.01	----
Thorium	7440-29-1	0.01	mg/kg		<0.01	<0.01	<0.01	<0.01	----
Copper	7440-50-8	0.01	mg/kg		**1.33**	**2.22**	**0.13**	**0.20**	----
Manganese	7439-96-5	0.01	mg/kg		**17.7**	**5.98**	**1.43**	**1.89**	----
Molybdenum	7439-98-7	0.01	mg/kg		**0.02**	<0.01	<0.01	<0.01	----
Nickel	7440-02-0	0.01	mg/kg		**1.11**	**1.14**	**0.24**	**0.15**	----
Lead	7439-92-1	0.01	mg/kg		**0.02**	**0.08**	<0.01	<0.01	----
Antimony	7440-36-0	0.01	mg/kg		<0.01	**0.02**	<0.01	<0.01	----
Uranium	7440-61-1	0.01	mg/kg		<0.01	**0.02**	<0.01	<0.01	----
Zinc	7440-66-6	0.05	mg/kg		**2.56**	**2.18**	**2.61**	**3.33**	----
Vanadium	7440-62-2	0.1	mg/kg		<0.1	<0.1	<0.1	<0.1	----
Aluminium	7429-90-5	0.1	mg/kg		**7.5**	**13.6**	**0.2**	**0.4**	----
EG020T: Total Metals by ICP-MS									
Arsenic	7440-38-2	0.1	mg/kg		**26.8**	**18.4**	**21.1**	**15.1**	----
Selenium	7782-49-2	1	mg/kg		**2**	**2**	**2**	**2**	----
Barium	7440-39-3	0.1	mg/kg		**38.4**	**39.7**	**63.1**	**61.5**	----
Beryllium	7440-41-7	0.1	mg/kg		**1.8**	**0.9**	**1.1**	**0.9**	----
Cadmium	7440-43-9	0.1	mg/kg		**0.1**	**0.1**	**0.2**	**0.2**	----
Cobalt	7440-48-4	0.1	mg/kg		**10.4**	**4.7**	**12.7**	**5.6**	----
Chromium	7440-47-3	0.1	mg/kg		**0.5**	**0.2**	**1.3**	**0.7**	----
Copper	7440-50-8	0.1	mg/kg		**76.8**	**62.2**	**38.3**	**50.7**	----
Thorium	7440-29-1	0.1	mg/kg		**1.9**	**2.1**	**1.9**	**1.7**	----
Manganese	7439-96-5	0.1	mg/kg		**745**	**365**	**382**	**295**	----
Molybdenum	7439-98-7	0.1	mg/kg		**1.0**	**1.1**	**1.4**	**0.9**	----
Nickel	7440-02-0	0.1	mg/kg		**7.8**	**3.1**	**11.6**	**4.9**	----
Lead	7439-92-1	0.1	mg/kg		**12.1**	**10.9**	**13.7**	**17.3**	----
Antimony	7440-36-0	0.1	mg/kg		**0.6**	**0.7**	**0.4**	**0.5**	----
Uranium	7440-61-1	0.1	mg/kg		**0.4**	**0.7**	**0.4**	**0.4**	----

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)				Sample ID	2022049_C10 Coarse Rejects	2022049_C11 Coarse Rejects	2022049_C12 Fine Rejects	2022049_C13 Fine Rejects	----
				Sampling date / time	17-Aug-2022 00:00	17-Aug-2022 00:00	17-Aug-2022 00:00	17-Aug-2022 00:00	----
Compound	CAS Number	LOR	Unit		EB2224164-001	EB2224164-002	EB2224164-003	EB2224164-004	--------
					Result	Result	Result	Result	----
EG020T: Total Metals by ICP-MS - Continued									
Zinc	7440-66-6	0.5	mg/kg		**64.3**	**59.0**	**138**	**121**	**----**
Vanadium	7440-62-2	1	mg/kg		**5**	**4**	**4**	**4**	**----**
EG035S: Soluble Mercury by FIMS									
Mercury	7439-97-6	0.0005	mg/kg		<0.0005	<0.0005	<0.0005	<0.0005	**----**
EG035T: Total Recoverable Mercury by FIMS									
Mercury	7439-97-6	0.1	mg/kg		**1.1**	**0.8**	**0.9**	**0.9**	**----**
EK040S: Fluoride Soluble									
Fluoride	16984-48-8	1	mg/kg		**3**	**3**	<1	<1	**----**
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.1	mg/kg		<0.1	<0.1	<0.1	<0.1	**----**



MINE WASTE AND
WATER MANAGEMENT

katestone
www.katestone.global

12 August 2022

Attn: Damien Plucknett

Senior Consultant - Environment
METServe
310 Edward Street
Brisbane QLD 4000

Email: Damien.Plucknett@metserve.com.au

Re: Emissions Analysis for the VCM Matilda Pit, Rail Loop and CHPP

Dear Damien,

In 2020, Katestone completed an air quality assessment of the Vulcan Coal Mine (VCM) (Document reference D19001-6). Vitrinite Pty Ltd (the proponent of the VCM) has submitted an EA and PRCP amendment application to include a CHPP and rail loop within the mine site. The amendment application was submitted, referring to Katestone's report (D19001-6) and stated that due to the significant separation distance to the nearest sensitive receptors, that the addition of the CHPP and rail loop were unlikely to cause a measurable difference to air quality. In response, the Department of Environment and Science (DES) has issued an information request, requesting the CHPP and rail loop be incorporated into the air quality dispersion model as part of the amendment application.

Since the initial amendment application the site plan has been further revised to incorporate mining of a new shallow open cut pit (Matilda Pit) within the rail loop alignment, to be developed concurrently with the main existing east pit. METServe have advised that there are no requirements to increase production rate or alter the project timeframes as additional planning work has been completed on the main pit while overall coal extraction has been reduced from what was originally proposed and approved. No changes are expected to the equipment fleet, workforce, or accommodation. Instead, material extracted from the Matilda Pit will supplement material no longer being mined from the main east pit. Additionally, Katestone has reviewed the D19001-6 assessment and notes the emissions of dust associated with a CHPP (activities including transfer of ROM, crushing and screening) were included in the emissions inventory and dispersion modelling assessment, thus accounting for an onsite CHPP. As the amendment focuses primarily on method of transport for product coal (train rather than truck) while other proposed changes involve only a redistribution of activities within the same mine lease area, new modelling has not been performed and is not considered necessary as impacts are expected to remain similar and all potential source types exist in the initial modelling.

This letter addresses potential air quality impacts from the proposed changes to the VCM. These changes include the transition to processing material at an onsite CHPP, the inclusion of a train load out (TLO) and rail loop, and the extraction of material from the Matilda Pit. The letter presents an analysis of expected emission rates from the proposed activities utilising the same approach taken by the initial assessment using regulatory emission factors and emissions data provided by METServe.

Please contact the undersigned on (07) 3369 3699 if you would like to discuss further.

Yours sincerely,

Daniel Gallagher

ATTACHMENT A – ASSESSMENT OF THE VCM

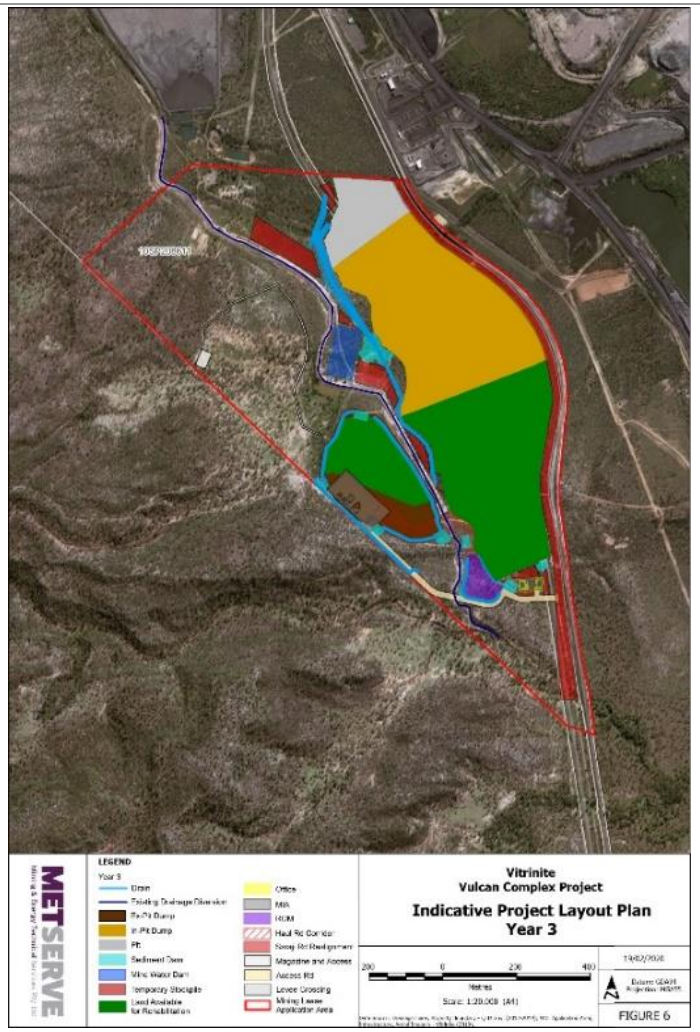
A1 AMENDED DESIGN AND ACTIVITIES

The VCM is approved to operate for four years with a Run of Mine (ROM) rate of up to 1.95 Million tonnes per annum (Mtpa). The mine has completed its first year of operations according to these requirements and as informed by the initial air quality assessment prepared by Katestone (Katestone report D19001-6). Details of the existing operations can be found in Katestone report D19001-6. Proposed changes to the site layout and operations to be conducted over the remaining three years will not increase the duration, equipment fleet, extent, or volumes extracted for the VCM.

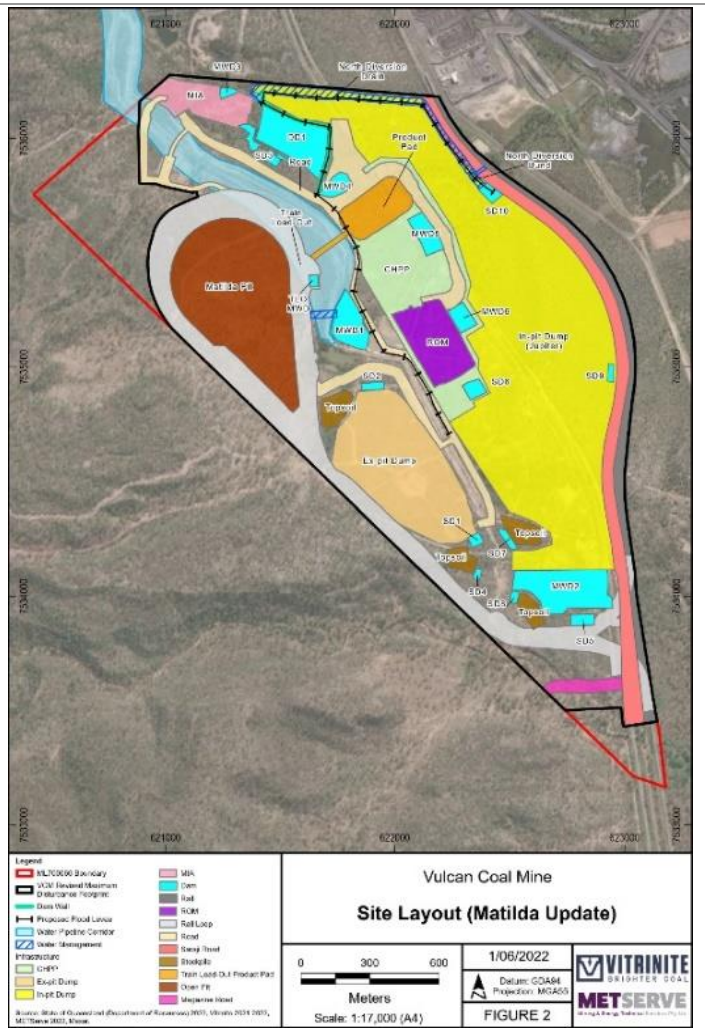
The proposed changes include:

- Construction of an onsite CHPP, TLO and rail loop over 18 months to replace the need for hauling ROM off site for toll washing and export at third-party facilities. This is expected to commence operation in year three of the mine life.
- Reduction in the ROM extraction volumes from the existing pit alongside development of the shallow open cut Matilda Pit to maintain approved extraction limits.
- Preference given to dumping waste materials in-pit, minimising the need for an out-of-pit dump and removing the requirement for an onsite tailings storage facility.

Figure A1 presents the layout as assessed in Katestone report D19001-6 and the proposed layout.



Previous mine extent and locations of operations



Newly proposed mine layout

Figure A1 Plans for initial and proposed mine layouts

A2 SENSITIVE RECEPTORS

The extent of the VCM site boundary has not changed, therefore, distances to sensitive receptors are equivalent to those presented in Katestone report D19001-6. Table A1 and Figure A 2 illustrate the distance between the sensitive receptors and the VCM site boundary, with sensitive receptors located more than 12 km south-east of the VCM site boundary.

Table A1 Sensitive receptors

Receptor ID	Type	Description	Easting (km)	Northing (km)	Distance and direction from the VCP
1	Residential	Property Manager	630434	7523439	12.1 km SE
2		Workers Accommodation	630689	7522987	12.8 km SE
3		Saraji Station residence	629573	7519127	15.5 km SE

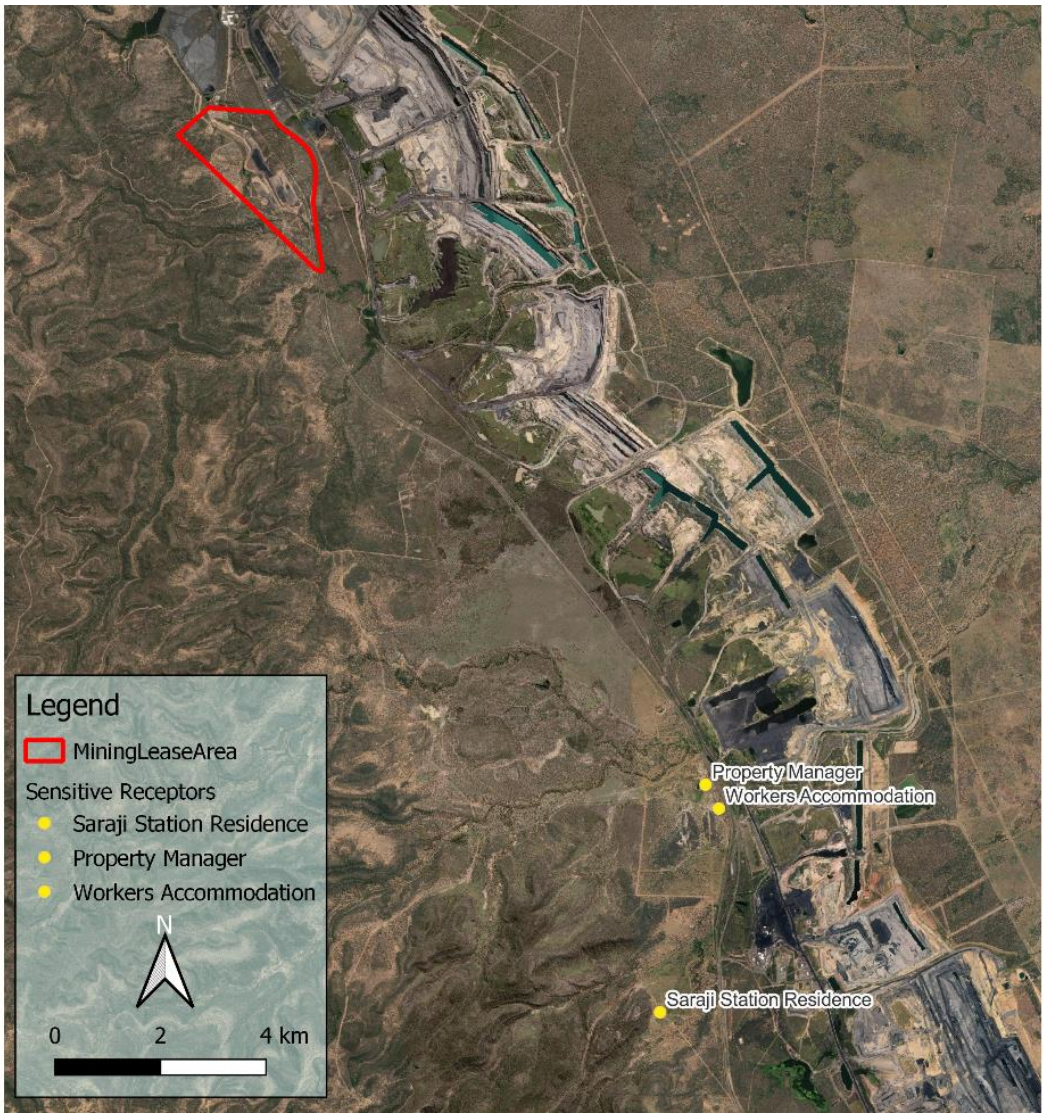


Figure A 2 Location of mine lease and sensitive receptors

A3 EMISSIONS INVENTORY

Annual total emissions and emission inventories for the initial assessment (Katestone report D19001-6) and proposed operations occurring in Financial Year (FY) 23, FY24, and Calendar Year (from July to December 2024) (CY) 24 are provided in Table A2 and Table A3, respectively. CY24 represents emissions for a six-month period.

The emissions inventories show the following changes relative to Katestone report D19001-6:

- TSP – emission rates are predicted to be 8% and 17% higher compared to D19001-6 for FY23, FY24 respectively, and 7% lower for CY24.
- PM_{10} – emission rates are predicted to be 12% and 26% higher compared to D19001-6 for FY23, FY24 respectively, and 2% lower for CY24.
- $PM_{2.5}$ – emission rates are predicted to be 9% and 20% higher compared to D19001-6 for FY23, FY24 respectively, and 12% lower for CY24.

Train loading and the onsite CHPP will commence operation in the second half of FY24, in the meantime ROM coal will still be trucked to a third-party facility. Therefore, no onsite processing of ROM will occur in FY23 other than the loading of trucks for offsite transport. Emissions increases are expected to be due to increased contributions from wind erosion and some additional hauls. The requirement for truck loading and hauling off site is replaced with train loading, and onsite processing coincides with decreasing extraction volumes in FY24 and CY24.

Table A2 Estimated TSP, PM_{10}, and $PM_{2.5}$ emission rates for the initial assessment of the VCM and for the proposed VCM operational amendments

Assessment	Mine Year	Units	TSP	PM_{10}	$PM_{2.5}$
D19001-6	Year 2	tonnes/annum	1,366	548	89[2]
VCM – Amendment	FY23/Yr2		1,453	606	96
	FY24/Yr3		1,586	679	107
	CY24/Yr4[1]		703	295	44

[1] Operations occurring over a 6-month period.

[2] This value is a correction to the D19001-6 assessment after identifying an incorrect emission rate for ROM excavation.

Table A3 Breakdown of TSP, PM_{10}, and $PM_{2.5}$ emission rates for the assessment D19001-6 and proposed operations for FY 23, FY 24, and CY 24

Activity	D19001-6 Year 2			FY 23 (Year 2)			FY 24 (Year 3)			CY 24 (Year 4)		
	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$
Pit activities												
Bulldozing overburden	0.05	0.05	0.01	0.08	0.08	0.01	0.05	0.05	0.01	0.00	0.00	0.00
Drilling and blasting	0.33	0.32	0.02	0.67	0.66	0.04	0.92	0.91	0.06	0.30	0.30	0.02
Excavating overburden	3.00	2.74	0.43	3.35	3.06	0.48	4.49	4.10	0.64	2.62	2.39	0.38
Excavating ROM	1.13	0.33	0.17	1.13	0.33	0.17	1.13	0.33	0.17	0.19	0.05	0.03
Dumping activities												
Truck dumping overburden	2.88	1.96	0.41	1.61	1.10	0.23	2.16	1.47	0.31	1.26	0.86	0.18
Truck dumping ROM	2.26	0.35	0.12	2.26	0.35	0.12	2.26	0.35	0.12	0.37	0.06	0.02
Bulldozing overburden	0.12	0.05	0.02	0.12	0.05	0.02	0.12	0.05	0.02	0.23	0.11	0.05
Bulldozing ROM	2.55	0.88	0.06	2.55	0.88	0.06	2.55	0.88	0.06	5.10	1.75	0.11
Haulage												
ROM coal haulage	1.49	0.37	0.04	1.27	0.32	0.03	1.36	0.34	0.03	0.27	0.07	0.01
Overburden haulage	3.63	0.91	0.09	2.74	0.68	0.07	4.10	1.02	0.10	2.11	0.53	0.05
Grading haul roads	9.20	1.68	0.29	9.71	1.77	0.30	9.71	1.77	0.30	9.71	1.77	0.30
Processing												
Sizing and crushing	0.94	0.34	0.03	0.00	0.00	0.00	0.47	0.17	0.02	0.15	0.06	0.01
Truck loading and transfers	1.38	0.22	0.10	1.00	0.15	0.05	1.15	0.18	0.06	0.02	0.01	0.001
TLO	-	-	-	0.00	0.00	0.00	2.8E-03	1.3E-03	2.0E-04	2.8E-03	1.3E-03	2.0E-04
Wind erosion												
Stockpiles	10.94	5.47	0.82	16.15	8.07	1.21	16.15	8.07	1.21	16.15	8.07	1.21
Exposed areas	2.24	1.12	0.17	2.75	1.37	0.21	2.96	1.48	0.22	0.85	0.43	0.06
Rehabilitated areas	0.70	0.35	0.05	0.70	0.35	0.05	0.70	0.35	0.05	0.70	0.35	0.05
Total (g/s)	**42.85**	**17.14**	**2.81**	**46.09**	**19.22**	**3.06**	**50.29**	**21.53**	**3.39**	**40.03**	**16.80**	**2.48**

Table note: Totals may not match manual sum of column due to rounding

A4 IMPACTS TO AIR QUALITY

In order to provide an indication of the expected impacts to air from the proposed mine plan, predicted ground-level concentrations for TSP, PM_{10} and $PM_{2.5}$ from the Katestone report D19001-6 have been scaled by the increases in emission rates discussed in the previous section. In the case of dust deposition previous ground level predictions have been scaled by the largest increase in emissions of either TSP, PM_{10}, or $PM_{2.5}$. This scaling depends upon the assumption that the existing modelling is representative of the new operations. This assumption is considered reasonable for the following reasons:

- Mine areas and locations: The total extent of mine areas including active pits, stockpiles, dumps and areas for rehabilitation will increase by at most 5% relative to Katestone report D19001-6 and will occur within the same mine lease area. No sources will occur closer to the sensitive receptors than in the existing assessment. Furthermore, given the locations are largely unchanged the influence of meteorological conditions on dispersion will remain unchanged.
- Extraction rates and equipment: Additional planning work has been completed on the main pit to maintain originally proposed and approved extraction rates. The proposed changes, therefore, involve only a redistribution of activities rather than additional extraction requiring larger equipment fleets.
- Rail transport and ROM processing replacing offsite processing and truck transport: The initial assessment included emissions of dust associated with the CHPP (activities including transfer of ROM, crushing and screening) alongside loading of product into trucks. Therefore, the processes and locations of ROM processing which will occur onsite once the CHPP and TLO are constructed are represented in the initial modelling and will still process the same quantities of material.

Results from the Katestone report D19001-6 are reproduced below in Table A4. Results scaled by emissions increases for FY23, FY24, and CY24 are shown in Table A5. The results indicate that impacts from the VCM at the sensitive receptors will remain minimal and that compliance with Schedule B: Air and in particular the values presented in Table B1 – Air Quality Limits of the existing EA (EA0002912) will be maintained.

Table A4 Predicted ground-level concentrations for the initial assessment (D19001-6) in isolation and including ambient background (µg/m³)

Receptor	Isolation						Including Background					
	TSP	PM_{10}	PM_{10}	$PM_{2.5}$	$PM_{2.5}$	Dust Dep	TSP	PM_{10}	PM_{10}	$PM_{2.5}$	$PM_{2.5}$	Dust Deposition
	Ann Avg	24hr Max	Ann Avg	24hr Max	Ann Avg	Max Monthly	Ann Avg	24hr Max	Ann Avg	24hr Max	Ann Avg	Max Monthly
Property Manager	0.3	3.1	0.1	0.9	0.0	0.9	60.5	38.1	30.2	5.2	3.6	71.9
Workers Accommodation	0.3	4.4	0.2	1.1	0.0	1.1	60.5	39.4	30.3	5.4	3.6	72.1
O'Sullivan Residence	0.4	4.4	0.2	1.4	0.1	1.3	60.6	39.4	30.3	5.7	3.7	72.3
Criteria	**90**	**50**	**25**	**25**	**8**	**120 mg/m²/day**	**90**	**50**	**25**	**25**	**8**	**120 mg/m²/day**

Table A5 Scaled ground-level concentrations for the proposed operations in isolation and including ambient background (µg/m³)

Year	Receptor	Isolation						Including Background					
		TSP	PM_{10}	PM_{10}	$PM_{2.5}$	$PM_{2.5}$	Dust Dep	TSP	PM_{10}	PM_{10}	$PM_{2.5}$	$PM_{2.5}$	Dust Dep
		Ann Avg	24hr Max	Ann Avg	24hr Max	Ann Avg	Max Monthly	Ann Avg	24hr Max	Ann Avg	24hr Max	Ann Avg	Max Monthly
FY 23	Property Manager	0.3	3.4	0.2	1.0	0.05	1.1	60.5	38.4	30.3	5.3	3.6	90.3
	Workers Accommodation	0.3	5.0	0.2	1.2	0.05	1.4	60.5	40.0	30.3	5.5	3.7	90.5
	O'Sullivan Residence	0.4	5.0	0.3	1.6	0.08	1.6	60.6	40.0	30.4	5.9	3.7	90.8
FY 24	Property Manager	0.3	3.8	0.2	1.1	0.1	1.1	60.5	38.8	30.3	5.4	3.7	90.3
	Workers Accommodation	0.4	5.6	0.2	1.4	0.1	1.4	60.6	40.6	30.3	5.7	3.7	90.5
	O'Sullivan Residence	0.5	5.6	0.3	1.7	0.1	1.6	60.7	40.6	30.4	6.0	3.7	90.8
CY 23	Property Manager	0.2	3.0	0.1	0.8	0.04	1.1	60.4	38.0	30.2	5.1	3.6	90.3
	Workers Accommodation	0.3	4.3	0.2	1.0	0.04	1.4	60.5	39.3	30.3	5.3	3.6	90.5
	O'Sullivan Residence	0.4	4.3	0.2	1.3	0.07	1.6	60.6	39.3	30.3	5.6	3.7	90.8
Criteria		**90**	**50**	**25**	**25**	**8**	**120 mg/m²/day**	**90**	**50**	**25**	**25**	**8**	**120 mg/m2/day**

Date: 28 June 2022

Ref: 197401.0210.L01V01

To: Damien Plucknett

Company: METServe

Email: Damien.Plucknett@metserve.com.au

Author: Pubudu Jayawardana/SP

Subject: Vulcan Coal Mine Amendment – Noise and Vibration Addendum Letter

Pages: 1 of 7

Dear Damien,

This addendum letter addresses the Department of Environment and Science (DES) information request relating to noise and vibration of the proposed amendment application for the Vulcan Coal Mine (VCM).

1. INTRODUCTION

It is noted that since the last noise assessment (197401.0210.R01V02_draft2, dated 26 August 2020) was completed, Vitrinite made some Project changes and which include a coal handling and preparation plant (CHPP), additional open pit, rail loop and train loadout facility (TLO) on site. The amendment was submitted referring to the original noise and vibration assessment (without the CHPP and rail). Subsequently, a Request for Information (RFI) from the Queensland Department of Environment and Science (DES) was issued regarding the previously lodged application for the VCM. The RFI outlined the following in regard to noise and vibration:

> *The potential impact to the EVs of noise (including vibration) from the proposed amendment application has been considered based on assumptions from the technical assessments previously undertaken for the project.*
>
> *Previous noise and vibration impact assessments found that noise, air-blast levels and ground vibration from the project would be compliant with noise and vibration criteria under modelled scenarios. The supporting information states for the proposed amendment, "Given the extended distances to residential receptors or sensitive commercial receptors, the additional infrastructure and operation proposed at the [project] are considered to be negligible."*
>
> *Further evidence is required to support the assumptions made (and as stated above) about the potential impact to EVs of air and noise in order to satisfy environmental objectives and performance outcomes as per Schedule 8 of the Environmental Protection Regulation 2019 (EP Reg). The environmental objectives in the EP Reg must be considered as part of the decision on the application as per section 176(2)(a) of the Environmental Protection Act 1994 (EP Act).*
>
> *Provide updated modelled scenarios that include the additional infrastructure that is proposed by the amendment application. In particular, modelled scenarios must address the potential impacts during the year when air and noise disruption from the project is predicted to be greatest.*
>
> *METServe to consult with noise quality specialists. If robust evidence can be provided without detailed modelling, this will be provided.*

The purpose of this addendum letter is to address noise and vibration concerns with above mentioned amendments to the Project.

2. PROPOSED AMENDMENT

2.1 Overview

The proposed amendment primarily includes the establishment of a CHPP, TLO, a dedicated rail loop and a small additional open cut pit on ML700060. Ancillary infrastructure will include product stockpiles, updated water management infrastructure, access roads and a number of minor amendments to existing infrastructure layouts. The open cut pit, referred to as the 'Matilda pit' is proposed to be located within the rail loop and will provide supplementary coal to the ROM stockpile. Development of the Matilda pit will not require an increase of the approved production rate, nor have a significant impact on the life of the project. The proposed amended Project layout is shown in **Figure 2.1**. The location of the site with respect to sensitive receptors is shown in **Figure 2.2**.

Construction of the CHPP, TLO and the rail loop, is expected to be completed within approximately 18 months. Once commissioned, operation of the CHPP, TLO and rail loop will replace the current approved road haulage of ROM coal to third party processing facilities, which will continue in the interim period. The Matilda pit is expected to be developed concurrently with the existing VCM pit.

2.2 CHPP

The Project will include a modular CHPP to process ROM coal into a number of marketable products (coking coal and thermal coal). Haul trucks will deliver ROM coal from the pit to the ROM hopper. The raw coal will be sized before being conveyed to a 300 t raw coal surge bin before being fed to the CHPP at up to 550 t/h. The CHPP will be an open steel structure. Coal will be processed through three circuits to produce a primary and secondary product. Products will be conveyed and stacked on the product coal stockpiles. Product coal will be reclaimed via dozer push into coal valves and conveyed to the TLO. The CHPP will operate 24 hours a day, seven days per week.

2.3 Rail loop and Train Load-Out Facility

The TLO will be positioned on the eastern side of the loop, on the western side of the existing levee. Product coal will be transported by aerial conveyor, across the levee from the product stockpile to the TLO. The TLO will link the product stockpiles with the proposed rail loop to load at a rate of 3,500 tph. The train load out facility will be managed via a fully automated system.

The rail loop will connect to the existing network in the south-east of the Mining Lease and will traverse the south-western boundary of the ML. The loop is positioned in the western portion of the ML, between the ML boundary and the existing BMA flood levee that runs north-south through the ML. The loop will require approximately 4.5 km of rail to be located on the ML. Controlled level crossings are proposed where the rail line will cross Saraji Road and connect to the existing Goonyella rail network.

2.4 Matilda Open Pit

The Matilda pit will be a small, shallow (maximum depth 40m) open pit within the rail loop alignment. It will target the Matilda coal seam which underlies the Alex and multiple Dysart Lower coal seams mined in the pit to the east. The Matilda pit will be mined concurrently with the main pit to the east. There is no requirement to increase the production rate or significantly alter project timeframes. This is because further planning work has been completed on the main pit and the amount of coal to be extracted has reduced from what was originally proposed and approved. Further, this means that there is sufficient capacity within the waste rock dump final landforms previously proposed to store some of the waste from this pit, without design modification.

There would be no change to the equipment fleet, workforce, accommodation etc. This is largely an exercise to supplement material that has been decided not to be mined from the main pit.

Figure 2.1: Amended Project Layout

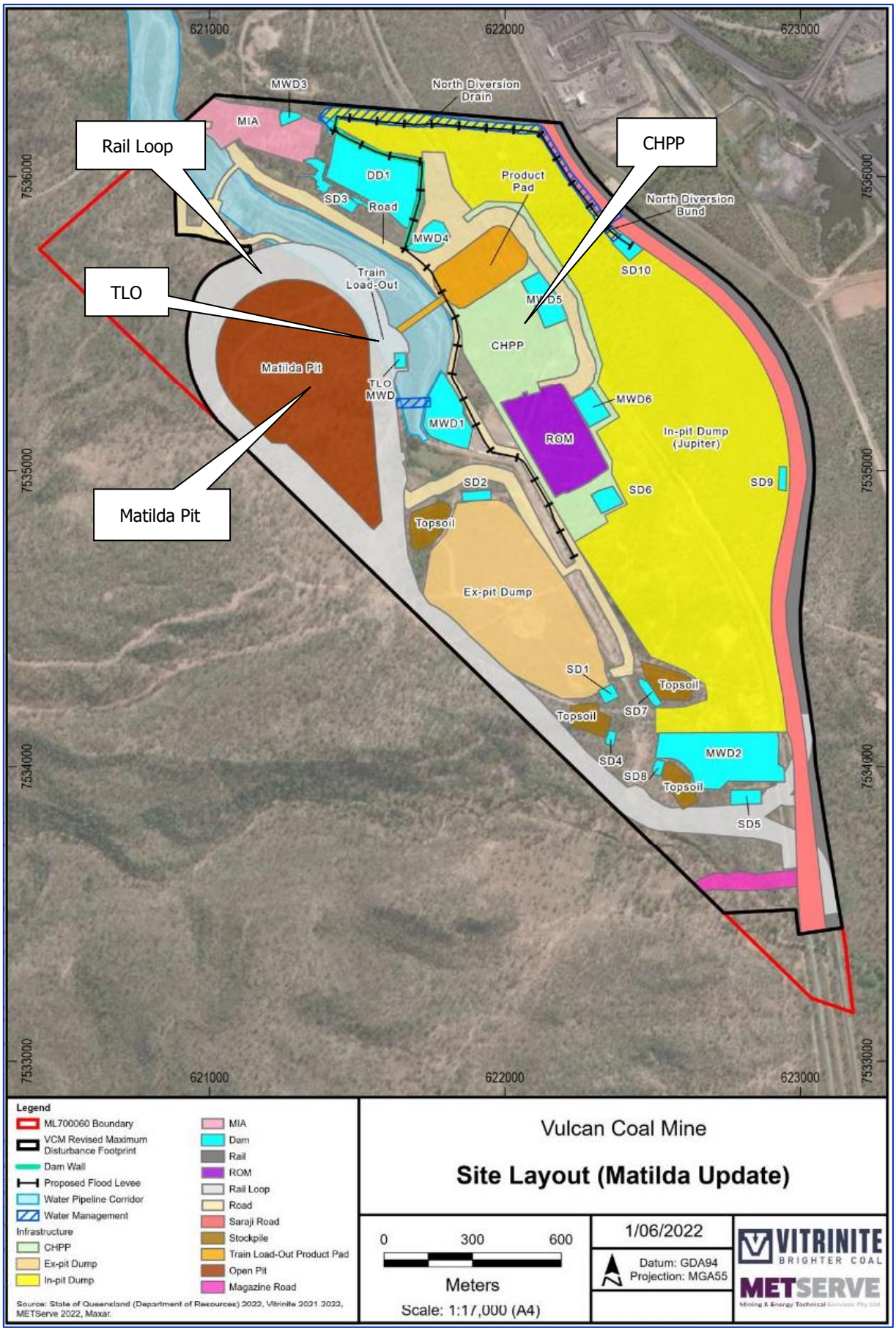
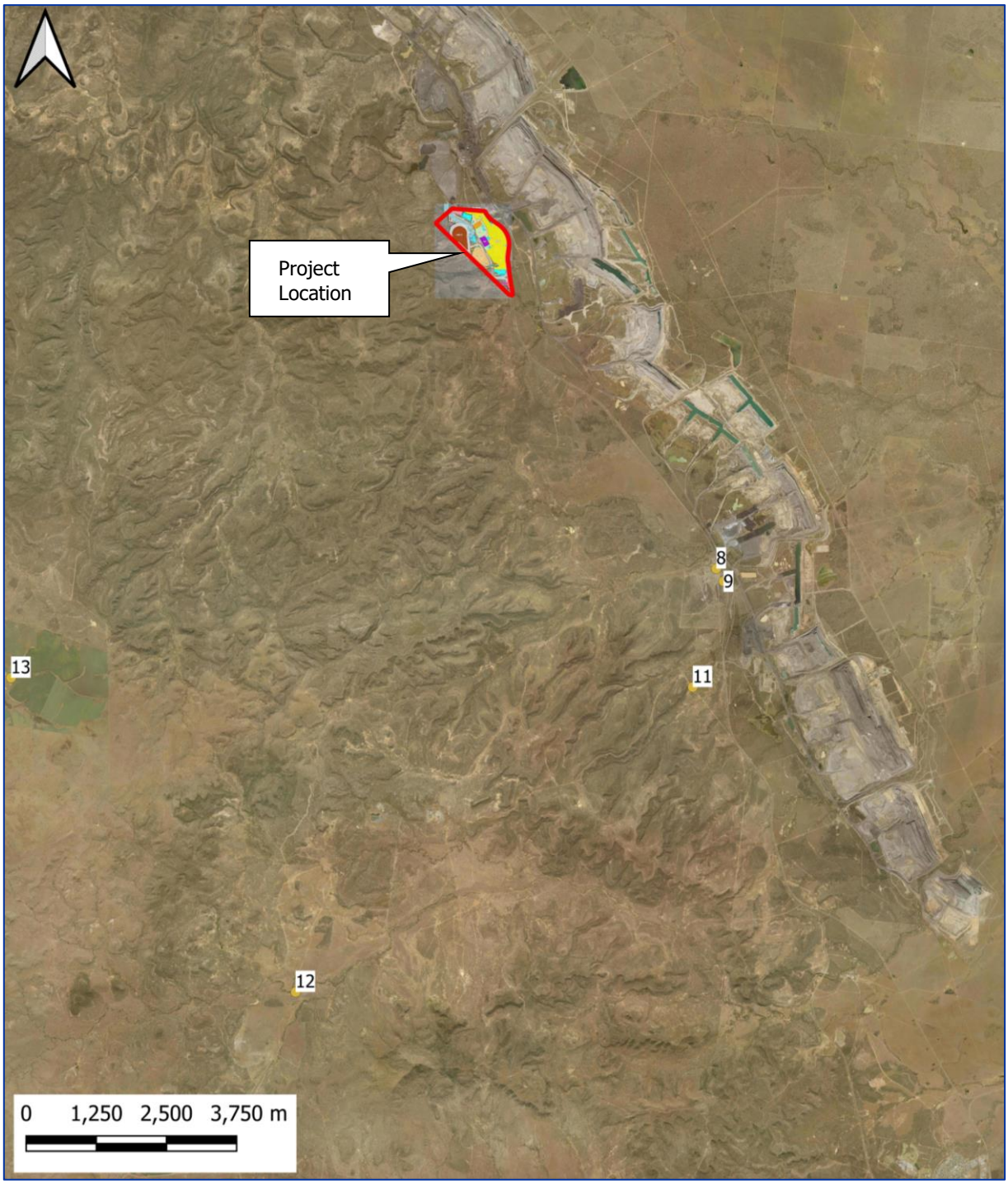


Figure 2.2: Location of Project and Residential Sensitive Receptors



3. ASSESSMENT

3.1 Overview

A review of the proposed amendment indicates that the CHPP, rail loop and train load-out facility are significant additional noise sources. However, there is no new equipment planned for Matilda open pit. The same equipment fleet is proposed with proposed amendment with slight changes to equipment locations. Given the closest residential sensitive receivers are located at least 10 kilometres away from the Project disturbance area, the slight changes in equipment location will not affect the overall noise contribution.

3.2 Noise Source Data

The sound power levels of the new noise sources are presented in **Table 3.1**. These sound power levels of the proposed CHPP, rail loop and train load-out facility were based on noise source data obtained from previous mining projects.

Table 3.1: Noise Source Sound Power Levels

Equipment	Octave Band Sound Power Levels $L_{w,eq}$ dBZ								Overall $L_{w,eq}$	
	63	125	250	500	1k	2k	4k	8k	dBZ	dBA
CHPP	125	119	113	113	110	107	101	93	127	115
Rail loadout bin	105	102	104	105	105	107	104	95	113	112
Train slow travel whilst loading	110	105	104	103	104	104	101	94	114	110

3.3 Predicted Noise Levels

The noise levels at sensitive receptors from the proposed noise sources were calculated for neutral and adverse meteorological scenarios as per the previous Trinity report (197401.0210.R01V02_draft2, dated 26 August 2020).

Noise levels at the sensitive receptors have been predicted using the CONCAWE algorithm. The calculated noise levels are shown in **Table 3.2**.

Table 3.2: Predicted Noise Levels

ID	Sensitive Receptor Name	Approximate Distance to New Noise Sources	Predicted Noise Levels L_{Aeq}, dBA	
			Neutral Condition	Adverse Condition
8	Property Manager	14,000 m	nil	3
9	Workers Accommodation	14,500 m	nil	2
11	Saraji Station Residence	17,000 m	nil	1
12	Luxor Residence	27,000 m	nil	nil
13	Cheeseboro Residence	22,500 m	nil	nil

Based on the noise levels in **Table 3.2**, it can be seen that the noise levels due to new noise sources are up to 3 dBA and are therefore considered a negligible addition to the overall noise levels presented in the previous Trinity noise report (197401.0210.R01V02_draft2, dated 26 August 2020).

It is also expected that the low frequency noise levels are to be compliant with the nominated criteria.

Therefore, compliance with noise criteria is readily achieved with the proposed amendment to the Project.

3.4 Vibration Review

A review of the proposed amendment indicates that there are no new significant vibration sources proposed.

The blasting assessment in the previous Trinity report (197401.0210.R01V02_draft2, dated 26 August 2020) showed that the airblast noise and vibration levels are compliant at the sensitive receptors. Therefore, any blasting activities proposed for Matilda open pit will also be compliant given the similar separation distance between the sensitive receptors and blasting activities.

4. CONCLUSIONS

A noise and vibration review has been conducted for the proposed amendment to Vulcan Coal Mine. The proposed activities are found be compliant with the noise and vibration criteria nominated in the previous Trinity noise report (197401.0210.R01V02_draft2, dated 26 August 2020). As per the **Section 3** of the letter, the amendments to the Project have negligible impact on the surrounding sensitive receivers and therefore meet noise objectives under the EP Regulation.

If you have any queries regarding this document please do not hesitate to contact the undersigned on +61 7 3255 3355.

Yours faithfully

Trinity Consultants Australia



Pubudu Jayawardana
Acoustic Engineer
pubudu.jayawardana@trinityconsultants.com



Trinity Consultants Australia

BRISBANE

A: Level 3, 43 Peel Street
South Brisbane, QLD 4101
T: +61 7 3255 3355
E: brisbane@trinityconsultants.com

GLADSTONE (Vision Environment)

A: Unit 3, 165 Auckland Street
PO Box 1267
Gladstone, QLD, 4680
T: +61 7 4972 7530
E: office@visionenvironment.com.au

SYDNEY

A: Level 6, 69 Reservoir Street
Surry Hills, NSW 2010
T: +61 2 8217 0706
E: sydney@trinityconsultants.com

Acoustics • Air Quality • Marine Ecology • Noise • Stack Testing • Water Quality

Memorandum

Date	6 September 2022	Pages	6
Attention	Damien Plucknett		
Company	METServe		
Job No.	1571-22-C		
Subject	Final landform drainage summary		

Dear Damien,

Overview

This memo has been prepared to outline the drainage concepts underlying the final landform designs for the Vulcan Coal Mine (VCM). WRM has provided details regarding the final landforms in the *Vulcan Coal Mine EA Amendment Surface water assessment* (WRM, 2022). This report summarises the design concepts provided in WRM (2022) and provides conceptual cross sections of the final landform profiles, which expand on the design details.

A plan view of the final landform profiles showing the locations of the conceptual cross sections is shown in Figure A. The cross sections showcase the key features of the landforms and are displayed as follows:

- Figure B shows cross section XS-1, which is taken north-south from the undisturbed slope through the backfilled pit to the north of the Jupiter Pit final landform, through the in-pit waste rock dump, to the undisturbed ridgeline on the southern side of the Jupiter Pit landform.
- Figure C shows XS-2 and XS-3, which are west-east cross sections taken from the undisturbed ridgeline to the west of the Jupiter Pit landform, through the backfilled pit/the in-pit waste rock dump, to Saraji Road and the Norwich Park Branch Railway on the eastern side of the Jupiter Pit landform.
- Figure D shows cross-section XS-4, which is an east-west cross section taken from the undisturbed ridge to the west of the Jupiter Pit landform, through the ex-pit and in-pit waste rock dumps, to Saraji Road and the Norwich Park Branch Railway to the east.
- Figure E shows cross section XS-5 and XS-6. XS-5 is taken north-south from the rehabilitated rail loop area through the western backfilled Matilda Pit/in-pit waste rock dump and out to the undisturbed slope to the south. XS-6 is a west-east cross section taken from the rehabilitated rail loop area out through the backfilled Matilda Pit/in-pit waste rock dump.

This report and the accompanying final landform conceptual cross sections are intended to be used to support a Progressive Rehabilitation and Closure Plan currently being prepared by METServe for the VCM.

Level 9, 135 Wickham Terrace, Spring Hill
PO Box 10703, Brisbane Adelaide St Qld 4000

Tel 07 3225 0200
wrmwater.com.au

ABN 96 107 404 544

Note that the cross sections are conceptual drawings which are not to scale. The cross sections are intended to showcase the key features of the final landforms and design principles which will be used in its detailed design. Specific design elements of the final landform (including final grades, material selection, and final geometries etc.) will be prepared as part of detailed design phase to support relevant rehabilitation reports.

Final landform design features

Figure A shows the conceptual final landform drainage plan, which shows the drainage principles intended to be used for the final landforms. The drainage plan was developed using end of life mine plans with an aim to retain water infrastructure constructed during operations. The landforms are intended to be free draining and to discharge water to the receiving environment which is consistent with water quality from surrounding background sites.

Key features of the final landforms shown in Figure A, as well as in the cross sections (Figure B, Figure C, Figure D and Figure E), are described in the sections below.

Waste rock dump drainage

An in-pit waste rock dump (Jupiter Pit) on the eastern side of the Project area, as well as an ex-pit waste rock dump and in-pit waste rock dump (Matilda Pit) on the western side of the Project area will be retained in the final landform (Figure A). No final voids are proposed as part of the final landform. The open cut pits will be backfilled with overburden material.

Key drainage features for the waste rock dumps include:

- The final surfaces of the eastern and western dumps will be designed to shed water and avoid concentrated flows. The design of the final landform surface is described in the 'Final landform geometry' section below. Drainage structures will be constructed on the top of the dump, on the batter slopes and at the toe of the dumps, in order to minimise erosion and avoid ponding.
- Plateau drains will collect runoff from the plateau and generally drain them to drop structures and sediment dams. Contour banks on the batter slopes will collect residual runoff not collected in the plateau drains.
- Drop structures will collect runoff from the plateau drains and control the flow down the batter slopes, discharging the flow at the toe of the landform.
- Contour banks will control runoff from the batters.
- Surface water drains will collect runoff at the toe of the dumps and direct it towards sediment dams. These surface water drains will be retained from the operational phase of the Project.
- Erosion control measures will be used in the construction of the plateau drains, surface water drains, contour banks and drop structures as appropriate. These control measures (shown in Figure B, Figure C, Figure D and Figure E) may include topsoiling and vegetating the drainage structures, incorporating erosion resistant liners (e.g., geotextile liners) and/or rock lining the structures.

Dams

A number of dams will be retained, or introduced as part of the final landform design:

- Sediment dams SD1 – SD10 will be retained from the operational phase and will collect surface water runoff generated from the dumps and release it to the receiving waters.
- Sediment dams SD11 and SD12 will be constructed as part of the final landform design to collect runoff from the northern side of the eastern in-pit waste rock dump.
- Sediment dams SD13 – SD15 will be retained from the operational phase and will collect surface water runoff generated from the western in-pit waste rock dump and release it to the receiving waters.
- Sediment dam SD16 will be constructed as part of the final landform design of the western in-pit waste rock dump to collect runoff from the east of the dump.
- A catchment runoff dam DD1 will be retained from the operational phase and will collect undisturbed runoff from the northwest of the final landform. It will spill to the proposed drainage corridor. DD1 will be retained until the drainage corridor has been fully established.
- Operational details regarding the dams (including catchment areas and full supply volumes) are outlined in WRM (2022).

When a sediment dam catchment is completely rehabilitated, and water quality monitoring of the runoff has established that it is consistent with natural background conditions, the sediment dam and associated drainage infrastructure will be decommissioned. Surface runoff and seepage from the rehabilitated catchment will be allowed to shed directly to the receiving environment.

Existing flood levee and drainage diversion

An existing flood levee and drainage diversion, which drains southward through the Project area between the in-pit and out-of-pit dumps (Figure A), was constructed in the Project area prior to its commencement. The flood levee may or may not be retained for the final landform. Flooding results presented in WRM (2022) show Post-closure Conditions assessed against both retaining and removing the existing flood levee.

Proposed drainage corridors

A drainage corridor will divert flows from the western side of the Jupiter Pit eastern in-pit waste rock dump, out to the east (Figure A). The drainage corridor is designed as free-flowing gravity drains.

The drainage corridor is a narrow channel on the southwestern side of the Jupiter Pit eastern in-pit waste rock dump, commencing at the western edge of the in-pit waste rock dump, draining from SD6 and through SD11. The drainage channel will collect runoff from the drop structures along the western side of the in-pit waste rock dump, as well as undisturbed residual runoff draining from the eastern side of the existing levee. The corridor wraps eastward through the backfilled section of the eastern in-pit dump, joining with a discharge channel from the outlet of DD1. The corridor flows around the northern edge of the backfilled pit, discharging through the existing culverts under the Norwich Park Branch Railway to the east. The corridor is proposed to be approximately 2.2 km in length.

The drainage diversion diverting the western upstream clean water catchment around the Matilda Pit final landform will be formed by the Matilda Pit drainage diversion constructed during operations. The drainage diversion will collect undisturbed upstream runoff and discharges to the existing drainage diversion. The drainage diversion is proposed to be approximately 900 m in length.

Cross sections of the proposed Jupiter Pit drainage corridor are shown in XS-1 (Figure B), XS-2 and XS-3 (Figure C).

Flooding maps within Appendix C of the SWA (WRM, 2022) indicate the areas of the landform which are inundated during flood events and the impacts when compared against Pre-mining Conditions. Figures C.1, C.2, C.7 and C.8 of the SWA indicate:

- Under both 1% and 10% AEP conditions, floodwaters will be confined to the proposed drainage corridor draining around the final landform toe. Retaining the flood levee, flood results indicate peak inundation for the 10% AEP and 1% AEP events will be approximately 1.4 m and 2.6 m respectively within the drainage corridor upstream of the proposed Saraji Road. Without the flood levee, flood results indicate peak inundation for the 10% AEP and 1% AEP events will be approximately 2.8 m and 4.0 m respectively within the drainage corridor upstream of the proposed Saraji Road.
- The results shown in Figures C.3 and C.9 of the SWA (WRM, 2022) that the proposed drainage corridor has sufficient capacity under both levee scenarios to convey flood events up to the 0.1% AEP.
- In addition, the flood assessment presented in WRM (2022) indicate that under 1% AEP conditions, peak velocities within the drainage corridor are up to 1.5 m/s (with levee) and 2.2 m/s (without levee). Under 0.1% AEP conditions, maximum velocities in the drainage corridor are up to 2.5 m/s (with levee) and 2.8 m/s (without levee).
- Under the 10% and 1% AEP conditions, floodwaters will be confined to the proposed drainage diversion around the Matilda Pit final landform. Under 0.1% AEP conditions, the floodplain is inundated within the vicinity of the drainage diversion. The flood results indicate peak inundation for the 10% AEP, 1% AEP and 0.1% AEP events will be approximately 1.2 m, 1.6 m and 2.2 m respectively within the drainage diversion.
- Under the 10% AEP, 1% AEP and 0.1% AEP events, maximum velocities in the drainage diversion upstream of the Matilda Pit final landform will be 1.2 m/s, 1.3 m/s and 1.7 m/s respectively. Rock-lining the drainage diversion and/or rock-chute drop structures will be required where the proposed drainage diversion connects with the existing drainage line up to where the drainage diversion discharges to the existing drainage diversion to reduce high velocities and prevent scour and erosion.
- Flooding results from the SWA (WRM, 2022) for the 1% and 10% AEP events retaining the levee have been conceptually represented in Figure B, Figure C, Figure D and Figure E.

Considering the peak velocities referenced above, erosion and scour protection will be required along the proposed corridor structure around Jupiter Pit, the proposed diversion around Matilda Pit and for the toe of the final landforms, particularly if the existing flood levee is removed post closure. Erosion control measures will need to be carefully considered at the inlet and outlet of the drainage corridor, as well as the downstream culvert crossings. Suitable erosion and sediment control measures will be determined during detailed design. Possible erosion controls include:

- topsoiling and revegetating the drainage corridor;
- rock lining the corridor and landform toe;
- operating DD1 until all erosion controls have been implemented in the channel and/or revegetation is established;
- implementing seepage minimisation measures (such as the addition of a liner along the base of the diversions) to minimise seepage from the corridor to the underlying backfilled material (as shown in Figure B and Figure C); and

- routine monitoring of erosion and sedimentation along the drainage corridor to ensure the diversion is stable during natural flow events.

When the drainage corridor is rehabilitated, DD1 will be decommissioned. DD1 will remain until this time to allow in-stream vegetation to establish before receiving upstream catchment flows.

The size and configuration of the proposed drainage corridor and the proposed drainage diversion around Matilda Pit will be confirmed during detailed design; however, it is expected that they will be designed to convey at least 0.1% AEP flow event (assuming the existing drainage levee is removed) as they will form part of the permanent landform structure.

Final landform profile

The conceptual cross sections in Figure B, Figure C, Figure D and Figure E show the intended profile of the two final landforms, including across the in-pit and out-of-pit waste rock dumps. The conceptual landform surfaces have been developed using the finished level of the dumps supplied from Vitrinite Pty Ltd and have been shaped in order to evenly shed water down the landform and minimise erosion.

The key features of the final landform profiles are described below:

- Cross section XS-1 shows a north-south profile across the backfilled pit and eastern in-pit dump (Figure B). As shown, the final landform is intended to be shaped to direct runoff inwards towards the plateau drains situated along the surface. This sloping will ensure that runoff generated along the surface will be collected and controlled through the drainage structures along the surface and minimise uncontrolled flows down the landform batters.
- The surface of the final landforms will be topsoiled and will be vegetated consistent with final rehabilitation plans.
- Batter slopes (shown in Figure B, Figure C, Figure D and Figure E) will be graded at a maximum of 15% and therefore, will be well below the angle of repose.
- Cross section XS-2, XS-3, and XS-4 (shown in Figure C and Figure D) show a west-east profile across the out-of-pit and eastern in-pit waste rock dump. The dumps are intended to be shaped to grade to the west in order to direct runoff along the western side of the final landform to the planned drainage structures.
- Contour banks and plateau drains along the final landform surfaces are intended to be lightly vegetated and lined with a suitable erosion control material (as shown on Figure B, Figure C, Figure D and Figure E).

The materials used in the construction of levees and final landforms will be considered at the time of detailed design.

Memorandum

For and on behalf of

WRM Water & Environment Pty Ltd



Laurence Ziukelis

Lead Project Engineer

References

WRM, 2022 — *Vulcan Coal Mine EA Amendment Surface water assessment*. Prepared for Vitrinite Pty Ltd, Report number 1571-22-B, July 2022.

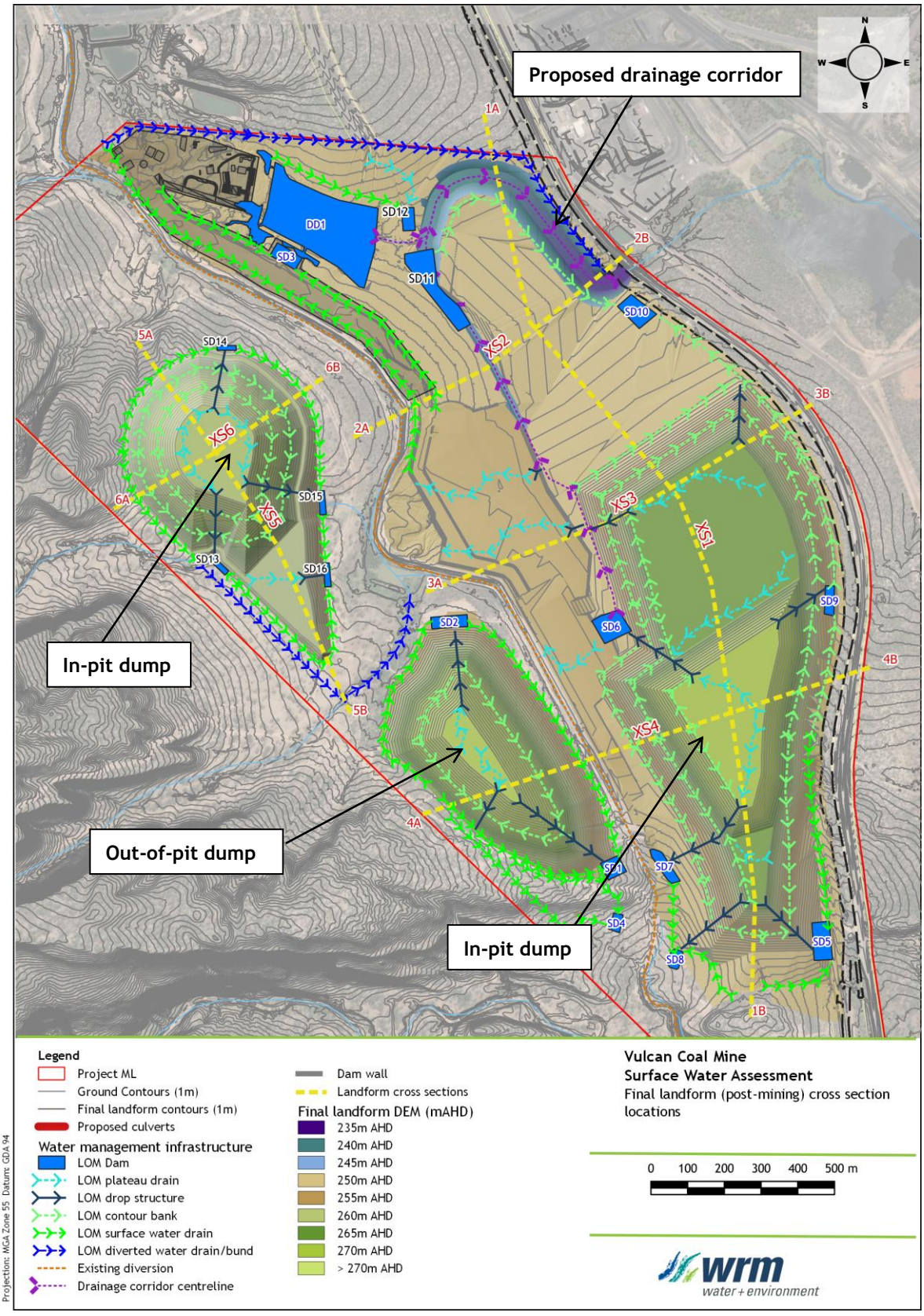
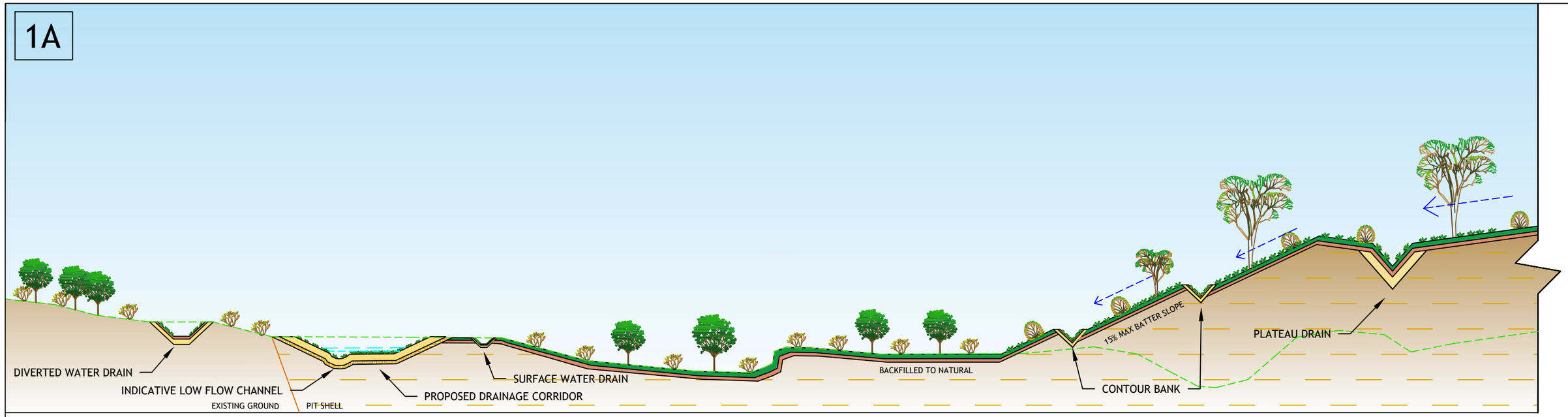
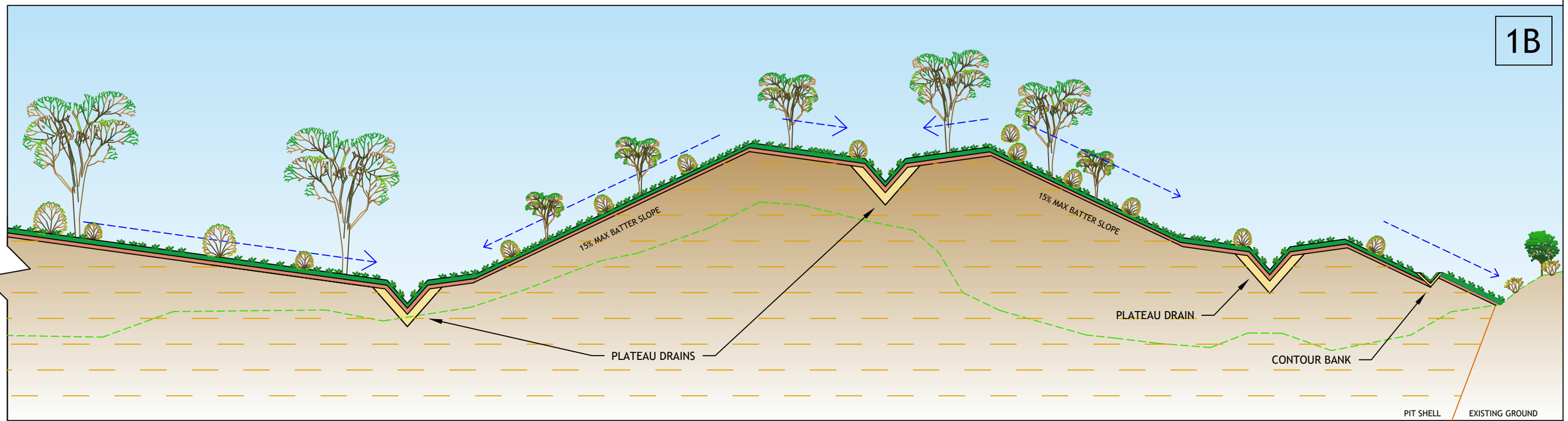


Figure A – Final landform (post-mining) cross section locations

1A



1B



LEGEND

- INDICATIVE RUNOFF PATH
- GROWTH MEDIUM
- 1% AEP PEAK FLOOD LEVEL (WITH LEVEE)
- 10% AEP PEAK FLOOD LEVEL (WITH LEVEE)
- BACKFILLED SPOIL
- SEEPAGE CONTROL MATERIAL
- EROSION CONTROL MATERIAL
- INDICATIVE EXISTING GROUND LEVEL

Dwg. No.	Reference Dwg.	Rev.	Revision Details	By	Chk'd	Date

WRM Water & Environment Pty Ltd
water + environment
ABN 96 107 544 ACN 107 404 544
LEVEL 9, 135 WICKHAM TERRACE, SPRING HILL,
BRISBANE, QLD 4000. PO BOX 10703.
PHONE (07) 3225 0200
FAX (07) 3225 0299
E-MAIL: admin@wrmwater.com.au

Client: METSERVE

Project: VULCAN COAL MINE

	Initial	Signat.	Date
Designed			
Drawn			
Checked			
Approved			
Scale	NTS		

FINAL LANDFORM
CONCEPTUAL DRAINAGE
(XS-1)

Job No. 1571-22

Drawing No. FIGURE B

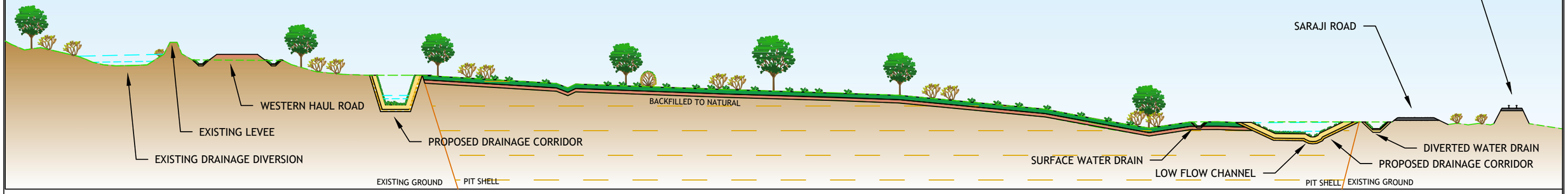
Rev. C

FILE: J:\1571-22 VCM Matilda EA Amendment\Analysis\Civil3D\1571-22 Conceptual cross sections.dwg model5
DRG. SIZE: A3 PLOT SCALE: 1 = NTS
DATE OF LAST UPDATE: 06 Sep 22 - 10:51am

THIS DRAWING IS THE PROPERTY OF WRM WATER & ENVIRONMENT PTY. LTD. IT IS SUBJECT TO RETURN UPON DEMAND AND MAY NOT BE PASSED ON TO ANY THIRD PARTY, OR USED DIRECTLY OR INDIRECTLY FOR ANY OTHER PURPOSE OUTSIDE OF THIS PROJECT. ©2020

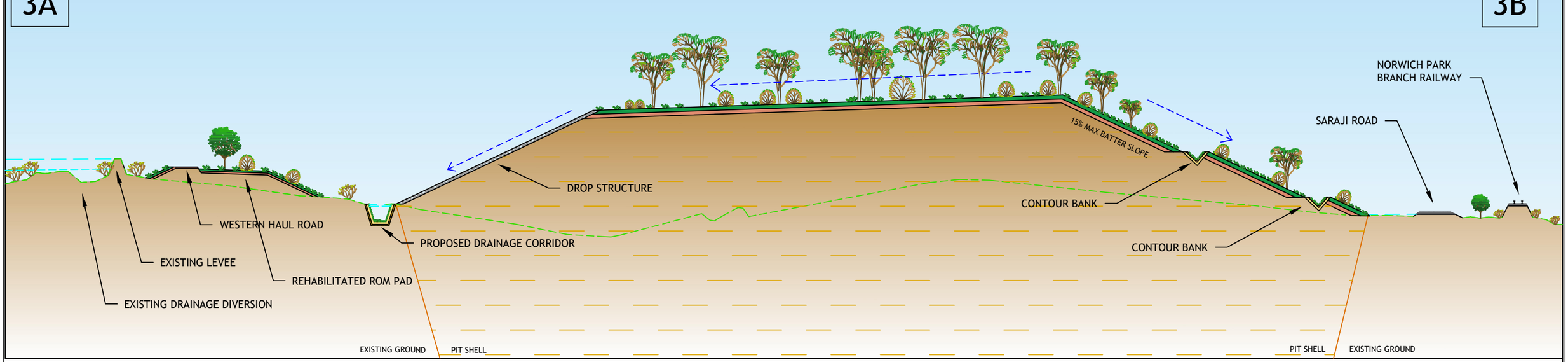
2A

2B



3A

3B



LEGEND

- INDICATIVE RUNOFF PATH
- GROWTH MEDIUM
- 10% AEP PEAK FLOOD LEVEL (WITH LEVEE)
- 1% AEP PEAK FLOOD LEVEL (WITH LEVEE)
- ROCK LINING
- SEEPAGE CONTROL MATERIAL
- EROSION CONTROL MATERIAL
- INDICATIVE EXISTING GROUND LEVEL
- BACKFILLED SPOIL

Dwg. No.	Reference Dwg.	Rev.	Revision Details	By	Chk'd	Date

WRM Water & Environment Pty Ltd
wrm water + environment
ABN 96 107 544 ACN 107 404 544
LEVEL 9, 135 WICKHAM TERRACE, SPRING HILL,
BRISBANE, QLD 4000. PO BOX 10703.
PHONE (07) 3225 0200
FAX (07) 3225 0299
E-MAIL: admin@wrmwater.com.au

Client: METSERVE

Project: VULCAN COAL MINE

	Initial	Signat.	Date
Designed			
Drawn			
Checked			
Approved			
Scale	NTS		

FINAL LANDFORM
CONCEPTUAL DRAINAGE
(XS-2 & XS-3)

Job No. 1571-22

Drawing No. FIGURE C

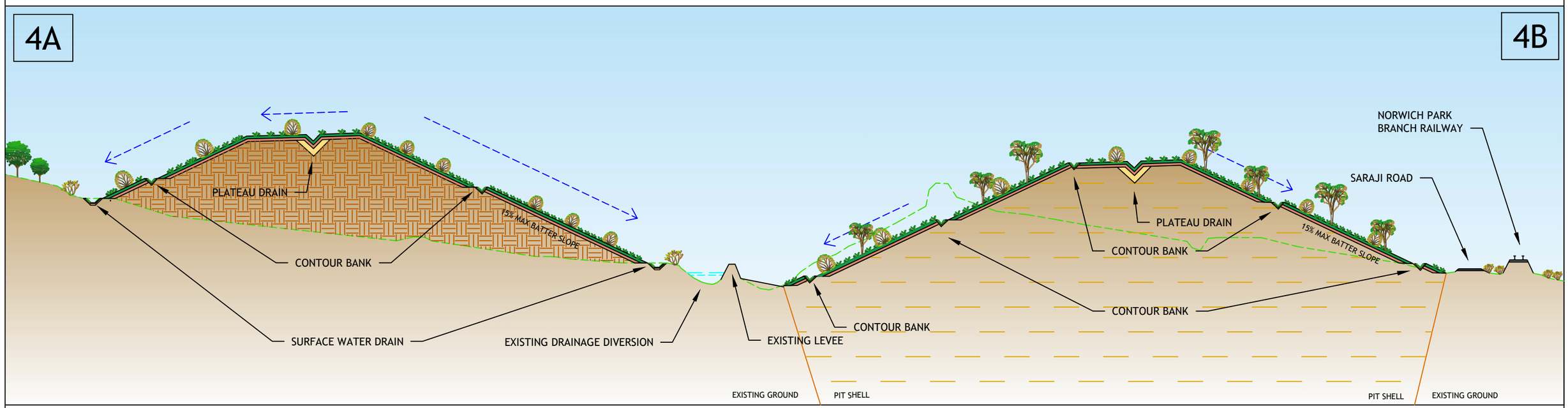
Rev. B

FILE: C:\Users\model5\AppData\Local\Temp\AcPublish_12996\1571-22 Conceptual cross sections.dwg model5
DRG. SIZE: A3 PLOT SCALE: 1 = NTS
DATE OF LAST UPDATE: 16 Aug 22 - 9:59am

THIS DRAWING IS THE PROPERTY OF WRM WATER & ENVIRONMENT PTY. LTD. IT IS SUBJECT TO RETURN UPON DEMAND AND MAY NOT BE PASSED ON TO ANY THIRD PARTY, OR USED DIRECTLY OR INDIRECTLY FOR ANY OTHER PURPOSE OUTSIDE OF THIS PROJECT. ©2020

4A

4B



LEGEND

- INDICATIVE RUNOFF PATH
- GROWTH MEDIUM
- 10% AEP PEAK FLOOD LEVEL (WITH LEVEE)
- 1% AEP PEAK FLOOD LEVEL (WITH LEVEE)
- EROSION CONTROL MATERIAL
- SEEPAGE CONTROL MATERIAL
- SUITABLE OVERBURDEN MATERIAL
- INDICATIVE EXISTING GROUND LEVEL
- BACKFILLED SPOIL

Dwg. No.	Reference Dwg.	Rev.	Revision Details	By	Chk'd	Date

WRM Water & Environment Pty Ltd
ABN 96 107 544 ACN 107 404 544
LEVEL 9, 135 WICKHAM TERRACE, SPRING HILL,
BRISBANE, QLD 4000. PO BOX 10703.
PHONE (07) 3225 0200
FAX (07) 3225 0299
E-MAIL: admin@wrmwater.com.au

Client: METSERVE

Project: VULCAN COAL MINE

	Initial	Signat.	Date
Designed			
Drawn			
Checked			
Approved			
Scale	NTS		

FINAL LANDFORM
CONCEPTUAL DRAINAGE
(XS-4)

Job No. 1571-22

Drawing No. FIGURE D

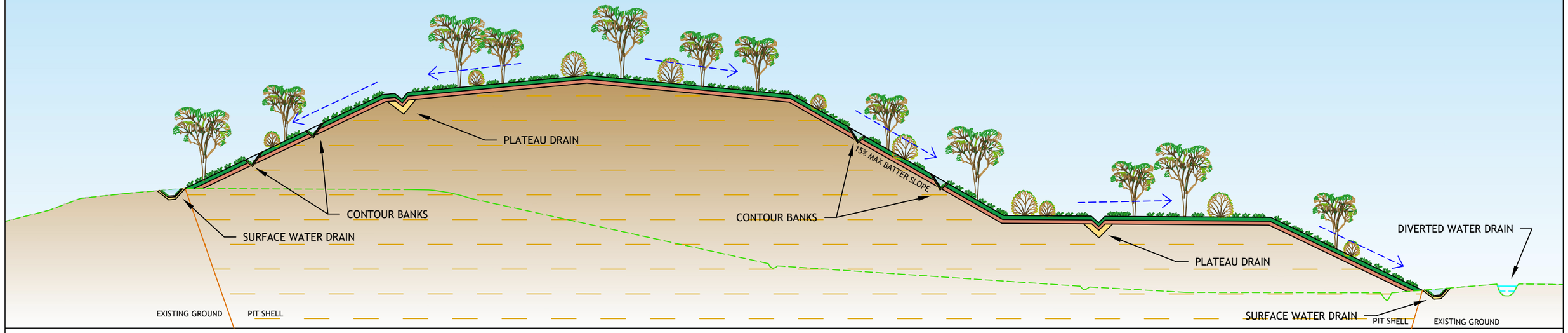
Rev. B

FILE: C:\Users\model5\AppData\Local\Temp\AcPublish_12996\1571-22 Conceptual cross sections.dwg model5
DRG. SIZE: A3 PLOT SCALE: 1 = NTS
DATE OF LAST UPDATE: 16 Aug 22 - 9:59am

THIS DRAWING IS THE PROPERTY OF WRM WATER & ENVIRONMENT PTY. LTD. IT IS SUBJECT TO RETURN UPON DEMAND AND MAY NOT BE PASSED ON TO ANY THIRD PARTY, OR USED DIRECTLY OR INDIRECTLY FOR ANY OTHER PURPOSE OUTSIDE OF THIS PROJECT. ©2020

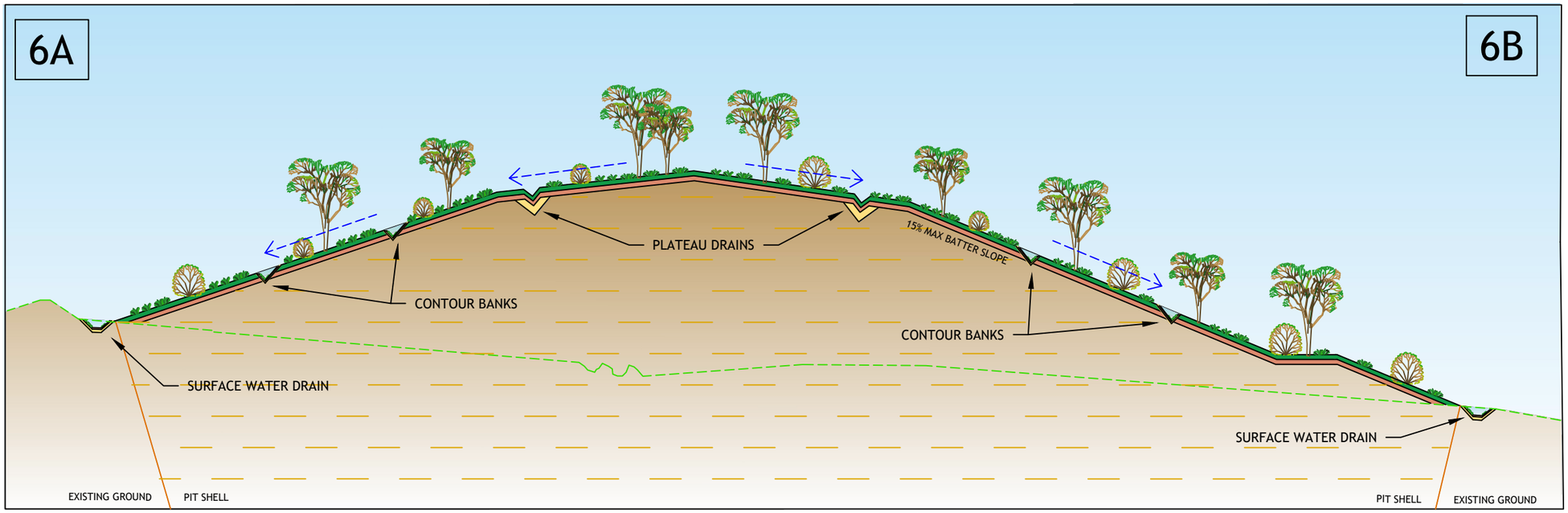
5A

5B



6A

6B



LEGEND

- INDICATIVE RUNOFF PATH
- GROWTH MEDIUM
- 10% AEP PEAK FLOOD LEVEL (WITH LEVEE)
- 1% AEP PEAK FLOOD LEVEL (WITH LEVEE)
- SUITABLE OVERBURDEN MATERIAL
- SEEPAGE CONTROL MATERIAL
- EROSION CONTROL MATERIAL
- INDICATIVE EXISTING GROUND LEVEL
- BACKFILLED SPOIL

Dwg. No.	Reference Dwg.	Rev.	Revision Details	By	Chk'd	Date

WRM Water & Environment Pty Ltd
wrm water + environment
ABN 96 107 544 ACN 107 404 544
LEVEL 9, 135 WICKHAM TERRACE, SPRING HILL,
BRISBANE, QLD 4000. PO BOX 10703.
PHONE (07) 3225 0200
FAX (07) 3225 0299
E-MAIL: admin@wrmwater.com.au

Client: METSERVE

Project: VULCAN COAL MINE

	Initial	Signat.	Date
Designed			
Drawn			
Checked			
Approved			
Scale	NTS		

FINAL LANDFORM
CONCEPTUAL DRAINAGE
(XS-5 & XS-6)

Job No. 1571-22

Drawing No. FIGURE E

Rev. B

FILE: J:\1571-22 VCM Matilda EA Amendment\Analysis\Civil3D\1571-22 Conceptual cross sections.dwg model5
DRG. SIZE: A3 PLOT SCALE: 1 = NTS
DATE OF LAST UPDATE: 26 Aug 22 - 10:30am

THIS DRAWING IS THE PROPERTY OF WRM WATER & ENVIRONMENT PTY. LTD. IT IS SUBJECT TO RETURN UPON DEMAND AND MAY NOT BE PASSED ON TO ANY THIRD PARTY, OR USED DIRECTLY OR INDIRECTLY FOR ANY OTHER PURPOSE OUTSIDE OF THIS PROJECT. ©2020